# ENERGY EFFICIENCY AND MOBILITY
## A roadmap towards a greener economy in Latin America and the Caribbean

Fabian Maximilian Kreuzer
Gordon Wilmsmeier

UNITED NATIONS
ECLAC

german
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DEUTSCHE ZUSAMMENARBEIT

**Project document**

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Economic Commission for Latin America and the Caribbean

This document was authored under the technical coordination of Fabian M. Kreuzer and Gordon Wilmsmeier of the Division of Natural Resources and Infrastructure of the Economic Commission for Latin America and the Caribbean (ECLAC). Its preparation was made possible through a financial contribution from the Government of Germany, in the framework of the cooperation project with ECLAC on energy (GER/12/004).

Manlio Coviello, Chief of the Energy Unit of the Division of Natural Resources and Infrastructure of ECLAC, was coordinator of this project and supervised the activities relating to the preparation of this document.

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This document is the English language version of LC/W.602/Rev1.



LC/W.602

Printed at United Nations, Santiago, Chile.

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# Abbreviations

| | |
|---|---|
| 2DS | Two-Degrees Scenario |
| 4DS | Four-Degrees Scenario |
| ABEIVA | Associação Brasileira de Empresas Importadoras de Veículos Automotivos |
| ADEME | Agence de l'Environnement et de la Maîtrise de l'Energie |
| AFE | Administración de Ferrocarriles del Estado |
| AFV | Alternatively Fuelled Vehicle |
| ALTA | Latin American and Caribbean Air Transport Association |
| AMVA | Área Metropolitana del Valle de Aburrá |
| ANFAVEA | Associação Nacional de Fabricantes de Veículos Automotores |
| ANP | Agência Nacional do Petróleo, Gás Natural e Biocombustíveis |
| APEC | Asia-Pacific Economic Cooperation Organization |
| APG | ASEAN Power Grid |
| ASEAN | Association of Southeast Asian Nations |
| ASI | Avoid – Shift – Improve |
| BA | Buenos Aires |
| BID/IADB | Banco Intermaericano de Desarrollo / Inter-American Development Bank |
| BIEE | Base de Datos de Indicadores de Eficiencia Energetica / Energy Efficiency Indicators Database |
| BMVBS | Bundesministerium für Verkehr, Bau und Stadtentwicklung |
| BRT | Bus Rapid Transport |

| | |
|---|---|
| CAF | Banco de Desarrollo de América Latina / Development Bank of Latin America |
| CAFE | Corporate Average Fuel Economy |
| CAGR | Compound Annual Growth Rate |
| CARICOM | Caribbean Community |
| CARIFTA | Caribbean Free Trade Association |
| CDM | Clean Development Mechanism |
| CENPES | Centro de Pesquisas Petrobras |
| CEPAL/ECLAC | Comisión Económica Para América Latina y el Caribe / Economic Commission for Latin America and the Caribbean |
| CETESB | Companhia Ambiental do Estado de São Paulo |
| CLIL | Centro Latinoamericano de Innovación en Logística |
| CLRTAP | Convention on Long-range Transboundary Air Pollution |
| GNC/CNG | Gas Natural Compremido / Compressed Natural Gas |
| CNT | Confederação Nacional do Transporte |
| $CO_2$ | Carbon Dioxide |
| CONPET | Programa Nacional de Racionalização do Uso de Derivados de Petróleo, Gás Natural e Biocombustíveis |
| COP | Colombian Peso |
| CSEP | China Sustainable Energy Programme |
| dwt | dead weight ton |
| e.g. | exempli gratia, for example |
| EC | European Commission |
| ECA | Emission Control Area |
| EEDI | Energy Efficiency Design Index |
| EIA | Energy Information Administration (US) |
| EJ | Exajoule |
| EMEP/EEA | European Monitoring and Evaluation Programme/European Environment Agency |
| EPA | Environmental Protection Agency |
| EPE | Empresa de Pesquisa Energética |
| EPM | Empresas Públicas de Medellin |
| EPOMM | European Platform on Mobility Management |
| ESCAP | Economic Commission for Asia and the Pacific |
| EU | European Union |
| EXCEN | Centro de Excelência em Eficiência Energética |

| | |
|---|---|
| FC | Fuel Consumption |
| FFV | Flex-Fuel Vehicles |
| FTP | Federal Test Procedure |
| PIB / GDP | Producto Interno Bruto / Gross Domestic Product |
| GFEI | Global Fuel Economy Initiative |
| GHG | Greenhouse Gas Emissions |
| GIZ | Gesellschaft für Internationale Zusammenarbeit (German Development Cooperation) |
| GJ | Gigajoule |
| LPG | Liquified Petroleom Gas |
| GNV | Gas Natural Vehicular |
| HDV | Heavy Duty Vehicle |
| HEV | Bus Híbrido Diésel |
| HFO | Heavy Fuel Oil |
| HSR | High-Speed-Rail |
| i.e. | id est, that is |
| IBAMA | Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis |
| ICAO | International Civil Aviation Organization |
| ICCT | International Council on Clean Transportation |
| ICT | Information and Communication Technology |
| IEA | International Energy Agency |
| ILS | Intelligent Logistics Systems |
| IMF | International Monetary Fund |
| IMO | International Maritime Organization |
| INMETRO | Instituto Nacional de Metrologia, Normalização e Qualidade Industrial |
| INN | Instituto Nacional de Normalización |
| IPCC | Intergovernmental Panel on Climate Change |
| IPEEC | International Partnership for Energy Efficiency Cooperation |
| IPI | Imposto de Produtos Industrializados |
| IRENA | International Renewable Energy Agency |
| ISIS | Institute of Studies for the Integration of Systems |
| IT | Information Technology |
| ITDP | Institute for Transportation and Development Policy |
| ITF | International Transport Forum |
| ITS | Intelligent Transport Systems |

| | |
|---|---|
| IVL | Swedish Environmental institute |
| JIT | Just-In-Time |
| Koe | kilogrammes of oil equivalent |
| km | kilometers |
| LAC | Latin America and the Caribbean |
| LANIC | Latin American Network Information Center |
| LCA | Life Cycle Assessment |
| LNG | Liquified Natural Gas |
| MACC | Marginal Abatement Cost Curves |
| MBOE | Million Barrel of Oil Equivalent |
| MCTI | Ministerio de la Ciência, Tecnologia e Inovação |
| MDRI | Ministerio del Desenvolvimento, Indústria e Comércio Exterior |
| MJ | Megajoule |
| MM | Mobility Management |
| MME | Ministério de Minas e Energia |
| MPCD | Miles de Pies Cúbicos Diarios |
| MVD | Montevideo |
| MW | Megawatt |
| NAFTA | North American Freetrade Association |
| NCCP | National Climate Change Plan |
| NEEAPS | National Energy Efficiency Action Plans |
| NGV | Natural Gas Vehicle |
| NMT | Non-Motorized Transport |
| NOx | Nitrogen Oxide |
| OECD | Organisation for Economic Co-operation and Development |
| OEM | Original Equipment Manufacturers |
| OLADE | Organización Latinoamericana de Energía |
| OMS | Organización Mundial de Salud |
| OMU | Observatorio de Movilidad Urbana para America Latina |
| ONDAT | Observatorio Nacional de Datos de Transporte |
| ONG | Organización No Gubernamental |
| PDR | People’s Democratic Republic |
| pkm | person-kilometers |
| PM | Particulate Matter |
| POT | Planes de Ordenamiento Territorial |
| ppm | parts per million |

| | |
|---|---|
| PRONASE | National Program for Sustainable Energy |
| PROURE | Programa de Uso Racional y Eficiente de la energía y uso de fuentes de energía no convencionales |
| RVSM | Reduced Vertical Separation Minimum |
| SAME | Simulación y Análisis de la Matriz |
| SCR | selective catalytic reduction |
| SE4ALL | Sustainable Energy For All |
| SEEMP | Ship Energy Efficiency Management Plan |
| SEMARNAT | Secretaria de Medio Ambiente y Recursos Naturales de México |
| SENAT | Serviço Nacional de Aprendizagem do Transporte |
| SEST | Servicioo Social de Transporte |
| SIDS | Small Island Developing States |
| SIEE | Sistema de Informaciones Económicas y Energéticas |
| SIN | Sistema de Interconexión Nacional |
| SIT/ITS | Sistema Inteligente de Transporte / Intelligent Transport System |
| SITVA | Sistema de Transporte Integrado del Valle de Aburrá |
| SMM | Secretaría de Movilidad de Medellin |
| SO2 | Sulphur Dioxide |
| TAGP | ASEAN Gas Pipeline (TAGP) |
| Tcal | Teracalorías |
| TERI | The Energy and Resources Institute |
| TOD | Transit-Oriented Development |
| toe | tones of oil equivalent |
| TPES | Total Primary Energy Supply |
| TSO | Transmission System Operators |
| TTW | Tank-To-Wheel |
| UK | United Kingdom |
| UN | United Nations |
| UNASUR | Unión de Naciones Suramericanas |
| UNCTAD | United Nations Conference on Trade and Development |
| UNEP | United Nations Environment Programme |
| UPME | Unidad de Planeación Minero y Energético |
| URNE | Unidad de Recursos Naturales e Energía |
| US$/USD | United States Dollar |
| US/USA | United States of America |
| USI | Unidad de Servicios de Infraestructura |

| | |
|---|---|
| VAT | Value Added Tax |
| UCTE | Union for the Co-ordination of Transmission of Electricity |
| vkmt | Vehicle Kilometers Travelled |
| VTMIS | Vessel Traffic Monitoring and Information System |
| WEC | World Energy Council |
| WEF | World Economic Forum |
| WTT | Well-To-Tank |
| WTW | Well-To-Wheel |

# Foreword

The transport sector is a major consumer of energy, accounting for 19% of global final energy consumption in 2013; and the same sector is going to represent 97% of the overall increase in world oil consumption between 2013 and 2030. Consequently, in terms of energy security and greenhouse gas emissions, of a transport sector dominated by oil, reducing the consumption of fuel in this sector is (and should be) one of the highest priorities for all countries.

At the same time, the International Energy Agency estimates that there is potential for profitable technical improvement in the fuel economy of new vehicles, and that this improvement may reach 50% in 2030 This would result in a reduction of about 500,000 tonnes of oil equivalent in the use of fuel and about 1 Giga ton annual reduction of $CO_2$ emissions.

Achieving this goal will be a huge (though possible) challenge, and requires - worldwide - strong policies that maximize technology absorption and minimize losses in fuel economy due to increased vehicle size, weight and power. Policies that help to improve the fuel economy of vehicles are one of the most cost-effective measures to achieve the challenging global goal: 50% $CO_2$ reduction by 2050 below 2005 levels in the entire transport sector.

Much analysis and proposals on sustainable transport policies have been developed around the world, both at government and research institutions. It is clear that no action will provide the single solution and it is imperative to act simultaneously on: i) improvement of technology in vehicles, leading to increased energy efficiency; ii) the change in driver behavior, to use less fuel per kilometer; iii) reducing the distances traveled per vehicle; and iv) a change in the type of travels towards more sustainable modes of transport.

In general, the recommendations for energy efficiency in transport are mainly focused on the first two priorities on the list, while the portfolios of policies —instrumental to the needs of the countries— should use trans-sectoral and multi-dimensional approaches, such as public transport planning and land use.

In ECLAC, we consider that the time has come to provide Latin American and Caribbean countries with a deeper understanding and a more strategic vision (and adapted to the realities of the region) on these issues; in this sense, we hope that this document will help countries to improve and further expand their portfolios of energy efficiency policies in the transport sector, in order to achieve the ambitious goals of energy efficiency, needed to ensure a sustainable energy future.

# Summary

## A. Energy efficiency and mobility

The continued worldwide increase in energy consumption is of concern to governments around the world and alternatives for the currently fossil fuel based global economic system are being debated at high level and across regions in order to curb current energy consumption.

Economic development has traditionally come with a transformation of mobility. Mobility constitutes an ontological absolute for emerging societies. Nevertheless, the emerging demand for human and material mobility comes at a cost and at the same time raises demand for energy.

Latin America and the Caribbean have engaged in a period of robust and sustained economic growth since the 1990s, which has also altered the pattern of and increased the demand for energy for mobility within the region and the region's interaction in the global market place. Inherently, mobility until today, despite strong efforts, is based on the consumption of fossil fuels.

Currently, mobility of people and goods accounts for 20% of total primary energy use globally and ¼ of energy-related $CO_2$ emissions.[1] Oil is the major fuel used in the transport sector. Reasons for the continuing dominance of oil are among others a) its high energy density, b) its competitiveness in price compared to alternatives, and c) technological lock-in. Given the relevance of mobility not only as a principal user of fossil fuels, but in consequence also as a major source of emissions and other external effects, there is an urgent need to review the pathways of energy consumption in Latin America and the Caribbean and to derive ideas to improve energy efficiency of mobility.

Technological advances are important to improve energy efficiency of mobility but are only part of the picture. Likewise it will be important to work on promoting a mobility shift to more efficient transport modes – thus aiming for a more holistic approach to increase efficiency of mobility.

Furthermore, avoiding the need for mobility should form an intrinsic part of policy design. As the mobility of people and goods spreads from the local to international scale and solutions are costly, international cooperation and coordination of efforts are inevitable and of mutually benefit to all actors.

The United Nations and the Economic Commission for Latin America and the Caribbean (ECLAC) in particular for Latin America and the Caribbean region, are committed to support and

[1] International Energy Agency (IEA), 2012, Energy Technology Perspectives 2012.

advice the Member States in the difficult challenge of implementing and driving energy efficiency in mobility. In 2012, the United Nations' Secretary General Ban Ki-Moon has brought to life the *"Sustainable Energy for All" Initiative (SE4ALL)*. The overarching goal of SE4ALL is to improve universal access to modern energy services by 2030 with three particular objectives:[2]

1. Ensure universal access to modern energy services;
2. Double the share of renewable energy in the global energy matrix; and
3. Double the global rate of improvement in energy efficiency.

The goals to increase renewable energy and to drive energy efficiency are strongly interlinked. Most of the current scenarios predict that the various renewable energy targets can only be achieved if countries introduce robust energy efficiency measures at the same time. The challenges are as huge as the possible gains.

One core action area of energy efficiency is mobility SE4ALL[3]. The initiative estimates that saving in the magnitude of 70-80 Exajoule per year could be achieved in mobility – comparable to the annual power production of 100 times the Itaipú power plant.

Technical efficiency in transport accounts for around one-third of the savings the sector is potentially able to make. Fuel efficiency improvements promise to be the biggest contributors. Only if these improvements can be achieved, it would be possible for the projected 2.5 billion cars on the road by 2050 (most of them in developing countries) to consume the same amount of fuel the 850 million cars that are currently on the roads are consuming. Technically this would be possible today.

Two-thirds of the potential savings in the sector have to come from shifting existing demand to more efficient transportation modes or to actually curb the increasing demand for mobility of passengers and freight.

In order to measure progress towards the SE4ALL's energy efficiency goal, the World Bank has proposed energy intensity as the indicator to track improvements in energy efficiency. As energy intensity is influenced also by other factors (for example structural changes in the economy, prices and others), this decision reflects the challenge of measuring progress in this field. This is particularly true in developing countries in which "the development of energy efficiency indicators (…) is limited by the availability and quality of data and by a lack of dedicated resources and expertise to collect, track, and analyze those data"[4].

Therefore, doubling the rate of improvement of energy efficiency is going to be defined as rate of improvement in energy intensity (measured in primary energy terms and GDP at purchasing power parity), also in the absence of any better data available.

The global rate of energy intensity from 1990-2010 decreased by 1.3% annually. Consequently, SEA4ALL defines an annual average reduction goal of 2.6% as the target from now on until 2030. For Latin America and the Caribbean this will be a particular challenge as the rate of energy intensity reduction between 1990 and 2010 was only 0.5% - 0.7% annually.

This work, synthesizes the analysis and proposals for improving energy efficiency of mobility in LAC for policy and decision makers derived from ECLAC's Position Paper on Energy Efficiency and Mobility; it also provides arguments and analysis for the search to decouple demand for mobility from demand for energy and creates a nexus between these sectors to set the foundation for future integrated strategies in this field.

[2] SE4ALL, 2013, http://www.sustainableenergyforall.org/.
[3] SE4ALL, 2012, Technical Report of Task Force 2.
[4] SE4ALL, 2013, Global Tracking Framework.

**Energy efficiency** in this sense is defined as[5]:

$$\text{Energy efficiency} = \left(\frac{\text{Useful energy output}}{\text{Energy input}}\right) \text{ in an equipment or process.}$$

This definition, however, only displays part of the underlying debate about energy efficiency and mostly refers to technically achieved energy efficiency. Energy conservation from consumption reduction is usually not captured by this definition. In the energy profession, most of the (policy) measures, consequently, have addressed energy efficiency (and, thus, technological measures).

**Mobility** describes the spatial movement of material, persons or information and is socially constructed. Mobility is realized by various means and constitutive elements; and thus, can be differentiated by purpose, meaning and competences. Constitutive aspects of mobility are also the physical infrastructure and characteristics of services that are the facilitators of mobility. In the context of this work mobility is characterized and differentiated first by type: passenger, material and information, at second by the level of reach and finally by mode.

Mobility is measured in terms of distance covered and volume transported. In the case of human mobility this is passenger/km and for materials ton/km. However, in the context of energy efficiency these measures fall short as neither includes the share of “unproductive mobility”, which is equivalent to the unused capacity of a transport service. Further it neither reflects the potential substitution of physical mobility by information exchange.

**Energy efficiency and mobility**

The most common approach to analyze energy efficiency of mobility is the so-called A-S-I approach to transport management: A: AVOID, S: SHIFT and I: IMPROVE:

- *AVOID: Enabling users to avoid motorized trips → Increase system efficiency*
- *SHIFT: Shift mobility to the most efficient transport mode → Increase travel efficiency*
- *IMPROVE: Improve fuel efficiency of the transport mode → Increase vehicle efficiency*

Only IMPROVE targets technical improvements of the process (and is captured by the aforementioned, traditional definition of energy efficiency). Yet, the other two strategies should be covered under an integrated energy efficiency analysis.

This study proposes a much more comprehensive view on ASI in order to account for energy efficiencies systemically. Consequently, IMPROVE defines as the target to minimize the consumption of each individual vehicle in the fleet of a specific mode.

SHIFT calculates the sum of all energy consumed for a similar “volume” of mobility comparing different travel options and combinations of modes (using a bicycle instead of a car). Based on the considerations above this definition also captures tele-working, which traditionally was considered to be in the AVOID segment. By way of example: Working from home also requires energy e.g. for the use of personal computers and the servers for working remotely and, thus, the mobility demand is only shifted to a more efficient mode – electronic traffic.

An AVOID measure can only be a conscious decision to avoid satisfying the mobility need at all.

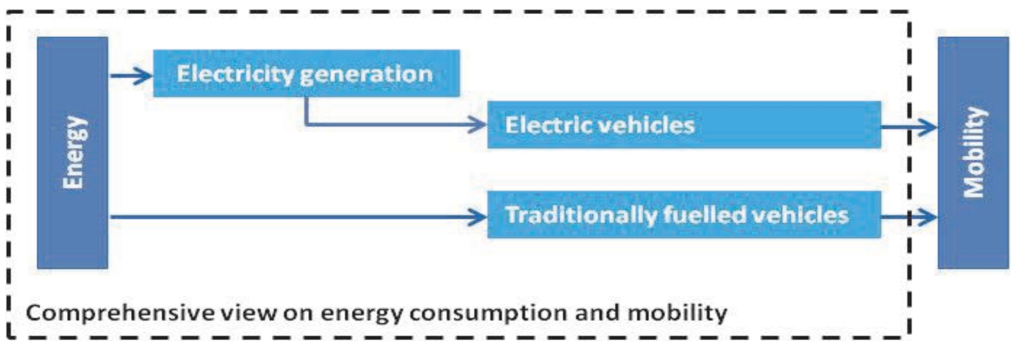
National, sub-national, regional and municipal policy instruments are very important and they can be adjusted well to local market characteristics. Application of measures in sequence can reduce and risk of implementation. Another crucial requirement for public policy is good coordination.

[5] ECLAC, 2010, Indicadores de Políticas Públicas en Materia de Eficiencia Energética en América Latina y el Caribe.

Future policy should be designed using an integrated approach and viewed as the compilation of sectoral development plans. In mobility, however, a high dispersion and multiplicity of public sector visions on infrastructure and infrastructure services can be found in Latin America and the Caribbean; the relevant government bodies in charge of energy, transport, economy and environment might have very different views on the future of infrastructure and infrastructure services. This translates into unarticulated policy development processes.

Therefore, it should be noted that a comprehensive analysis which would lead to fully integrated solutions and all encompassing integrated policies should always consider their impact on the energy matrix of a country or region. Electric verhicles are the most prominent example. While the introduction of electic vehicles definitely lowers the fossil fuel consumption in the traditional transport sector, it might not have the same positive impact on the overall energy balance given than some countries generate electricity from coal, oil and gas. Policy making should considere these linkages. This work explores these linkages as far as possible, a quantitative analysis, however, is almost impossible as comprehensive data is rare.

**DIAGRAM 1**
**COMPREHENSIVE VIEW ON ENERGY CONSUMPTION AND MOBILITY**




Source: Author elaboration.

In the context of reaching the overall goal of a more sustainable development, of which the implementation of energy efficiency and the curbing of the relationship between mobility growth and energy consumption is one important building block, the region requires a review of the current policies under a new paradigm that incorporates an integrated and sustainable vision.

## B. The mobility perspective —the Avoid, Shift and Improve approach

The most common approach to classify measures that increase energy efficiency and/or reduce GHG-emissions in transport is the "Avoid - Shift - Improve" approach (ASI).

Dimensions of efficiency in transport, i.e. system, travel or vehicle efficiency can be related to GHG-efficiency, energy efficiency and to a less extent efficiency in terms of traffic safety or pollutants like NOx, SOx or particulate matter.

Levels of energy efficiency significantly vary between economies and between regional and urban contexts. Among others it depends on the level of urbanization, income, trade intensity, efficiency and utilization of technologies, city layout and environmental awareness of consumers.

Indicators for system efficiency, travel efficiency or vehicle efficiency can differ from a few percent points to the factor of 10.

### *AVOID* motorized trips and reduce travel distances

Avoiding transport without negatively affecting economic development can be achieved by

- *Improved planning and management of logistics and passenger transport,*
- *Strategic prioritization of energy efficiency in urban planning and transport infrastructure construction and*
- *The consequent use of modern information and communication technology.*

Improved planning and management can decrease the amount of necessary tonne-kilometres (tkms) in freight transportation for example by local sourcing and decentralization of warehousing.

However, energy efficiency of these measures needs to be further investigated, especially with regard to the trade-off between energy consumption in transport and in decentralization. I.e. energy consumption for building and operating the additional warehouses has to be considered, too – not to speak of the trade-off in costs.

Tonne-kilometres can further be avoided by increasing vehicle utilization, i.e. avoiding empty or semi-empty truck tours. 13% of truck-kilometres in international transport and 27% in national transport in the European Union are run empty – 36% to 48% in India, about 50% in China.[6]

Bilateral or multinational cooperation on the planning, construction and operation of cross-border transport corridors, intelligent logistics systems (ILS), and specialized logistical infrastructure have further potential. Information and communication technology – e.g. use of video conferencing, electronic mail and telephone are further measures to avoid both transport and costs.

Examples for measures in AVOID[7]

| Measure | Context | Results |
|---|---|---|
| Information services for freight companies | Online logistics information platform providing freight information exchange services for trucking companies in Henan province, China | Reduction of empty running from 53% (2006) to 38% (2008). Average savings per month of 43.9 mill. kilometres or 8.8 mill. litres of fuel |
| Transport collaboration | Collaboration of two competing companies in central UK | 280,000 truck-kilometres per year |
| Teleworking | Teleworking in USA | 1998: Reduction of at most 1% of total household vehicle-km<br>2005: Reduction of vehicle-km by 0–2% |

### *SHIFT* the transport of goods and persons to the most efficient transport mode

Travel-efficiency, i.e. the energy consumption per kilometer travelled, can be improved by shifting transport from energy-intensive modes, air travel to rail, or motorized individual transport to mass transit (trains or busses) or non-motorized transport.

Five areas of intervention can be differentiated according to the Bogota Declaration as part of the shift strategy.

The first two are to promote increased use of maritime, river, and railway modes to transport goods and people, through strategic investments and the promotion of intermodal logistics management and the use of more sustainable modes of interurban passenger transport.

6 McKinnon, 2012, Improving the Energy Efficiency of Freight Transport: A Logistical Perspective (presentation).
7 In the cases in which at the time of production of this report the final evaluation results were available, the results presented are achieved results in cases where implementation is on-going the ex ante estimated results are presented.

Energy consumption of constructing vehicles and corresponding infrastructure, maintenance and vehicle dismantling should also be taken into account.

Energy consumption for construction of Metro or high-speed train networks can be a dominating factor in such a comparison. However, it can be difficult to find correct and context-specific data on complete life-cycle energy consumption.

Examples for interregional or interurban energy efficient modal shifts in passenger transport are Bus Rapid Transfer (BRT)-Systems (e.g. in Latin-American or Asian Mega-Cities) or high-speed train networks (e.g. in Europe or Japan).

Special attention should be given to smoothly connect complementary mass transit systems – augmenting consumer value by reducing total travel time for passengers or goods and hence increasing demand for such services.

Car sharing can be regarded as energy efficient transport, even when the energy efficiency of a shared car is essentially the same as of a private car.

The third area is the promotion of active travel modes as an integral part of the transport system. 'Fuel efficiency' on bicycle or on foot can be high depending on speed, weight and weather conditions. Measures to promote these modes are the most cost-efficient to reach energy efficient urban transport. This stands in contrast to their often limited representation in policy discussions or public budgets for urban transport. The safety of pedestrians and cyclists needs to be prioritized first, however, in order to promote these modes.

Area four and five of interventions include to promote transport demand management and behavioral changes towards sustainable mobility alternatives through information and education. Opposite to the other shift objectives these focus on measures that affect the demand-side rather than the supply-side of the transport market.

Examples for measures in SHIFT[8]

## *IMPROVE* technology and management of transport services

The third pillar of the ASI-approach is the improvement of vehicle efficiency, i.e. energy efficient operation of existing vehicle technology, development and marketing of new vehicles, market introduction of clean fuels, regular vehicle inspections, and information and communication services.

Four areas of intervention can be differentiated according to the Bogota Declaration.

- Promoting the use of cleaner vehicles and fuels: In order to improve GHG and energy efficiency of vehicles there are three main strategies:
  a) IMPROVEMENT of conventional vehicles,
  b) A mixture of alternative fuels (for example ethanol, biodiesel, LPG, etc.), and
  c) Market introduction of alternative fuel vehicles (AFV).

These measures apply to all passenger and freight vehicles including ships.

Examples:

- Hybrid powertrains in busses are capable to reduce fuel consumption by up to 30 % depending on the travel profile but cost about 25% to 30% more to purchase.
- Shipping services can implement slow steaming, improved design, engine efficiency improvements and fuel switching.

[8] In the cases in which at the time of production of this report the final evaluation results were available, the results presented are achieved results in cases where implementation is on-going the ex ante estimated results are presented.

| Measure | Context | Results |
|---|---|---|
| Shift of passenger transport to Bus Rapid Transfer | BRT Bogotá, Colombia: TransMilenio Phase II to IV | 53% of $CO_2$ reduction per year (equivalent to 80,128 tonnes CO2-equivalent per year) |
| Shift passenger transport from small and medium busses to cable cars | Cable Cars Metro in Medellín, Colombia | 69% of $CO_2$ reduction per year (equivalent to 17,172 tonnes CO2-equivalent per annum) |
| Shift freight transport to train | Modal shift from road to train for transportation of cars in India | 91% of $CO_2$ reduction per year (equivalent to 23,001 tonnes CO2-equivalent per year) |
| Introduction of city tax | Introduction of a city tax in Stockholm, Sweden in 2006 (incl. parallel reduction in public transport fares; residents of the city centre voted in favour of the tax) | 2.7% reduction in CO2-emissions (about 42,500 tons/year) |
| Employer travel reduction strategies (TDM) | Introduction of a law in WA, USA requiring travel plans in its most urban areas for companies with over 100 staff | Share of employees who drove to work in the targeted organizations reduced from 72 to 68% (affecting about 12% of all trips made in the area) |
| Travel-feedback programmes (TDM) | Introduction of travel-feedback programmes in residential areas, workplaces and schools in Japan | Car use was reduced by 12% and CO2 emissions by 19% |

- Central for improved energy efficiency in aviation are light weight materials, improved engines, aerodynamics and construction.

For all modes vehicle efficiency can further be improved by

- *Eco-driving, i.e. training of drivers on how to operate the vehicle in a more energy efficient manner*. Investigations from driver trainings in Germany and UK showed long-term fuel economy improvements of approx. 10%.[9] So called clean vehicles or alternative fuel vehicles (hydrogen fuel cell or battery-electric vehicles) repeatedly attained high media attendance in the past but failed and fail to conquer relevant market share.
- The *establishment of technical vehicle inspection*. The effectiveness of vehicle inspections can further be increased by including customer advisory services on eco-driving, purchase of energy efficient tires or vehicle maintenance (incl. low-viscosity engine oil and regular tire pressure checks).
- *Promoting the adoption of Intelligent Transportation Systems* such as electronic tolls, transportation control centers and user information in real time.

Examples for measures in IMPROVE[10]

Often the cost efficiency of efficiency measures regarding mobility is less prioritized in public discussion but of significant importance. Little information on cost-benefit-ratios is available for transport. Furthermore, it is difficult to cite general cost-benefit-ratios for ASI-measures as they will be heavily influenced by the economic, geographic and political context.

[9] IE Europe, 2009, ECODRIVEN Campaign Catalogue for European Ecodriving & Traffic Safety Campaigns.

[10] In the cases in which at the time of production of this report the final evaluation results were available, the results presented are achieved results in cases where implementation is on-going the ex ante estimated results are presented.

| Measure | Context | Results |
|---|---|---|
| Fuel economy standard | Introduction of a new car fuel economy standard for light duty vehicles (passenger cars) in 1995 in Japan | 19% until 2004 |
| Eco-driving | Promotion of safe and fuel efficient driving to HGV drivers in Scotland (SAFED initiative) | 10% |
| Speed reduction | Reduction of max. speed for trucks from 65 mph to 60 mph in USA | Up to 8% |
| Eco-driving | Ecodriving training for drivers of passenger cars in Germany and UK | 20.7% and 22.5% long-term improvements after training of approx. 10% |
| Speed reduction | Container ships lowering their speed from 26 to 18 knots ("slow-steaming") | 30% |
| Introduction of clean vehicles | Replacement of fossil fuel powered scooters by electric scooters in various cities and regions of India (recent CDM-Project) | Reduction in GHG-emissions will be about 69% or 24,563 tonnes CO2 equivalent per year (theoretical values) |

However, it can be said that improve measures, like market introduction of clean cars, which enjoy high popularity in governments and media, often come at a higher cost for public budgets than shift or avoid measures.

Some economic instruments like energy pricing can even pay for themselves from the moment of implementation. Depending on the context, it is sensible to pay attention to political costs. These can weigh more than the financial costs, e.g. for unpopular avoid measures like increasing parking fees or reduction of public parking space, introduction of road toll or abolishment of fuel price subsidies.

Political costs can be reduced by designing policy instruments in a way that voters understand that their benefits exceed their costs. Examples: Positive polls for the introduction of a city toll for Stockholm city centre or the reallocation of road space to pedestrian areas and bike lanes in New York.

Policy makers should be aware of the gap between what is technologically possible and what is economically feasible, i.e. attractive and cost-efficient to consumers.

Sound understanding of a) the needs and economic situation of the targeted consumer groups (demand) and b) the competition from already established transport services (supply) is key.

There is an imbalance between a) the evaluation of their theoretical efficiency potential and b) the evaluation of their marketability and competitiveness to established transport options, the latter being much less pronounced. As a consequence, market introduction of many efficiency technologies fails or can only be competitive on the market with continuous subsidies.

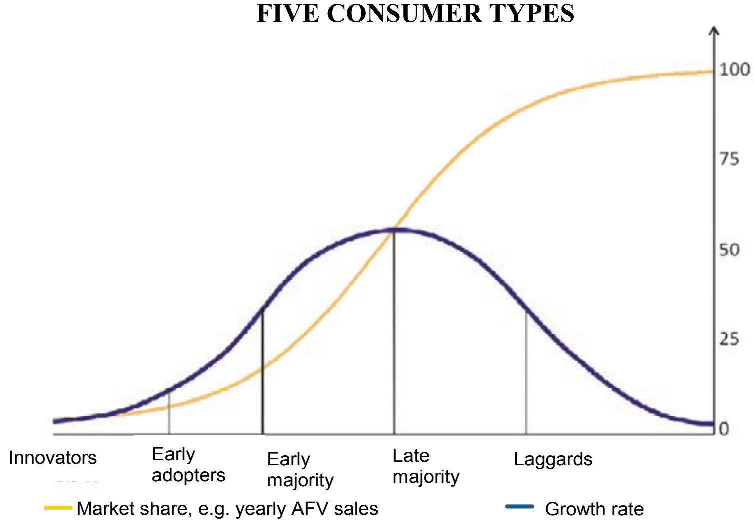
Depending on the specific consumer group, willingness-to-pay for energy efficient transport varies and, as such the velocity with which an innovation is diffused.

Willingness-to-pay is highest for the group of "innovators" and decreases gradually towards the group of "laggards".[11] Market introduction of initially more "expensive" products or services should hence first target the innovators (R&D and demonstration phase), later the early adopters (early and niche markets) and finally the majority of consumers (mass market). It is, consequently, crucial to identify the "innovators" for the targeted transport market or market segment to be able to design effective policy instruments.

Timing, type and duration of policy instruments should be carefully planned in accordance to the preferences and needs of these target groups. This way, policy makers can check for progress in market introduction before commencing with further investments.

[11] Consumers' evaluation of willingness to pay is also including convenience costs.

**FIGURE 1**
**DIFFUSION OF INNOVATION OVER PRODUCT LIFE CYCLE, INDICATING FIVE CONSUMER TYPES**



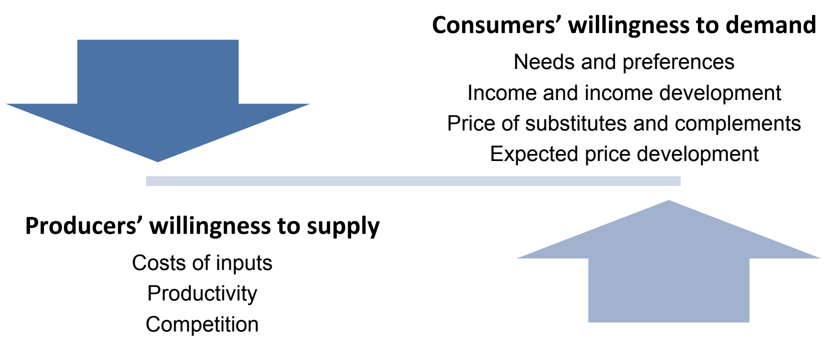

Source: Koen, 2011, Lecture Notes "Innovation Management".
Note: AFV = Alternative Fuel Vehicle.

Uncertainty and interdependence are inherent in the process of technological change in transport and need to be considered during policy design. These characteristics, coupled with positive feedback cycles, can contribute to the emergence of ‘‘technological lock-in’’, which prevents a market from adopting a new technology.

However, governments can overcome such “technological lock-in” by means of specifically designed policy instruments. Differences in government coordination are for example one of the principal reasons for the differences in the uptake of Natural Gas Vehicles (NGV) in Japan, Germany and Argentina.

To effectively develop the market of energy efficient transport, it is, therefore, essential to understand the factors affecting the willingness to demand and the willingness to supply.

**DIAGRAM 2**
**SUPPLY AND DEMAND WILLINGNESS**




Source: Author’s elaboration.

Market failure is a concept within economic theory wherein the allocation of goods and services by a free market is not efficient. The existence of market failure can be used as a justification for government intervention in markets, e.g. in transport markets.[12] Market failures occur as:

[12] Arrow, 1969, Analysis and Evaluation of Public Expenditures: The PPP System & Gravelle and Rees, 2004, Microeconomics & Stiglitz, 2000, Economics of the Public Sector.

a) Failure of competition
b) Undersupply of public goods
c) Externalities
d) Incomplete markets, and within that most dominantly coordination failure in complementary markets
e) Information failures (imperfect information, underinvestment in R&D, principal-agent issues and bounded consumer rationality).

In LAC maritime transport is responsible for over 90% of all international freight movements in terms of volume and thus the most important facilitator for the region's participation in the global market place.

Despite the fact that the sector has received little attention from governments in the region, the search for competitiveness of the region and increasing costs for marine fuels have put pressures on the industry to be more fuel efficient.

In shipping an "energy efficiency gap" exists between the possible measures and actually implemented measures regarding energy efficiency.

Some of the most promising options for more energy efficiency include an improved ship design (estimated at 10-50%), alternative fuels and operational measure (for example slow streaming, turnaround time in ports, etc.).

At the moment, particularly Liquefied Natural Gas (LNG) is perceived as a possibility.[13] LNG is also a fossil fuel that contributes to increasing $CO_2$-emissions but at the same time reduces $SO_X$ and $NO_X$ emissions. Thus, LNG powered ships are an option for emission control areas where marine gasoil is the only other fuel alternative available today unless abatement technology is installed. Two challenges exist: 1) the costly engine retrofits for existing ships, making LNG an option primarily for new builds, and 2) the additional space requirements for LNG storage. The lack of infrastructure for LNG in many ports also impacts the wider use of this fuel.

A number of these energy efficiency measures in shipping are cost efficient. But institutional barriers impede taking advantage of this potential and a shift will require a variety of actors to work together. Furthermore, the hinterland infrastructure needs to be adequately prepared and supplied.

A modal comparison reveals that bulk shipping remains the most efficient mode of transport (due to the larger size, lower speed and a higher fraction of usable weight). Fuel efficiency is lowest for trucks. The $CO_2$ emissions are directly proportional to the fuel efficiency in these examples. The $NO_X$ emissions are highest for the container ship. The level of fuel efficiency is significantly influenced by the load factor. Modal shift from road to sea will increase the fuel efficiency, but it may come at the expense of increased emissions of noxious substances if these are not mitigated in a coherent approach.

## C. Energy efficiency and mobility patterns in LAC

On one hand, and despite the economic importance of transport for Latin America, the current stock of transport infrastructure does not reach levels similar to economies in other parts of the world. The density or territorial coverage of the paved road network is significantly lower (44 m/km2) compared to developed countries (944 m/km2, Western European average and 390 m/km2 for the United States).[14]

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13 Traditionally, the main use of LNG in the energy matrix has been for electricity generation, for industrial production as well as heating rather than for transport.

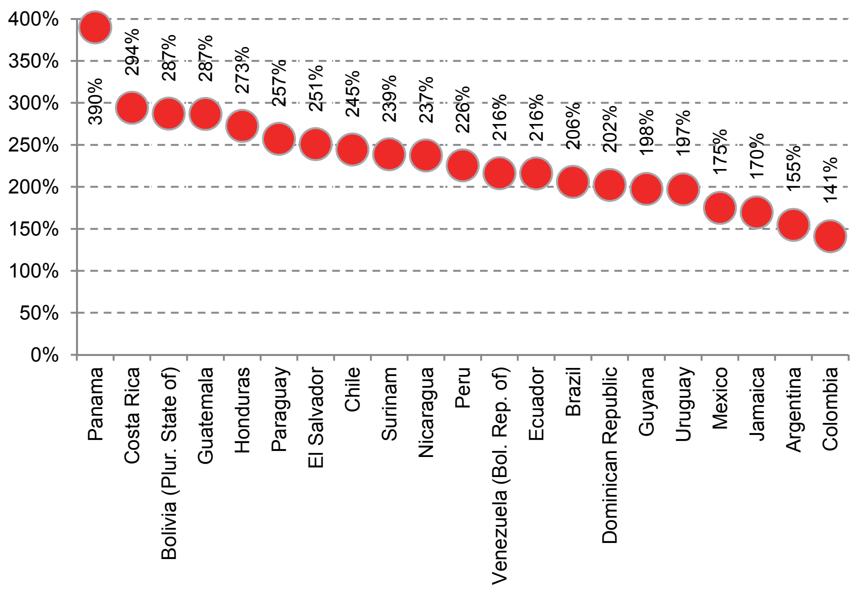
14 CEPAL, 2011, Infraestructura para la Integración Regional.

Similarly the gap in quality and availability of transport infrastructure between Latin America and other developing regions widended especially compared to Asia.

On the other hand, in recent years the final energy consumption in transport in Latin America totaled 1,500 million barrils of oil equivalent (MMboe), representing 35% of the total in 2011.[15]

In many countries the transportation sector is the largest sector of energy consumption. This relative importance depends on one side on the structure of the transportation sector's demand, level of activity, modes used, size of the vehicle fleet, etc., and on the other hand, the relative importance of other sectors, primarily the industrial, residential and services sectors.

**FIGURE 2**
**EVOLUTION OF FINAL ENERGY CONSUMPTION OF THE TRANSPORT SECTOR IN 2010 IN RELATION WITH THE CONSUMPTION IN 1990**




Source: Authors based on data of OLADE, 2013, Simulación de Medidas de Eficiencia Energética en los Sectores Industrial y Transporte de América Latina y el Caribe al Año 2030.

All countries in the region more than doubled their energy consumption in the transport sector between 1990 and 2010.

It is interesting to note that the Latin American countries can be divided into three groups in terms of total energy consumption in transport:

a) **Countries with lower energy consumption show a heterogeneous behavior** expanding their already important sectoral consumption further, except for the Dominican Republic;

b) **Countries with a higher consumption (between 2,000 and 20,000 kilotonnes of oil equivalent** (ktoe) in 2010) which also increased their consumption sector, but to a more modest extend (Chile, Colombia, Ecuador, Guatemala, Peru and Venezuela); and

c**) Countries with the highest sector consumption** that also expanded their consumption significantly (Brazil and Mexico).

Despite efforts towards the production of transport data in some countries, unfortunately certain physical indicators of transport activity of people and goods are still not available in a systematic and consolidated way for Latin American countries.

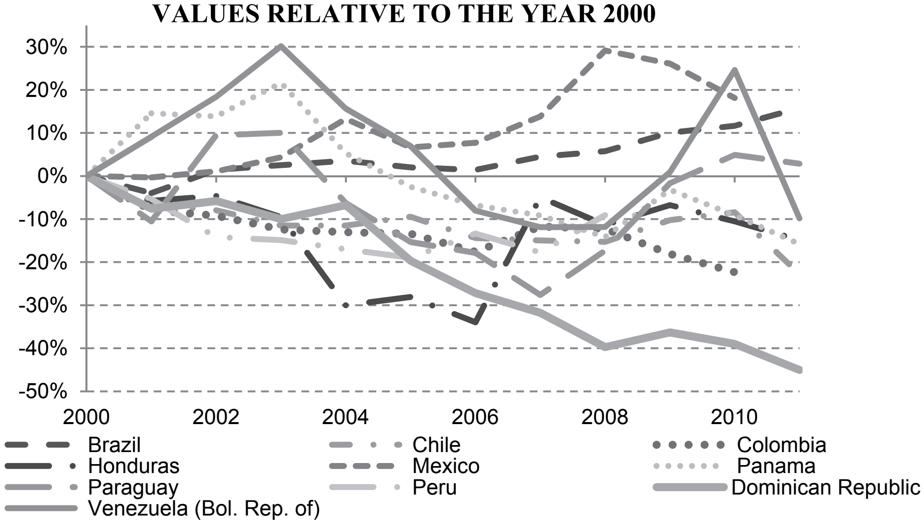
15 OLADE, 2013, Simulación de Medidas de Eficiencia Energética en los Sectores Industrial y Transporte de América Latina y el Caribe al Año 2030.

In the first instance, it seems to be a viable a solution to use as an indicator the total energy consumption per unit of GDP of the sector as transport demand correlates to a high extent with economic activity. Thus, one possible indicator is the energy intensity of transport, defined as the ratio of energy consumption in the transport sector to economic value added in that activity or sector of the GDP – and this is also the indicator recommended by the SE4ALL Initiative[16].

For the period under review (2000 to 2010), seven of the ten countries studied presented a reduction in transport energy intensity, while in other countries this indicator increased:

Examples: Brazil (+ 5%), Dominican Republic (+12%) and Venezuela (+18%).

**FIGURE 3**
**ENERGY INTENSITY OF TRANSPORT IN SELECTED LATIN AMERICAN COUNTRIES, VALUES RELATIVE TO THE YEAR 2000**




Source: Authors based on data of CEPAL, 2012, Anuario Estadístico de América Latina y el Caribe and OLADE, 2013, Simulación de Medidas de Eficiencia Energética en los Sectores Industrial y Transporte de América Latina y el Caribe al Año 2030.
Note: The value for Peru in 2005 was corrected for an obvious error in the data.

The significant expansion of the vehicle fleet, particularly in individual transportation, is an important issue. The growing number of cars per capita, on a road network without corresponding expansion, has made mobility a challenge and a high priority issue for the administration of many cities and especially in the Mega Cities of Latin America, with high economic costs, negative impacts on the quality of life of their inhabitants in terms of comfort and time to move, and regarding air pollution.

With respect to the programs to promote energy efficiency in mobility it is important that the user is always taken into account in the design of the programs. One can promote energy rationality through two elements; technology and the form use. In addition to expanding these works, it would be important in Latin America to thrive for a better articulation between the programs encouraging efficiency and other naturally aligned purposes, such as reducing emissions (with local and global valuation of the benefits), development and industrial competitiveness, security of energy supply, urban development, public transport and road infrastructure. Of course, it will not be by coincidence that energy efficiency in the transport sector will increase, which makes the role of the government crucial as the entity for the formulation of strategies and for inducing changes.

There are three main barriers to the promotion of energy efficiency in LAC in the transport sector.[17]

a) The general uncertainty about the regulatory environment in which actions are carried out;

[16] Note that intensity on an economic base comes with difficulties in interpretation and limitations to properly reflect the efficient use of energy due to structural changes occurring within the sector.
[17] CEPAL, 2009, Situación y perspectivas de la eficiencia energética en América Latina y El Caribe.

b) The fact that many of the countries in the region are exporters of energy and/or control the market for energy services removes, in many cases, incentives for reducing energy consumption;

c) The interesting mix of clean energy that consume several countries in the region (thanks to hydropower and biofuels) leads to a feeling that considerations on the environmental impact are less important.

Institutional framework: Although there is a framework in several countries in the region, agencies or ministerial divisions responsible for promoting energy efficiency, their action is almost always focused on electrictricity end use, with reduced coverage of the transport sector.

Moreover, the mere existence of laws or regulations that make energy efficiency mandatory does not guarantee the success of a national energy efficiency program. The context of this sector, diversified in terms of modes and equipment, with various kinds of users and objectives, makes the promotion of energy efficiency even more challenging.

Similarly, the lack of a national laboratory system for the evaluation of motor vehicles and the lack of experts does not facilitate a prompt resolution of the challenges – as the important share of imported used vehicles in the fleet of some countries of Latin America does not help.

Although it is neither possible nor desirable to simply copy other countries' regulations and initiatives should be designed "to fit" each country, the situation of the transport sector in Latin America, in which neighboring countries live with similar consumption patterns and similar problems, creates conditions that are particularly conducive to promote cooperation on energy efficiency matters.

That may be in areas related to the development of regulatory schemes, implementation and evaluation of programs and exchange and training of program managers. Performance monitoring and impact evaluation of measures to encourage efficiency in transportation systems is an area where cooperation can be particularly effective, due to the need to develop and test methodologies, defining indicators and establishing comparisons.

The Latin American Energy Organization (OLADE) developed an assessment of the regional potential to promote energy efficiency in the transport sector, simulating the adoption of measures to encourage energy efficiency in the transport sector up to the year 2030[18].

The simulation starts in 2011 (where the transport in Latin America was at a final consumption of 211 Mtoe, 35% of the total final energy consumption in the region).

**BOX 1**
**EXAMPLES OF PROGRAMS TO PROMOTE ENERGY EFFICIENCY IN MOBILITY IN LATIN AMERICA**

**Inspection programs and driver training**

These programs usually geared to drivers of commercial vehicles, such as buses and trucks, seek to evaluate the operating conditions of the engine (usually diesel engines, checking the conditions of the air-fuel-mixture and emission of pollutants at different loading rates) and informing drivers on how to drive safely and efficiently, emphasizing the associated energy economies and economic implications.

Examples (given that these programs are being implemented the results are estimated and should be verified after the end of the program):

Brazil: Driver training and information program (SEST/SENAT), approx. 14% of energy savings per trained driver.
Programs for saving fuel in transport enterprises (CONPET), annual savings of 252 million liters of diesel (2012)
Assessment of the impacts of driver training (COMLURB), saving up to 13% fuel.
Mexico: Clean Transport Project (SEMARNAT), 26.4% savings in fuel consumption.

[18] OLADE, 2013, Simulación de Medidas de Eficiencia Energética en los Sectores Industrial y Transporte de América Latina y el Caribe al Año 2030.

Box 1 (conclusion)

**Programmes to promote efficient vehicle technologies**

Programs for the promotion of more efficient vehicle technologies can achieve results with low involvement of drivers. However, these programs are typically more expensive, be it for developing more efficient technologies, be it for introducing them, which may require promotion and marketing mechanisms, including the definition of rates of taxes that take into account such aspects.

Vehicular labeling programs and performance standards are one example. The experience in Latin American is still limited, but in some countries there are initiatives in this direction (Brazil, Chile and Mexico).

The implementation mode is important regarding the scope of the program. Labeling in Brazil reaches 55% of sales in the automotive industry in the domestic market. According to the current legislation over the next five years all vehicles and models should be labeled – a feature that the Chilean program has from the beginning.

The Mexican label follows closely the example of the United States, the regulatory standard "Corporate Average Fuel Economy (CAFE)".

Increased vehicle efficiency has its cost. In the case of the Mexican program, it is estimated that the average vehicle price may increase in 2014 by 4.7% due to the Regulation 163 on energy efficiency and fuel economy coming into force. Due to the implementation of this standard, subcompact cars prices may rise by 6.30%, compacts by 3.80%, luxury cars by 2.58% and sports cars by 2.66%, while the multiple use vans may raise by 3.6% and light Sub Urban Vehicles (SUV) by 5.23% (Reforma [diario], 2013, Autos subirán de precio con norma de eficiencia energética).

Taxation based on the adoption of efficient technologies. The tax burden is higher for more powerful, and therefore generally less efficient, vehicles. Beyond that, efficiency can be promoted through establishing a tax structure with discounts based on the fulfillment of performance targets. Example: The InovarAuto Program, implemented in Brazil in May 2013. The goals defined by InovarAuto are compatible with the European goals for 2015 (130 g $CO_2$/km), adapted by Brazil taking into account the differences in driving cycle, fuel, and road conditions.

Finally, there are also special programs such as the evaluation of the use of spoilers by trucks.

Examples (given that these programs are being implemented the results are estimated and should be verified after the end of the program):

Brazil, Chile, Mexico: Vehicular labeling programs and standards of performance. Mexico is estimated to save 35 million liters of fuel per year; there are no assessments for Brazil and Chile.

Brazil: Taxation based on the adoption of efficient technologies (MDIC and MCTI) between 19 and 34% fuel savings.

Chile: Evaluation of the use spoilers by trucks (CLIL) potential savings between 12 and 16% of the fuel consumption.

Source: Author's elaboration.

For the projection of regional energy consumption, an average annual growth rate of 3.3% from 2011 was adopted, corresponding to an increase of 85% during the period 2011-2030 in the flows of energy balance, which coincides with the estimates presented by the International Energy Agency (IEA) that forecasts the energy demand in Latin America may double until 2030.

The introduction of efficient technologies and increased use of innovative energy carriers, such as biofuels and electricity, in transport may induce a significant change in the energy matrix and reduce energy consumption by 102 Mtoe per year, with the simulated scenario claiming about 26% less energy demand than in the base case.

## D. Conclusions and recommendations: towards a joint agenda in energy efficiency and mobility in Latin America and the Caribbean

The importance of mobility for energy consumption around the world and particularly for Latin America and the Caribbean cannot be underestimated.

Given historic and current developments, potential gains from increased energy efficiency in transport are huge.

The Sustainable Energy For All (SE4ALL) initiative by the United Nations provides an opportunity for governments in the region to study more in depth the current status quo of energy efficiency in the transport sector, to research best available options and to develop targeted measures for improvements.

**BOX 2**
**LAC CASE STUDIES - COMPARING ENERGY EFFICIENCY FOR MOBILITY OPTIONS**

In order to provide a more detailed insight into transport in Latin America and the Caribbean, three case studies were selected for a profound assessment. The case studies were carefully selected to reflect different realities – an international example from Latin America, an urban mobility example in Latin America and a domestic mobility example from the Caribbean. All case studies looked at passenger and freight mobility although sometimes emphasis was placed on only one of the two.

**International mobility in Latin America: Buenos Aires - Montevideo**

This case study compared air, sea and road mobility options. Rail was included as a potential, currently not operational option. Also, combined/multimodal mobility was investigated as an option (combining road/rail/public transport and ferry). It was found that in both cities, emissions from the transport sector stem predominantly from individual motorized transport (with the exception of $NO_X$ primarily emitted from public transport).

The analysis reveals that the multimodal option ferry – road (with public transport) is the most energy efficient one for passenger transport in the MVD-BA corridor. This option is also rather price competitive (except for the case when compared to a private vehicle with maximum 4-passenger occupation). The least energy efficient modes are air and individual road transport. Freight transport has its maximum potential to decrease energy consumption using maritime transport between the two cities. Good efficiency values were also obtained in the case of the multimodal transport ferry – road, which according to the estimated values for energy efficiency can be considered the third most efficient option (the hypothetical, non-operational option rail would score second).

**Urban mobility in Latin America: Medellin**

In Medellin, passenger and freight mobility was researched with a closer look to passenger mobility. It was found that there is good institutional support for sustainable transport solutions (which also translates in financial support that is crucial for the development and implementation of projects). Consequently, energy efficiency tendency is going the right direction (and emission data alike). The (recognized) local authority is able to develop, implement and enforce sound policies adapted to the local context.

But still stronger efforts are required as, although there is a certain vision trying to move more people in public transport, individual passenger mobility is growing (with some relation to the level of income). Furthermore, it is important to integrate freight mobility into a vision for urban transport (with the challenge that many times the transported cargo is not even to be delivered in the city but only passing through) despite the current emphasis on passenger urban mobility. Integrated urban solutions in this sense are influenced by many variables such as price, security, etc.

**Domestic mobility in the Caribbean: Jamaica and Trinidad & Tobago**

In the Caribbean, intra- and inter-island travel was assessed on a domestic basis given the importance of this form of mobility for the Small Island Developing States (SIDS).

In Jamaica, intra-island travel between Montego Bay and Kingston uses 0.54 l/passenger in a bus, 0.98 l/passenger in a taxi and 13.86 l/passenger in an airplane. It can, therefore, be concluded that measures should be target first of all individual road transport (given that the share of air travel is rather small although absolute efficiency is worst). Policy measures should include linking transport and energy policies towards an integrated approach.

Mobility between the two islands of Trinidad and Tobago was the second case study. Mobility options of the inter-island travel use 0.48 l/passenger by water taxi, 0.89 l/passenger by short ferry and 11.25 l/passenger by plane. This clearly favors water borne travel modes. However, energy efficiency is a challenge for Trinidad and Tobago, given that the country is an important oil producer in the region and, as most of the oil producing nations, fuel is subsidized. An issue to consider in increasing the attractiveness of waterborne mobility options will be the infrastructure of the hinterland in order to connect sea travel to the necessary feeder travel via land.

Source: Author’s elaboration.

In order to develop and implement complementary and integrated policies, ECLAC proposes a comprehensive view of energy efficiency in mobility based on the so called ASI-approach.

A: AVOID trips and increase the system’s efficiency;

S: SHIFT mobility to more efficient modes to increase travel efficiency;

I: IMPROVE fuel efficiency to augment vehicle efficiency.

Only by thinking mobility systemically, sustainable energy efficient solutions can be found. Policy design needs to be integrated between the transport and the energy specialized entities in order to be sustainable and capture non-energy-related mobility considerations in policy making.

Understanding of and collaboration with the markets and market development are essential in order to design policies so that they are appropriate, targeted and sustainable.

Institutional capacity is an important pre-condition, but also a weak element in the majority of LAC countries. Public administrations play a key role in shaping transport markets in general and in particular the framework for improving energy efficiency, notably in the enforcement of existing regulation.

Setting fuel taxes appropriately, abolishment of fuel subsidies, prioritization of funds and R&D incentives encourage markets that favor energy efficient solutions.

**BOX 3**
**THE CHALLENGE OF FUEL SUBSIDIES**

The case of fuel subsidies deserves particular attention among the tools for improving energy efficiency. The IEA (2012, Energy Technology Perspectives 2012) estimated that eliminating inefficient subsidies that encourage wasteful consumption of energy and fossil fuels could reduce growth in energy demand by some 4%, even by 2020.

Fuel subsidies are meant to serve a variety of purposes: From climate change mitigation to promotion of local energy sources, industrial policies and the attainment of social issues (e.g. keeping low inflation rates).

Fossil-fuel subsidies (gasoline and diesel) and fuel subsidies for non-fossil fuels (e.g. bio-fuels subsidies, LNG subsidies, etc) must be treated separately, due to the different impacts and implications in terms of energy policy.

Fossil fuel subsidies are usually impeding advances in energy efficiency. The case of non-fossil fuel subsidies, however, is not yet clear due to the lack of systematic research; case studies indicate that subsidies could help to increase the share of alternative fuels in the market, if limited in time.

Source: Author's elaboration.

However, policy objectives and implementation strategies need to be clear, medium and long-term and comprehensive.

While goals can be complementary in many cases, there are times when policy makers have to decide whether they aim for a) energy efficient mobility; b) mitigation of greenhouse gas emissions; or c) mobility with low consumption of crude oil-based fuels.

In the search of good (and bad) practice examples one can look at different experiences worldwide and in LAC.

In Latin America a key challenge is to obtain appropriate data to actually be able to understand and analyze the local context. Data are crucial to make founded recommendations and well informed decisions that effectively fit the context.

The current pathways of energy consumption in mobility of the LAC countries vary and require different approaches and solutions. But each individual country irrespective of its size and state of economic development faces eminent pressure to curb energy consumption of mobility without jeopardizing social and economic welfare and development.

Transport services and the related infrastructure are key for the integration for the region in the global market. However, effective policies directed to reduce and manage energy consumption and emissions are widely absent in the region. With maritime transport being one of the most energy efficient possibilities of transport, great importance should be given to making this mode more environmentally friendly, energy efficient and competitive to other modes.

Furthermore, infrastructure for several transport modes and multimodal transport is not developed adequately. Often, the decision to opt for a more energy efficient mode is impeded by a significantly higher travel time, high costs, or lack of quality and security. This is particularly true for urban transport – where the current focus on passenger mobility should not obstruct the view on urban freight movements that are equally important and growing in numbers.

Consequently, close cooperation between energy and transport experts is needed urgently to research functioning best practices worldwide targeting an increase of energy efficiency in mobility with the goal to propose locally adapted solutions in the quest of decoupling of energy consumption and mobility.

This will not only require technical solutions but also a change (shift) in strategy and mindset (avoid) of decision makers and within the population as a whole. Only this will help shifting mobility to more sustainable transport modes and ultimately to avoid some of the demand for mobility in the future.

# I. Fundamentals of energy efficiency and mobility

## A. Introduction

The continued worldwide increase in energy consumption is of concern to governments around the world and alternatives to the currently fossil fuel based system are under debate. Energy efficiency in this context is seen to have a high potential and to be implemented quickly. This is particularly important for mobility, i.e. the movement of people, goods and information[19]. Economic development has traditionally come with a transformation of mobility. Mobility constitutes an ontological absolute for emerging societies. Nevertheless, the emerging demand for human and goods mobility comes at a cost and often raises demand for energy. Latin America and the Caribbean have engaged in a period of robust and sustained economic growth since the 1990s. This has altered the pattern of and increased the demand for energy in mobility within the region and the region's interaction within the global market place. Inherently, mobility until today, despite strong efforts, is based on the consumption of fossil fuels.

Currently, the global mobility of people and goods accounts for 20% of total primary energy use and 25%of energy-related $CO_2$ emissions (IEA, 2012a). Oil is the major fuel used in the transport sector with North America and Australia, being the greatest consumer per capita equivalent to 1.2 to 1.5 toe/capita. However, emerging economies depict the highest growth rates in oil consumption per capita. By way of example India and China consume in the range of 0.05 to 0.15 toe/capita (IEA, 2012a). Reasons for the continuing dominance of oil are among others a) its high energy density, b) its competitiveness in price compared to alternatives, and c) technological lock-in. Given the relevance of mobility not only as a principal user of fossil fuels, but in consequence also as a major source of emissions and other external effects, there is an urgent need to review the pathways of energy consumption in Latin America and the Caribbean and to derive ideas to improve energy efficiency of mobility.

Given the current paradigm of growth, questions need to be discussed in how far traditional pathways and patterns of mobility can be transformed into more sustainable ones. These new pathways should break the dependency on fossil fuels, curb the environmental impacts of mobility, but at the same time not jeopardize already established access to mobility.

[19] In the context of this work mobility of information is not addressed in detail, but is an important part of today's mobility pattern.

# B. Context

In order to provide a 360° view on the matter, ECLAC in a joint multidisciplinary approach of the Natural Resources and Infrastructure Divsion (NRID) have developed have engaged in an extensive to analyse the links and interdependencies of energy consumption and mobility. The paper was a request by ECLAC's member states and principal partners at the III. Policy Dialogue on Energy Efficiency in Panama City, 2012. The series of policy dialogues on energy efficiency is the principal forum of ECLAC on this topic directed to high level government officials and takes place once a year, always with a different key topic highlighted. A summary of this document was presented at the "IV. Dialogue on Energy Efficiency and Mobility" in Mexico City, 2013. The work gives an overview on the state of the art in the discussion of energy efficiency and mobility at global and regional level and provides insight in current mobility and energy consumption patterns for selected cases in Latin America and the Caribbean. Further it presents best practices, policy strategies and technical solutions with potential for decoupling of mobility and energy consumption. Mobility in this work includes human (passenger), goods (freight) and information mobility at all geographical levels: urban, regional and international. The multidisciplinary approach allows for combining the perspectives from the energy and transport sectors in the search to create a macro and integrated vision and perspective, independent of sectoral or unimodal viewpoints.

In this first step the position paper is seen as the basis to lead discussions at regional, sub-regional and national level on how effective and efficient policy and technical measures can be introduced and advanced in the future.

Innovation and technical solutions are important measures in the search to improve energy efficiency of mobility and many are already available and economically viable. According to the IEA (2012b) improvements in fuel economy of up to 30-50% could be achieved by 2030 compared to 2005 by consequently implementing existing technology. In order to reap the benefit of these solutions, awareness, political will and access to financial resources are required in Latin America and the Caribbean (LAC). Technological advances, however, are only part of the picture. Likewise it will be important to work on promoting a mobility shift to more energy efficient transport modes – thus aiming for a more holistic increase in efficiency of mobility system as a whole. Furthermore, avoiding the need for mobility should form an intrinsic part of policy design. As the mobility of people and goods spreads from the local to international scale and solutions are costly, international cooperation and coordination of efforts are indispensable and of mutually benefit to all actors. The European Commission (2011) in its last White paper concludes that "old challenges [to improve the sustainability of mobility] remain but new have come" which can be addressed internationally. Further, the EC proposes a common European transport area on all geographical levels and for all modes; land, water and air with the Single European Sky, Single European Railway Area and "Blue belt" proposals respectively.

The United Nations and ECLAC in particular for Latin America and the Caribbean, are committed to support and advice the Member States in the challenge to tackle the task of implementing and driving energy efficiency in mobility. In 2012, the United Nations' Secretary General Ban Ki-Moon has brought to life the "Sustainable Energy For All" Initiative (known as SE4ALL) accompanied by the "International Year of Sustainable Energy for all" following a declaration by the General Assembly (A/RES/65/151). The overarching goal of SE4ALL is to improve universal access to modern energy services by 2030. The particular objectives to be achieved by 2030 are the following three (SE4ALL, 2013):

- Ensure universal access to modern energy services;
- Double the share of renewable energy in the global energy matrix; and
- Double the global rate of improvement in energy efficiency.

It is important to note that the goals on renewable energy and energy efficiency are strongly interlinked. Most of the current scenarios predict that the various renewable energy targets that countries have given themselves can only be achieved if they introduce robust energy efficiency measures at the same time. The challenge is as considerable as the possible gains are. The Task Force 2 of SE4ALL estimates that achieving the later two objectives would reduce global energy demand by 30% and Greenhouse Gas (GHG) Emissions roughly by 60% (SE4ALL, 2012). One of the core action areas to achieve these reductions, according to the Global Action Agenda of SE4ALL (2012), is mobility. The report estimates that changes in mobility should contribute 70-80EJ to the overall reduction target, comparable to the annual power production of 100 times the Iguaçu, Brazil power plant.

According to the same report, technical efficiency in transport accounts for more or less one-third of the savings the sector is potentially able to make. Fuel efficiency improvements or switching to electric vehicles promise to be the biggest contributors. Only if these improvements can be achieved, it would be possible for the projected 2.5 billion cars on the road by 2050 (most of them in developing countries) to consume the same amount of fuel the 850 million cars that are currently on the roads are consuming. Technically this would be possible today. The remaining two-thirds of the potential savings of the sector have to come from shifting existing demand to more energy efficient modes of transport or to actually curb the increasing demand for mobility of passenger and freight.

The thirst for oil in satisfying mobility needs makes energy efficiency crucial as options for renewable energy sources are limited or only accessible on a large scale with high costs and/or further research. The International Renewable Energy Agency (IRENA) (2013), an institution to create a roadmap towards doubling the share of renewable energy, shows that most of the potential for renewable energy in mobility comes from alternative fuels for road transport. However, the implementation of alternative fuels may not come without other social and environmental costs.

In the effort to measure progress towards the SE4ALL's energy efficiency goal a framework was launched recently that defines the rate of improvement in energy intensity (measured in primary energy terms and GDP at purchasing power parity) as the measure in which doubling the rate of improvement of energy efficiency will be tracked (SE4ALL, 2013a).

The framework states that the historic global rate of energy intensity from 1990 – 2010 decreased by 1.3% annually. Therefore, in the effort to double the decrease of energy intensity SE4ALL has set 2.6% annual average reduction as the target from now on until 2030. For LAC, this will be a particularly difficult as the annual rate of energy intensity reduction between 1990 and 2010 was only 0.5% - 0.7% (compared to 1.3% globally). Consequently, to reach SE4ALL goal for the region now requires an average 2.6% - 3.0% annual reduction until 2030 (SE4ALL, 2013a). Nevertheless, Latin American and Caribbean countries do not form part of the group of highly energy intensive countries over the considered timeframe; except for Trinidad and Tobago that was number four in world energy intensity. Peru was even among the least energy intensive countries. The reduction of energy intensity in LAC might also be considered to be a consequence of the modest levels of economic development and the structure of economic activity between 1990 and 2010 rather than a result of actual energy efficiency measures. Based on historic data analysis, SE4ALL names Mexico and Argentina among the so-called fast moving countries – countries with the highest energy savings as a result of a reduction in energy intensity over the period 1990 – 2010 with 14EJ and 11 EJ respectively avoided energy intensity.

The issue of measuring progress also points to another challenge, the one of generating and obtaining data in the first place. Or as the Global Tracking Framework puts it (SE4ALL, 2013a, p.143): "The development of energy efficiency indicators in many developing countries is limited by the availability and quality of data and by a lack of dedicated resources and expertise to collect, track, and analyze those data." A particular focus should hereby be placed on the residential and transport sectors. This is one of the reasons why the Natural Resources and Energy Unit (NREU) is currently implementing a project called "Database for Energy Efficiency Indicators" (know by the Spanish acronym BIEE), aiming towards providing the foundations for better data access in the future. Once completed, this efficiency database for LAC may also contribute to the current preparations of the Member States for the Post-2015 development agenda. This project complements other efforts of NREU, such as smart grids (Nigris and Coviello, 2012), Public-Private-Partnerships for innovative solutions (Coviello, Gollán and Pérez, 2012) and regional integration (Ruchansky, 2013) in the context of energy being a valuable natural resource (Altomonte et al., 2013, Kozulj, 2012, Acquatella, 2008, Altomonte and Coviello, 2004).

Mobility, referring to the movement of people and goods, is not only a result of economic development, but at the same time is a key facilitator for the integration of the region into the global economy. The Infrastructure Services Unit (ISU) over the last decades has closely worked with the governments of the region and analyzed the evolution of mobility, and the embedded and immobile infrastructures. Considering that infrastructure shapes mobility, ISU has worked to support the development of adequate and integrated networks and the necessary services and policies for using it. Overall, transport infrastructure investments have a positive impact on economic growth, create wealth and jobs, and enhance trade, geographical accessibility and the mobility of people and goods. Thus, development of infrastructure services and infrastructure is a prerequisite for economic and social development in the region, creating accessibility at varying levels, but at the same time the related external effects of mobility growth need to be mitigated. In this respect ISU has identified key issues and challenges for future sustainable development, ranging from the gap in infrastructure (Sánchez and Wilmsmeier, 2005; Sánchez and Perotti, 2011), the need for logistics integration (Wilmsmeier and Monios, 2012, Pérez Salas, 2013), the need for advanced strategies in infrastructure charges (Wilmsmeier, 2012), improved energy efficiency (Fridell et al., 2013), improved accessibility (Grieco, 2012), to the need for the implementation of integrated and sustainable policies for infrastructure, logistics and mobility with a co-modal vision (Cipoletta, 2011). Energy consumption and energy efficiency are inherently connected to this integrated approach and a prerequisite in a framework of sustainable development.

## C. Objective

This document puts forward an analysis of and proposals for improving energy efficiency of mobility in LAC for policy and decision makers as well as all other interested private and public sector stakeholders.

What are the current global trends in energy consumption? What is the share of mobility? What are available technical solutions to improve energy efficiency of mobility? What strategies have been implemented? Which ones have been successful/not successful?

What is the current state of mobility, energy consumption and energy efficiency in LAC? What is the energy performance in selected corridors or regions? What are the lessons learned?

Building on the knowledge and expertise from professionals in the energy and transport sectors, this position papers provides arguments and analysis for the search to decouple demand for mobility from demand for energy and creates a nexus between these sectors to set the foundation for future integrated strategies in this field.

## D. Key concepts

This part introduces key concepts for understanding energy efficiency and mobility and elaborates the framework of discussion. Understanding these concepts is essential in order to communicate in a common language, formulate targeted responses and link energy efficiency and mobility.

Defining energy efficiency:

Energy efficiency has recently gained popularity as a quick fix to reach a more sustainable energy system. In 2010, NREU published its flagship report “Energy efficiency in Latin America and the Caribbean: Situation and outlook” reviewing the status quo and policies on energy efficiency in 26 countries of the region (ECLAC 2010, cf. Carpio and Coviello, 2014). The report identified that one of the major gaps is the measurement of advances in energy efficiency in Latin America and the Caribbean.

In a posterior publication ECLAC reviews common indicators to measure energy efficiency and proposes a set of indicators for Latin America (Horta, 2010) and defines energy efficiency as follows:

$$Energy\ efficiency = \left(\frac{Desired\ useful\ energy\ effect}{Energy\ consumption}\right) \text{ of an equipment or process}$$

which is equal to

$$Energy\ efficiency = \left(\frac{Used\ energy}{Energy\ consumed}\right) \text{ of an equipment or process}$$

This definition, however, only displays part of the underlying debate about energy efficiency. As the document notes[20] (and can further be explored for example in Moriarty and Honnery, 2012) there is also the notion of energy conservation. Although different views on the exact distinction between energy efficiency and energy conservation exist, it is often inferred that the former refers to energy consumption reductions based on technical advances and the later to a conscious decision of the consumer to reduce his consumption. In the energy profession, most of the (policy) measures, consequently, have addressed energy efficiency (and, thus, technological measures).

This may partly be rooted in the fact that the demands for energy and mobility are both derived demands. Usually, the services that energy provides are demanded (heat, movement, etc.). In the case of mobility, this even becomes more complicated. The mobility service that is desired is to obtain a product or displace oneself. Therefore, mobility is a derived demand and thus the energy needed to provide the service of mobility a second order derived demand. Consequently, the present document will try to integrate the perspectives and approaches from the energy and transport sector.

Defining mobility:

Mobility describes the spatial movement of material, persons or information and is socially constructed. Mobility is realized by various means and constitutive elements; and thus, can be differentiated by purpose, meaning and competences. Constitutive aspects of mobility are also the physical infrastructure and characteristics of services that are the facilitators of mobility.

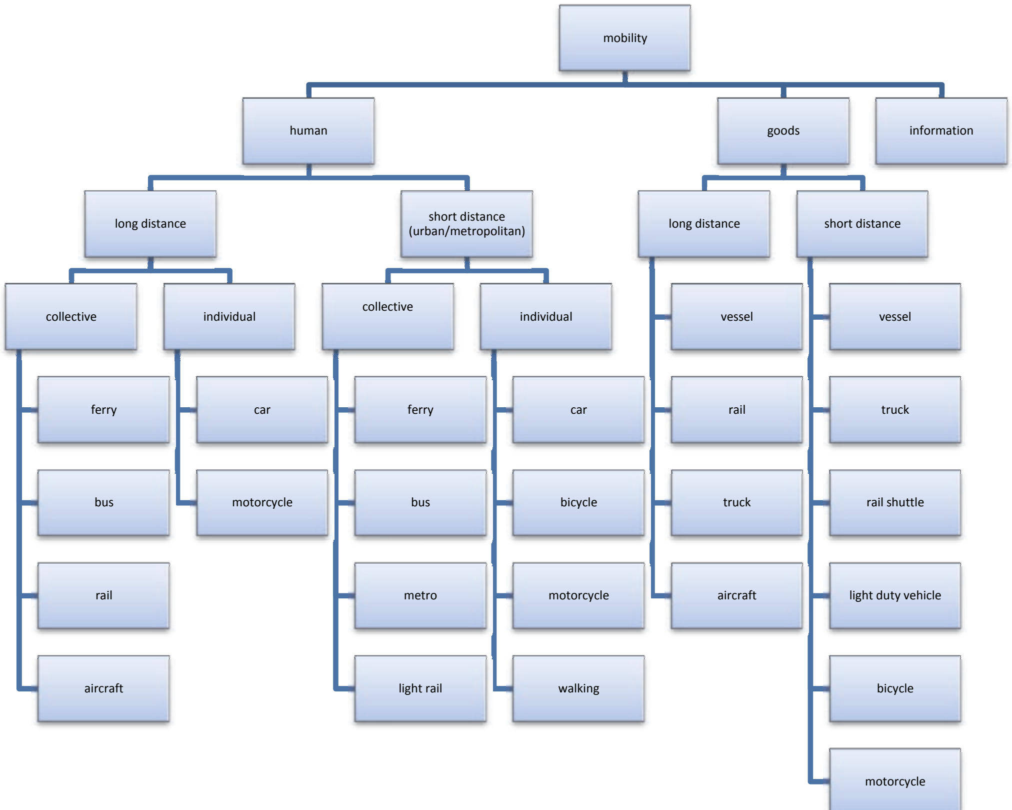
In the context of this work mobility is characterized and differentiated first by type: passenger, goods and information, at second the level of reach and finally by mode.

The central question of mobility in the context of sustainability and also energy efficiency is how to find an equilibrium between, “too little movement or too much, or of the wrong sort or at the wrong time” (Sheller and Urry, 2006, p.208). An equilibrium of these would also result in less energy consumption and potentially improved energy efficiency. Further it is necessary to differentiate between productive and unproductive mobility. By way of example the empty repositioning of containers in maritime transport can be classified as unproductive mobility.

Mobility is measured in terms of distance covered and volume transported. In the case of human mobility this is passenger/km, for goods ton/km, for information bits/s. However, in the context of energy efficiency these measures neither include the share of “unproductive mobility”, which is equivalent to the unused capacity of a transport service, e.g. the empty seats in a bus on a specific route would be the share of unproductive mobility and would constitute potentials to improve efficiency either by capacity adjustment (deploying a smaller vehicle) or by increasing its used capacity.

[20] The document also elaborates further on the difference between efficiency and effectiveness as well as energy and exergy.

**DIAGRAM 3**
**CHARACTERISTIS OF MOBILITY OPTIONS**




Source: Author's elaboration.

In the search to decouple mobility and economic growth the differentiation between potential and realized mobility needs to be made. Potential mobility describes the set of possible movements from either one point to the other or within a given radius of action. Potential mobility is influenced by the density and variety of possible movements which in turn are increased by different modes of transport Realized mobility describes the actual movement between one point and the other or within a given radius of action. Realized mobility as influenced by the same factors as potential mobility but taking the pace of transport into account (German Federal Environment Agency, 2011). This differentiation is important in the application of the AVOID, SHIFT and IMRPVOE approach as detailed in the next section.

## E. Energy efficiency and mobility

The most common approach to analyze energy efficiency of mobility is the so-called A-S-I approach to mobility management: A: AVOID, S: SHIFT and I: IMPROVE (introduced by Dalkmann and Brannigan, 2007).

AVOID: Enabling users to avoid motorized trips → Increase system efficiency

SHIFT: Shift mobility to the most efficient transport mode → Increase travel efficiency

IMPROVE: Improve fuel efficiency of the transport mode → Increase vehicle and/or infrastructure efficiency

Only the last one, IMPROVE, targets technical improvements of the process (and is captured by the aforementioned, traditional definition of energy efficiency). Yet, the other two strategies should be covered under an integrated energy efficiency analysis. Furthermore, the ASI approach has recently been modified by some authors (e.g. Sakamoto, Dalkmann and Palmer, 2010) – sometimes adding a financial component or research component to the necessary measures.

This study, however, proposes a much more comprehensive view on ASI in order to account for energy efficiencies systemically. That has to consider the consumption of one car or a fleet of cars but for also the shift to all other possible modes or not satisfying the mobility need at all.

The authors propose the following definition(s):

| Improve | Shift | Avoid |
|---|---|---|
| $E_{1,m^*} < E_{1,m}$<br>$E_{2,m^*} < E_{2,m}$<br>$E_{3,m^*} < E_{3,m}$<br>...<br>$E_{n,m^*} < E_{n,m}$<br><br>With $E_{n*,m}$ being the energy consumed after the implementation of technological change for each individual vehicle n* of mode m and $E_{n,m}$ being the energy consumed previous to the technological change of vehicle n of mode m in a speficied area<br><br>$E_{n^*}$ and $E_n$ can be defined in term of equations (1) and (2). | $\sum_1^n E_{n,1(t)}{}^* + \sum_1^n E_{n,2(t)}{}^* + \sum_1^n E_{n,3(t)}{}^* + \cdots + \sum_1^n E_{n,m(t)}{}^* > \sum_1^n E_{n,1(t+1)}{}^* + \sum_1^n E_{n,2(t+1)}{}^* + \sum_1^n E_{n,3(t+1)}{}^* + \cdots + \sum_1^n E_{n,m(t+1)}{}^*$<br><br>Where a shift between modes m of a fleet of efficient vehicles n*results in a reduction of total energy consumption in comparison between t and t+1 for a fixed volume of mobility in a specifed area. | En,m * = 0<br><br>This can only result from a conscious decision not to satisfy the need for mobility at one point in time and, thus, consciously avoid using a vehicle with maximum energy efficiency n of a particular mode m. |

Source: Author's elaboration.

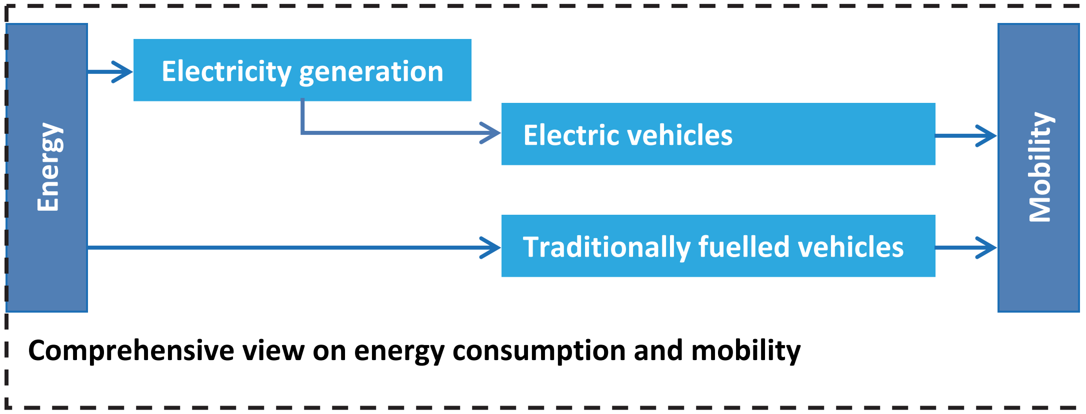
Consequently, the IMPROVE segment is defined as to minimize the consumption of each individual vehicle in the fleet of a specific mode. This may include the optimization of car tires, exchanging engines of ferries or a lighter construction of airplanes.

In the SHIFT segment the sum of all energy consumed for a similar "volume" of mobility compared in two points in time should be reduced due to a shift in the use of modes. By way of example, this includes using a bicycle and subway to go to work instead of taking the car for the whole journey as this maximizes travel efficiency. A further example could be the construction of a new rail infrastructure, which would facilitate the shift from other modes to rail. Based on the considerations above this would also capture teleworking, which traditionally was considered to be in the AVOID segment.

The proposal of a new definition is based in the following arguments: Working from home also requires energy e.g. for the use of personal computers and the servers for working remotely and, thus the mobility demand is only shifted to a more efficient mode – electronic traffic. A measure in the AVOID field can only be a conscious decision to avoid satisfying the mobility need at all. An example for such behavior would be the conscious decision to only consume regional vegetables in season.

Therefore, it now becomes clear why the above ASI definition comes is particularly appropriate for the energy profession. The definition would allow to be transferred to other fields of energy efficiency. The first step would always be improving the energy efficiency of the appliance used to provide the energy service. But on a system wide view, one could also try to shift to more efficient "modes" for providing the demanded energy service. Ultimately, the consumption of energy services could be avoided completely.

**DIAGRAM 4**
**COMPREHENSIVE VIEW ON ENERGY CONSUMPTION AND MOBILITY**




Source: Author's elaboration.

As such, the above definition would allow also for a minimization of the energy consumption as a whole – as, thus, for example include cases as electric vehicles. Electric vehicles are often cited as a very energy efficient and, most of all, clean mobility source. But essentially that depends on the generation source where the electricity used for charging the vehicle comes from. The above definition of energy efficiency already includes that.

## F. Regulation, incentives and policy coordination

The IEA (2012a) for example estimates that a 10% increase in urban density reduces per capita travel vehicle kilometer by 1% - 3% and also concludes the importance of policy intervention for hybrid-electric vehicles. Policy, however, needs to be well coordinated across different government entities and include the important question of financial resources.

Policy makers in modern economies have a variety of instruments at hand, which can be used in order to increase energy-efficiency of transport. The World Bank (1997) sees at least 18 instruments in four categories.[21]

**TABLE 1**
**POLICY INSTRUMENTS FOR SUSTAINABLE DEVELOPMENT**

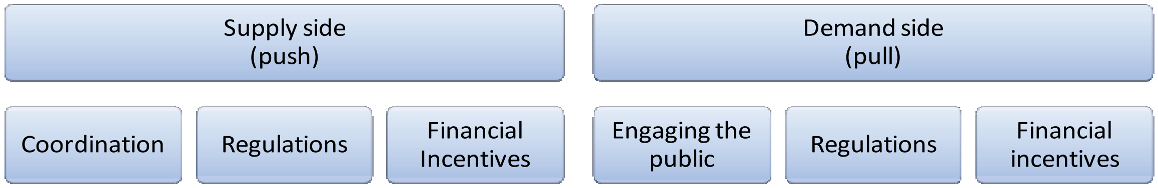
| Using markets | Creating markets | Environmental regulations | Engaging the public |
|---|---|---|---|
| Subsidy reduction | Property rights / decentralization | Standards | Public participation |
| Environmental charges | Tradable permits / rights | Bans | Information disclosure |
| User charges | International offset systems | Permits / quotas | Auditing |
| Deposit refund systems | | Zoning | Labelling |
| Targeted subsidies | | Voluntary agreements | Certification |

Source: Authors, adapted from World Bank, 1997.

In order to increase effectiveness of policy design a classification of policy instruments, which distinguishes between supply and demand-side, is recommended.

[21] In this report policy instruments are evaluated mainly with regard to their effects on energy consumption. Their use for mitigation of other external effects like noise, accidents and congestion are not covered.

**DIAGRAM 5**
**CLASSIFICATION OF POLICY INSTRUMENTS**

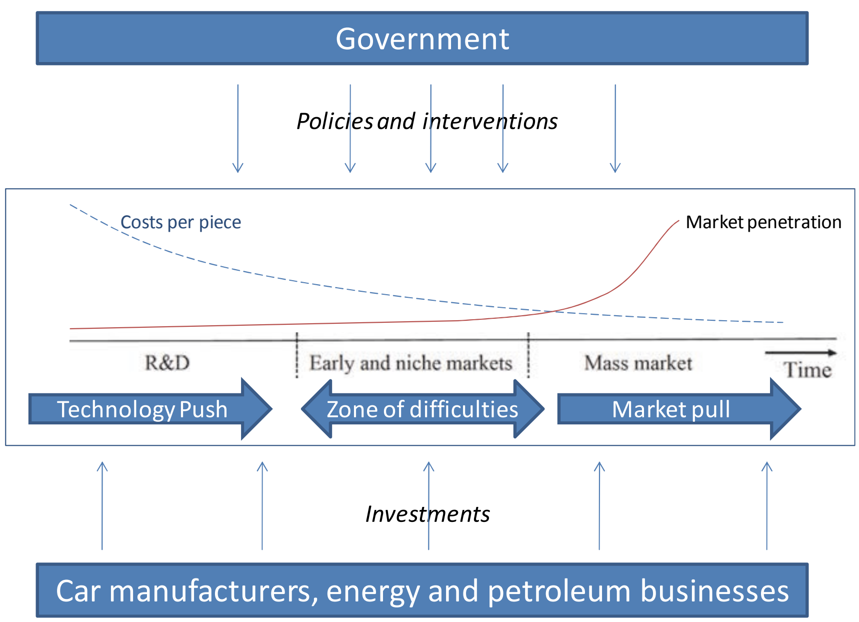



Source: Peters, 2011.

On the supply-side government coordination among different suppliers, especially in complementary markets is of increased importance. In order to increase fairness of competition between different technologies or suppliers and/or raise consumer awareness, both sides of the market, i.e. supply-side (push) and demand-side (pull), have to be targeted in policy design in accordance to their individual characteristics.

Grubb (2004) observes a need for government intervention especially during the phase of early markets. In this phase there are neither forces of "technology push" nor "market pull". In this "zone of difficulty" or "valley of death" the premium of costs per piece (e.g. per vehicle) over the costs of existing products is usually still high due to low economies of scale. Consumers are reluctant to pay that premium.

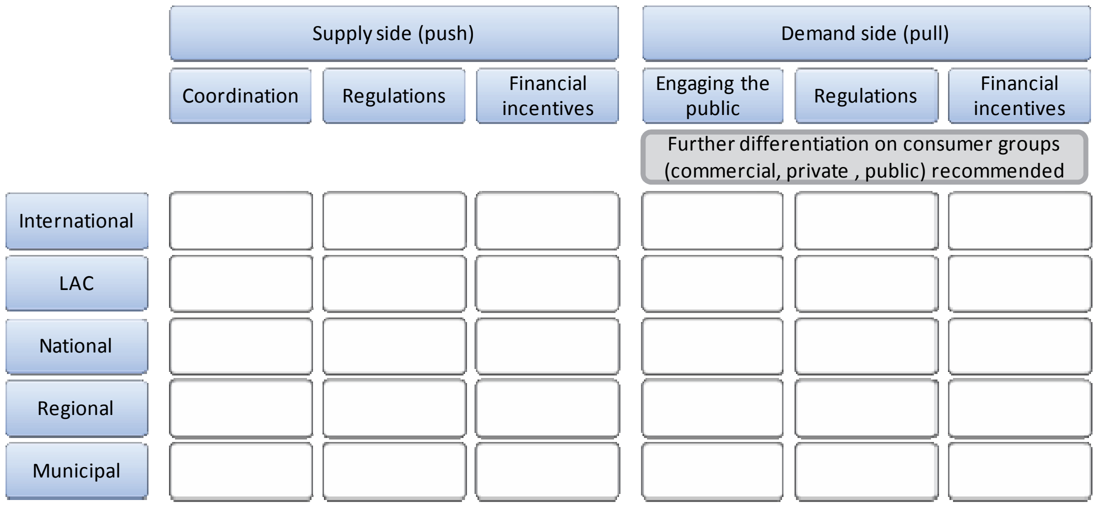
**DIAGRAM 6**
**ROLE OF GOVERNMENT AND PRIVATE STAKEHOLDERS FOR ALTERNATIVE FUEL VEHICLES (AFV) INTRODUCTION**




Source: Peters, 2011.

Demand-side policies need to be designed to the specific needs of the different consumer groups to be effective. These groups can be distinguished as private, public and commercial consumers. It is recommended to design policy instruments not only on international or national level. Regional and municipal instruments are very important and they can be adjusted to local market characteristics. This specific fit is recommended especially on "consumer information" or "government coordination" between different suppliers and consumers.

**DIAGRAM 7**
**CLASSIFICATIONS OF PUBLIC POLICIES INTO CATEGORIES DIFFERENTIATED BY GEOGRAPHICAL SCOPE OF APPLICATION**




Source: Authors, based on Peters, 2011.

Some policy instruments that effect supply of one mode effect demand of another mode. One example: conditioning on road use (e.g. only allowing those cars on Mondays with registration plates that start with letter “a”) reduces willingness to supply for cars and car trips. However, this measure will increase demand for bus trips as the effected car users on Mondays will need an alternative for their mobility needs.

Policy makers in transport often face the trade-off between effectiveness and acceptance of policy instruments. Among others it is shown that the analysis on “whether” and “how” the government should intervene should include various factors and stakeholder consultations. The lack of public support for some effective policy instruments will often influence the analysis: Increased fuel taxes on conventional fuels usually are one example of unpopular instruments. The analysis this way can result in a set of different policy instruments for both increased demand and supply rather than only one instrument.

Once effective instruments are chosen and adapted to target groups their timing and duration should be carefully planned. Incentives should not be applied in parallel but rather in sequence. This strategy is the less risky option especially for financial incentives or costly regulations because “investments” are made in stages rather than all upfront. This way, policy makers can check for progress in market introduction before commencing with further investments. A possible strategy that aligns different instruments for market introduction clean technologies in transport for example can be found in Bunzeck et al. (2010).

Also the duration of temporary policy instruments or their maximum financial costs to public budgets should be carefully planned ahead. Suppliers of energy-efficient transport solutions as every actor want to have long planning horizons for their business and this requires long-time or permanent policy instruments. It is risky and sometimes very expensive to establish financial incentives for efficiency technologies when their assumed scale effects are not sufficient for making them competitive within one or two legislation periods. In this case permanent non-financial instruments, e.g. regulations, should be considered (although it is not possible within this study to compare in detail temporary and permanent policies).

Another crucial requirement for public policy is good coordination. An insightful example is the chicken-egg dilemma between filling stations and vehicles for alternative fuels. The dilemma is best mitigated via coordinating the actions of all relevant stakeholders by a government-led strategic council, where an improved coordination shall be achieved between a) gas companies and vehicle manufacturers as well as b) between gas companies and filling stations.

## G. The call for sustainable and integrated policies for mobility

As previously discussed, national policy should be designed using an integrated approach and viewed as the compilation of sectoral development plans. The planning and implementation of policies should therefore be carried out with due consideration for the competitiveness and productivity of the goods or services that are produced, consumed, exported or imported by the country, as well as the mobility pattern of people, but not on the basis of the forms of transport used. Lastly, mobility (passenger and goods) should be placed at the service of productive and social development and be designed to support existing or future centers of production and social interaction. Consequently, national policy should encourage a process of continuous improvement that requires regular modifications as required by the internal and external environment where infrastructure and infrastructure services are to be located.

Previous work identified a weakened role of the state in LAC (Cipoletta, 2011), especially since the 1990s, which not only resulted in a reduction of public investment, but also of the use of instruments and tools for strategic planning. This has translated into significant challenges, which not only affect the transport sector, but also the interrelated issues such as energy efficiency and mobility. These challenges include: a) the absence of visions for policies that integrate transport, infrastructure, logistics and mobility, and b) a lack of the application of sustainability criteria in the implementation of policies.

The former is result of a high dispersion and multiplicity of public sector visions on infrastructure and infrastructure services, which translates into unarticulated policy development processes. Consequently, current policies in the region, with very few exceptions, address challenges in a segmented manner, are not contemplating long term visions and also are not derived in a proper institutional framework.

In the context of reaching the overall goal of a more sustainable development, of which the implementation of energy efficiency and the curbing of the relationship between mobility growth and energy consumption is one important building block, the region requires a review of the current policies under a new paradigm that incorporates and integrated and sustainable vision.

Further, as infrastructures profoundly condition mobility and user consumption patterns, choosing which ones are made and how they are designed will have a significant effect on energy consumption and thus the potential of energy efficiency e.g. via a SHIFT strategy. Developing low-carbon energy infrastructure will thus help pave the way for a low greenhouse gas emission and more energy efficient economy (Scottish Government, 2010).

Applying a broad view of mobility, energy efficient mobility also minimizes the associated carbon emissions. From this viewpoint the discussion of energy efficiency and mobility also contributes towards the strategy to develop a low-carbon infrastructure, whose carbon emissions are lower than the infrastructure alternatives available for providing a specific transport service (Claro, 2010).

## H. Outline

The remainder of the document is structured as follows. First, an overview on global energy consumption, mobility and energy efficiency is given; followed by a discussion of the Avoid, Shift, Integrate strategy and related measures.

Second, the current situation of mobility and energy consumption in LAC is analyzed and includes a selection of existing measures on improving energy efficiency of mobility in the region.

Third, the view on Latin America is complemented by case studies from several sub-regions to provide further analysis, a hands-on approach and examples.

The final section sets out recommendations and a research agenda to drive not only energy efficiency of mobility, but actual work on the decoupling of mobility and energy demand in the future.

# II. A global overview on energy efficiency and mobility

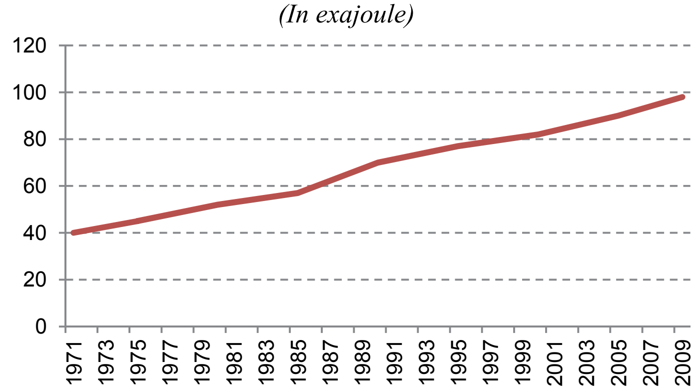
## A. The energy perspective —current situation and global challenges

This chapter provides an overview on global energy trends and the developments of energy consumption in mobility in the recent past, comparing developments in different regions and economic contexts. The chapter is developed with the perspective of the energy sector, which is complemented in the following chapter with the transport sector perspective.

## B. Trends of energy consumption in the transport sector

Measured on a long term basis (1971-2009), the global (world level) energy consumption in the transport sector rose between 2% and 2.5% annually, thus showing comparable development to the global average annual economic growth rate (IEA/OECD, 2009).

**FIGURE 4**
**WORLD TRANSPORT ENERGY CONSUMPTION (1971-2009)**
*(In exajoule)*

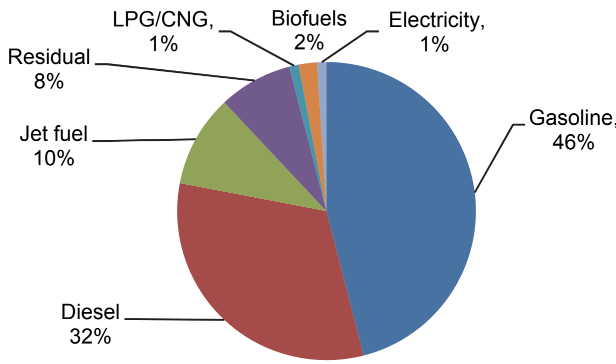



Source: Author, based on IEA/OECD, 2009.

A key characteristic of this development, and problem from an environmental and political (energy security) point of view, is the dominant role of oil as an energy source.

The share of oil consumption in transport at global level has grown on average 1.4% annually between 1971 and 2009 (IEA, 2012). In 2010, oil products corresponded to about 96% of energy sources used in transport (WEC, 2011).

**FIGURE 5**
**SHARE OF OIL AS ENERGY SOURCE IN TRANSPORT, 2010**




Source: Author, based on WEC, 2011.

In 2010, more than 60% of the globally consumed oil (around 51 million barrels per day) is related to the transport sector; in particular road transport modes (car, trucks and buses), which account for 73% of oil consumed in transport (respectively 52% car, 17% truck and 4% buses), against 10% in aviation, 10% in maritime transport, 3% rail and 3% of other transport modes (WEC, 2011).

Against the background of these general past trends in oil and energy consumption, the recent past, i.e. since 2000, has marked important changes, with particular differences in the pattern of development of OECD and non OECD countries[22] (WEC, 2011).

The following table depicts the development of energy use in OECD and non OECD countries in two different periods: from 1990 to 2000 and after 2000.

It can be observed that global transport energy consumption grew with a Compound Annual Growth Rate (CAGR) of about 1.8% in OECD countries, and about 2.8% in non-OECD countries. Between 1990 and 2000, growth rates of transport energy use in OECD countries were particularly high due to the increase in international aviation.

However, looking at transport energy consumption in more recent years, for example, for the period 2000 to 2006, the trends have significantly changed; average growth for this period was about 1.2% for OECD countries and about 4.3% for non-OECD countries annually. Energy use in non OECD countries increased fastest for domestic aviation, international navigation and road transport.

[22] OECD includes all members of the organization as of September 1, 2010, throughout all time series included in this report. Israel became a member on September 7, 2010, and Estonia became a member on December 9, 2010, but neither country's membership is reflected in this report.

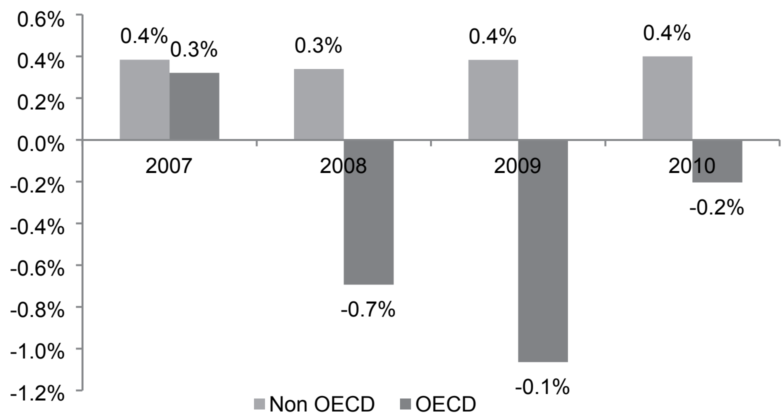
**TABLE 2**
**GROWTH RATES OF TRANSPORT ENERGY USE 1990-2006**

| | OECD Countries | | | | Non OECD Countries | | | |
|---|---|---|---|---|---|---|---|---|
| | 1990-2000 | | 2000-2006 | | 1990-2000 | | 2000-2006 | |
| | 90-95 | 95-00 | 00-06 | 90-06 | 90-95 | 95-00 | 00-06 | 90-06 |
| International aviation | 4.4% | 5.0% | 1.2% | 3.4% | -0.6% | 1.7% | 4.7% | 2.1% |
| Domestic aviation | -0.2% | 2.5% | -0.3% | 0.6% | -0.5% | 4.9% | 3.0% | 2.5% |
| Road | 2.3% | 2.1% | 1.4% | 1.9% | 2.5% | 2.9% | 4.2% | 3.3% |
| Rail | -0.1% | -0.3% | 2.3% | 0.7% | -4.4% | 2.9% | 2.3% | 0.3% |
| International bunkers | 1.1% | 2.3% | 2.5% | 2.0% | 4.6% | 3.9% | 5.4% | 4.7% |
| Domestic navigation | 0.8% | 0.5% | -1.0% | 0.0% | -2.6% | 6.5% | 4.0% | 0.0% |
| Total transport sector | 2.1% | 2.1% | 1.2% | 1.8% | 1.1% | 2.6% | 4.3% | 2.8% |

Source: Author, based on WEC, 2011.

The different trends in OECD and non OECD countries energy consumptions are confirmed for the period 2006-2010, in which data on the annual variation of fossil fuels energy consumption show a decreasing trend in OECD countries and an opposite, growing trend, in non OECD countries.

**FIGURE 6**
**SHARE OF FOSSIL FUEL ENERGY CONSUMPTION**
*(Annual variation)*




Source: Author, based on World Bank World Development Indicators, 2013.
Note includes Chile as OECD country, but not Slovenia.

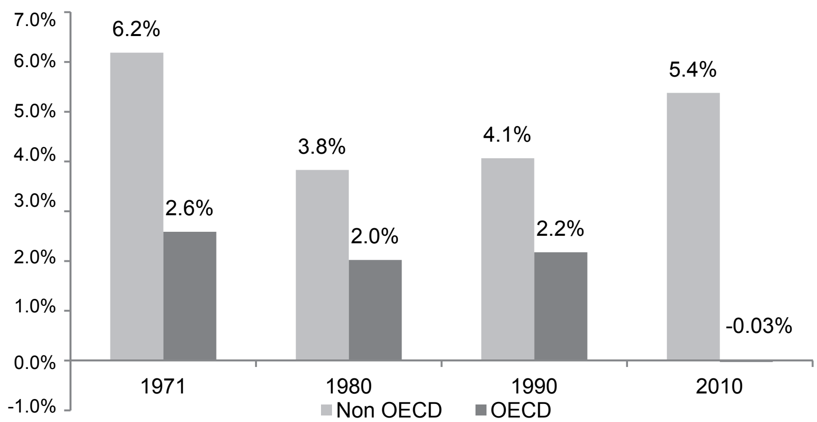
Global trends in energy use growth rates for transport in OECD and non OECD countries have also shaped the dynamic of $CO_2$ emissions (figure below). In the last decade, the non OECD countries overtook the OECD countries growth of $CO_2$ emissions from transport, reflecting the influence of higher rates of economic development and population growth.

It is important to stress that the average trends in OECD and non OECD countries show different energy-consumption growth rates per transport mode and varying pattern in terms of energy use per capita, type of fuel used and use of transport modes. For example (data for 2007):

- Transport energy use in North America reached average of over 2,300 tons of oil equivalent (toe) per 1,000 people; the same indicator in Chile was 200.
- OECD-North America, OECD-Pacific and Middle East countries depend heavily on gasoline as a transport fuel,

- Other OECD-Europe, China, and Latin America depend heavily on diesel;
- Non OECD countries show higher shares for buses, rails, and two-three wheelers.
- OECD countries mainly rely on passenger LDVs (cars, light trucks, and minibuses).
- People in OECD countries undertake more air travel per capita than those of non-OECD countries.

**FIGURE 7**
**$CO_2$ EMISSIONS FROM TRANSPORT ANNUAL VARIATION**




Source: Author, based on World Bank World Development Indicators, 2013.
Note includes Chile as OECD country, but not Slovenia.

Differences and similarities from a macro perspective are discussed in the following for passenger transport, freight transport and vehicle technologies and sales.

## 1. Passenger transport

Between 2000 and 2010, total global passenger travel increased by an average of 4% annually (IEA, 2013).

Within the OECD, on average, car travel represents 60% to 80% of motorized passenger travel (based on passenger-kilometers per year) – a share that has been constant over the past years. In terms of different uses of vehicle types, North America has a large share of light trucks, which includes sport utility vehicles, whereas Europe has few light trucks and smaller passenger vehicles.

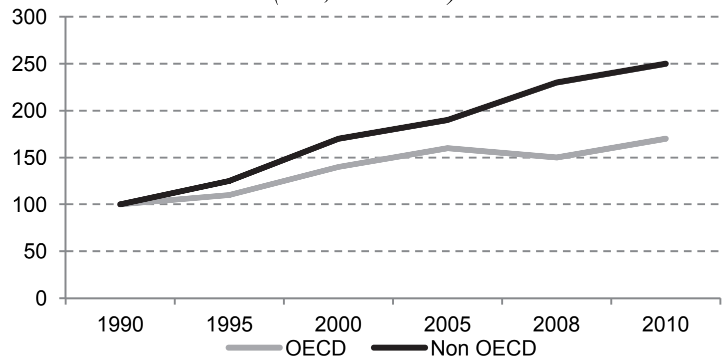
Non-OECD countries in general show a diversified pattern of motorized passenger travel modes. Passenger vehicle travel has grown rapidly for the past few decades, and continues to expand rapidly. In 2009, on average, car, buses and mini buses accounted for 60% of the total passenger kilometers, with an additional 20% for rail and coaches and 10% for 2 and 3 wheelers (IEA, 2012).

Non-motorized transport modes (i.e. walking and cycling) are of significant relevance in the mobility pattern of people, but due to the short average trip distance do not represent a large share in terms of passenger kilometers.

## 2. Freight transport

Freight transport activity is linked to economic growth. The following figure shows the trend over the period 1990-2010 of goods transport by road for OECD and non OECD countries. A continuous growth pattern can be observed, but with different trends: a) a slow reduction in 2007-2008 due to the economic downturn for OECD countries, and b) a rapid and continued growth for non OECD countries.

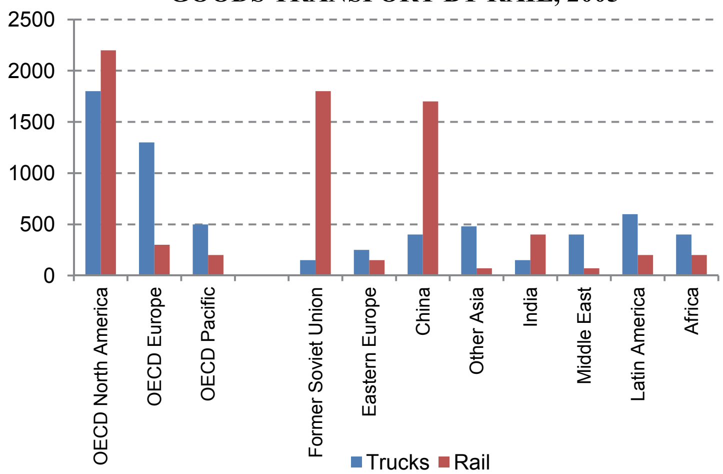
**FIGURE 8**
**ROAD FREIGHT TRENDS**
*(vkm, 1990=100)*




Source: Author, based on IEA, 2012.

In terms of volume, rail is still the dominant mode for freight (53% of tkm over land) at global level, but with significant regional differences (see figure below).

**FIGURE 9**
**GOODS TRANSPORT BY RAIL, 2005**




Source: Author, based on IEA/OECD, 2009.

Rail freight transport has particular relevance in large countries (e.g. China, USA, India, and the Russian Federation), moving significant share of raw materials. Comparing energy efficiency (energy intensity per tkm) of the two transport modes, rail transport uses less energy than road. In terms of total energy consumption (Mtoe) freight road transport dominates table below).

**TABLE 3**
**ENERGY USE BY TYPE OF TRUCKS AND FREIGHT RAIL TRANSPORT**
*(Mtoe)*

| | OECD | | NON OECD | |
|---|---|---|---|---|
| | 2000 | 2005 | 2000 | 2005 |
| Rail | 10 | 20 | 15 | 25 |
| Heavy freight trucks | 200 | 190 | 120 | 160 |
| Medium freight trucks | 30 | 20 | 40 | 40 |
| Light commercial vehicles | 60 | 70 | 30 | 40 |

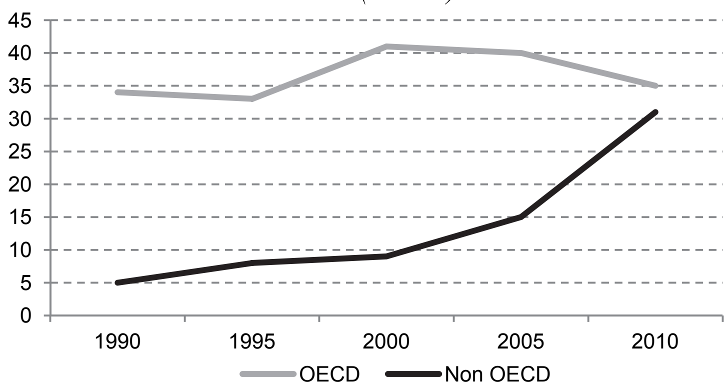
Source: Author, based on IEA/OECD, 2009.

The sustained trends of energy consumption growth in the non-OECD countries (in particular from trucks) could make energy consumption in these countries higher than in OECD countries in the near future, in case these trends are not stopped or reversed.

## 3. Vehicle technology and sales

Over the past years, one of the most striking trends in vehicle sales is the saturation of the passenger vehicles market in OECD countries, which is opposed by a significant increase in the non-OECD countries.

**FIGURE 10**
**PASSENGER CAR SALES**
*(Million)*




Source: Author, based on IEA, 2012.

Between 2000 and 2010, car sales in China increased 20-fold, i.e. from 500,000 units to 4 million in 2005 and 12 million in 2010.

In terms of type of fuel, in 2010 gasoline engines were still the most important world passenger car market, followed by diesel engines, with about 40% of market share in Europe and India (sales shares jumped from 23% in 2000 to 43% in 2005 and stabilized at this level in 2010, IEA, 2012).

Despite the dominance of gasoline-powered vehicles, alternative fuels and new technologies gained market shares in recent years. The underlying reasons range from government incentives, natural availability of local resources to technological development factors.

**BOX 4**
**EXAMPLES ON THE MARKET PENETRATION OF ALTERNATIVE FUEL VEHICLES**

About 30% and above of Natural Gas Vehicles (NGV) in Argentina and Bangladesh (year 2010) due to natural availability of local energy resources;

About 30% of cars fuelled by flex-fuel in Brazil (year 2010) due to natural availability of agricultural areas (ethanol);

About 20% of cars fuelled by liquefied petroleum gas (LPG) in South Korea and Turkey (year 2010) due to natural availability of local energy resources

About 10% of hybrid vehicles in Japan, due to specific policies dedicated to incentivize hybrid purchase.

Source: Author base on IEA, 2012.

The experience on hybrid passenger vehicles confirms that an available technology in the market may need a long time to gain significant market shares (IEA, 2012). Hybrid passenger vehicles, available since 1997, needed 13 years to reach 1% of total world's sales share. Therefore, the market entrance of new technologies (e.g. battery electric vehicles) in the near future could be a challenging task, without decisive policy support from government, e.g. fuel economy standards, infrastructure investment, and incentives.

Furthermore, in developing non OECD countries, the likely high prices of non conventional fuelled vehicles, e.g. hybrid, electric cars, the unsustainable burden of subsidies and lack of infrastructure may limit their widespread use. In these countries, more cost-efficient opportunities in energy reduction, in the short-term horizon, may come from improved operations, land use policies and alternative transport options by using available transport asset more effectively (World Bank, 2013).

## C. Future trends and scenarios on energy efficiency in transport

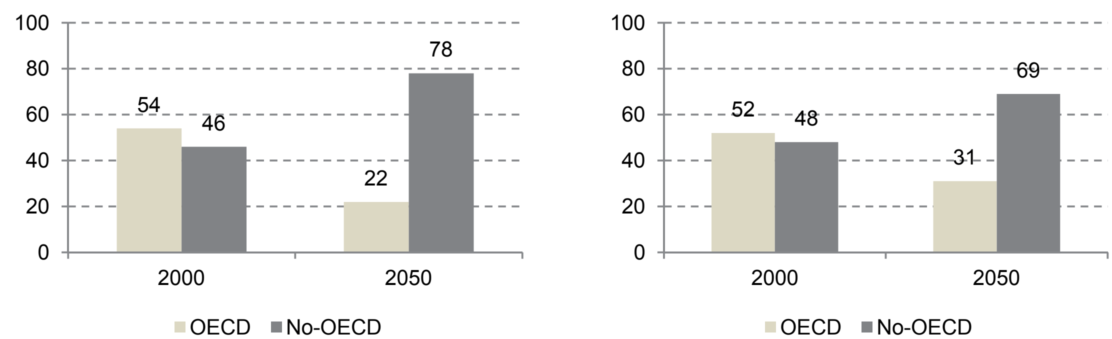
The long term evolution of transport systems, e.g. demand, energy consumption, and spatial distribution, etc, has been object of studies and impact assessments at EU and international level,[23] with the main aim to anticipate future trends in order to design efficient and sustainable transport policies.

Recently, 2050 has gained the status of reference time horizon, in the context of the long-term commitment towards the decarbonisation of transport system, in coherence with the international greenhouse gases (GHG) reduction targets.[24]

According to the International Transport Forum (ITF) forecasts (OECD/ITF, 2011) global long term future trends in mobility will be characterized by the continuation of the past trends. Transport volumes in the OECD countries in 2050, passenger and freight are expected on average to be lower than in non-OECD countries, reversing the situation registered in 2000.

**FIGURE 11**
**LONG TERM TRENDS IN MOBILITY, 2000-2050**

A. Shares of passenger mobility (pkm) B. Shares of freight mobility (tkm)




Source: Author, based on OECD/ITF, 2011.
Note: Does not include OECD Latin America countries, only OECD Europe, OECD North America and OECD Pacific.

The following table on modal split of passenger transport exemplifies the expected trend towards a strong increase in the use of cars and air transport in China and Latin America in comparison to OECD countries in different world regions until 2050.

[23] In Europe, funded by the European Commission (DG MOVE) 7th Framework Research Programme, must be quoted the following projects and studies: TRANS-TOOLS (2012), TRANSCENARIOS (2013) and TRANSVISIONS (2009). At international level, important references, among others, are the reports and studies from OECD/ITF (2011) and IEA (2012).

[24] For example, the EU Transport GHG: Routes to 2050 Project, http://www.eutransportghg2050.eu/.

**TABLE 4**
**LONG TERM PASSENGER TRANSPORT MODAL SPLIT, 2000-2050**

| | 2005 | | | | | |
|---|---|---|---|---|---|---|
| | Car | Air | Rail | Buses | Other | Total |
| OECD North Europe | 81 | 14 | 1 | 4 | 0 | 100 |
| OECD Europe | 63 | 16 | 5 | 13 | 3 | 100 |
| OECD Pacific | 56 | 13 | 9 | 16 | 6 | 100 |
| China | 7 | 9 | 15 | 43 | 26 | 100 |
| Latin America | 41 | 12 | 1 | 42 | 4 | 100 |
| | **2050** | | | | | |
| | Car | Air | Rail | Buses | Other | Total |
| OECD North Europe | 68 | 28 | 1 | 3 | 0 | 100 |
| OECD Europe | 50 | 30 | 6 | 11 | 2 | 100 |
| OECD Pacific | 44 | 28 | 11 | 13 | 4 | 100 |
| China | 55 | 14 | 10 | 11 | 10 | 100 |
| Latin America | 70 | 12 | 1 | 14 | 3 | 100 |

Source: Author, based on OECD/ITF, 2011.
Note: Does not include OECD Latin America countries, only OECD Europe, OECD North America and OECD Pacific.

In the context of freight land transport most of the growth in transport energy consumption is projected to be generated in developing non-OECD nations, with energy consumption among the developed OECD nations remaining relatively flat or declining in the medium and long term.

It should be mentioned, that the scenarios are limited to land transport and thus do not include international and domestic waterborne transport and aviation. However, both international aviation and maritime represent a growing share of the transport sector's energy consumption.

**TABLE 5**
**LONG TERM FREIGHT TRANSPORT MODAL SPLIT – LAND TRANSPORT, 2000-2050**

| | 2005 | | 2050 | |
|---|---|---|---|---|
| | Trucks | Rail | Trucks | Rail |
| OECD North Europe | 40 | 60 | 54 | 46 |
| OECD Europe | 86 | 14 | 90 | 10 |
| OECD Pacific | 72 | 28 | 81 | 19 |
| China | 25 | 75 | 56 | 44 |
| Latin America | 84 | 16 | 92 | 8 |

Source: OECD/ITF, 2011.
Note: Does not include OECD Latin America countries, only OECD Europe, OECD North America and OECD Pacific.

The discussion on how to address energy efficiency and emissions reduction in the aviation and maritime transport sectors has mainly been promoted by two international organizations, the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO) to which national countries contribute individually.

Air traffic continues to increase, and is expected to triple by 2050 (IEA, 2012). The main measures deemed to improve energy efficiency in the future rely on improved aerodynamics, lightweight material and more efficient engines (ICCT, 2012).

The maritime transport sector's demand for bunker fuels is driven by globalization of production and the geography of trade and is projected to grow in the medium-long term (2030) at an average of 2.5% annually (Purvin and Gertz, 2010), the most promising measures for improving energy efficiency are technological (e.g. retrofits) that could cut the ships' energy intensity by up to 50% for most large ship types (IEA, 2012).

Non-OECD transport energy consumption is expected to increase by 3.7% annually between 2008 and 2035, compared to 0.3% projected for the OECD nations. It is likely that slower growth of national economies and populations in OECD countries will contribute to reduce average transport energy demand.

**TABLE 6**
**TRANSPORT ENERGY USE BY WORLD REGIONS, 2008-2035**
*(in quadrillion Btu)*

| | 2008 | 2035 | Average growth rate 2008-2035 |
|---|---|---|---|
| OECD | 59.3 | 64.8 | 0.3 |
| Americas | 33.2 | 38 | 0.5 |
| Europe | 18.8 | 18.9 | 0 |
| Asia | 7.4 | 7.9 | 0.3 |
| | | | |
| Non OECD | 38.9 | 77.3 | 3.7 |
| Europe and Eurasia | 7.2 | 9.5 | 1.2 |
| Asia | 16.3 | 42.2 | 5.9 |
| Middle East | 5.4 | 9.5 | 2.8 |
| Africa | 3.6 | 5.3 | 1.7 |
| Central and South America | 6.4 | 10.7 | 2.5 |
| World | 98.2 | 142.1 | 1.7 |

Source: Author, based on DOE/IEA, 2011.
Note: OECD Americas includes Chile.

In the future world population growth will not be distributed evenly, with most of the growth occurring in Africa, China, India, and parts of Latin America (WEC, 2011).

Concerning urbanization trends, the majority of megacities has emerged and is continuing to grow in Asia, Africa, and Latin America. This has and will have widespread implications for transport, especially in rapidly growing cities, where rising vehicle ownership will lead to considerable shifts away from non-motorized transport and public transport.

Apart from demography, urbanization trends and economic growth, other important drivers behind the trends of energy consumption in transport may be identified through trends in vehicle fuel economy and new vehicle technologies, briefly described in the next sections.

## 1. Fuel economy

The reduction of the average fuel consumption (at global level) and $CO_2$ emissions of new cars conventionally fuelled vehicles represents an important indicator to measure energy efficiency of the road transport sector in the next decades. The International Energy Agency (IEA), in partnership with the Global Fuel Economy Initiative (GFEI, 2011) has undertaken a research program to monitor fuel economy of new cars around the world.[25]

In the overall energy scenario to make the transport system sustainable,[26] the target is to halve the fuel economy of new cars between 2005 and 2030.

**BOX 5**
**NEW VEHICLE TECHNOLOGIES**

New vehicle technologies, e.g. electric-hybrid vehicles, plug-in hybrid-electric vehicles, battery electric vehicles, etc. represent an important technology. In 2012 the share of non-plug-in hybrid-electric vehicles doubled world-wide (EIA, 2012), driven by Japan and USA sales. India announced policies to reach a medium-term plan (2020) to sell six million of vehicles and China, is going to invest up to $15 billion in alternative-energy vehicles over the next 10 years (EIA-US Energy Information Administration, 2011). Programs like these contribute to the cost reduction of battery production.

Source: Author's elaboration.

The current status shows that more efforts are required, particularly in the non OECD countries. Fuel economy during the period 2008-2011, expressed in (Lge/100km, liters of gasoline equivalent per 100 kilometers) improved at an average rate of -1.8% at global level, corresponding to -2.7% in OECD countries and -0.6% in non-OECD countries. Vehicle’s average age and road conditions are main factors that keep the average fuel economy in non-OECD countries at lower levels (IEA/OECD, 2012). Despite some improvements in the last period (2008-2011) in non OECD countries, i.e. -0.6% compared to +0.4% between 2005 and 2008, the global annual rate of improvement is well below the required -3.0% to meet the global target.

**TABLE 7**
**FUEL ECONOMY STATUS AT GLOBAL LEVEL**

| | lge/100 km | | | | | Annual change | | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2008 | 2010 | 2011 | 2030 target | 2005-2008 | 2008-2011 | Target 2011-2030 |
| OECD | 8.1 | 7.6 | 7.0 | 7.0 | | -2.2% | -2.7% | |
| Non-OECD | 7.5 | 7.6 | 7.5 | 7.5 | | 0.4% | -0.6% | |
| World | 8.0 | 7.6 | 7.2 | 7.2 | 4.0 | -1.7% | -1.8% | -3.0% |

Source: Author, based on IEA, 2013.
Note: OECD includes Chile.

In the future an appropriate mix of fuel economy standards, fuel taxes, and fuel economy labeling programs must be pursued in order to reverse the trends.

## 2. Conclusions

Given the past trends and future scenarios, the potential for improving energy efficiency in the next decades will come principally from the road sector and conventional vehicles (internal combustion engines with petroleum-based fuels), in particular in the non -OECD countries, both in the passenger and freight sector.

The rising transport activities in non OECD countries are driven by higher projected population growth and economic and urbanization trends. The fact of an almost saturated market (in terms of car ownership and travel distance) in OECD countries leads to the conclusion that technological development offers the highest potential to significantly improve energy efficiency in these countries.

[25] The state of advancement in fuel economy improvement can be assessed at world level in the IEA fuel economy readiness index, launched in 2012 (IEA, 2013).

[26] The IEA (2012) has defined a comprehensive energy scenario, the 2DS scenario, which presents a vision of a sustainable energy system consistent with the long-term objective to keep global temperature increase to 2°C by 2050.

The dependency on oil will not change in the next decades, therefore major uncertainties (oil supply, rising prices) are deemed to raise challenges to countries with projected higher growth in transport activities.

Government policies may change the situation, promoting alternative fuels, new technologies and sustainable transport policies.

# D. Energy efficiency policies in the transport sector

## 1. Introduction

The following section provides a brief overview and examples on measures and policies on energy efficiency in selected regions and countries.

## 2. Overview of policies and measures improving energy efficiency in transport

### a) ASEAN countries

The Southeast Asian Nations (ASEAN) is an association composed by the ten member states of Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam. The countries correspond to one of the fastest-growing regions in the world and its rapidly rising energy demand is driven by its economic and demographic growth.

In terms of energy endowment, the ASEAN countries benefit of natural resources, are rich in fossil fuel resources and have a significant potential in renewable energy, particularly wind, hydro and geothermal.

Transport-sector demand is deemed to grow quickly, driven by increasing per capita income and household vehicle motorization rates.

The energy efficiency policies in the transport sector are determined by the following two drivers:

- The increased urban population and economic activities in ASEAN countries that have led to steady increase in travel demand within the city, resulting in traffic congestion as traffic growth outpaces the upgrading of transport infrastructure and the implementation of effective traffic management measures.
- The ASEAN Plan of Action for Energy Co-operation (APAEC) 2010-15, which aims to secure a clean, sustainable energy supply through setting goals for energy efficiency and alternative fuels, i.e. removing subsidies to fossil fuels and cooperation on broadening the fuel mix via interconnectivity of the ASEAN Power Grid (APG) and the Trans ASEAN Gas Pipeline (TAGP).

The table below shows the inter-linkages between the specific goals and actions along a mid-term horizon.

The ASEAN Strategic Transport Plan (2010) sets out the importance of pursuing sustainable transport programs to increase energy efficiency and reducing consumption and emissions in the transport sector. In this regard, the ASEAN Ministers agreed to implement measures to mitigate climate change especially in the land transport sector and promotion of energy efficiency and sustainable urban transport in ASEAN cities.

In order to improve the public transport share in the selected capital cities that are currently coping with poor public transport, a study on Green Public Transport (Bus Rapid Transport) is envisaged. Later, based on the recommendations of this study the suggested projects/program needs to be implemented. However, considering the large scope of the work, the suggested projects will require additional number of years for implementation and will be continued beyond 2015.

**TABLE 8**
**ASEAN COUNTRIES: POLICIES FOR IMPROVING ENERGY EFFICIENCY IN TRANSPORT**

| | 2011 | 2012 | 2013 | 2014 | 2015 | Future |
|---|---|---|---|---|---|---|
| Exchange of experiences, projects & knowledge related to "Environmentally-Friendly Transport Systems, Vehicles and Fuels". | x | x | x | x | x | x |
| Adoption and implementation of pilot projects based on the successful experiences and projects related to" Environmentally.-Friendly Transport System, Vehicles and Fuels". | x | x | x | x | x | x |
| Conduct studies on promotion of Green Public transport System to improve and establish energy efficient green public transport (bus rapid transport) in the capital cities of AMSs as per requirement 2013. | x | x | x | | | |
| Implement the suggestions/projects of the above study on "Promotion of Green Public transport System". | | | | x | x | x |

Source: Author, based on ASEAN Strategic transport Plan, 2010.

### b) Brazil

Brazil disposes a very large share of renewable energy in total primary energy supply (TPES); 45% compared with the 8% average of OECD countries (EIA, 2011). As consequence, the energy and transport sectors are characterized by low-carbon sources. Hydropower represents four-fifths of installed electricity capacity, while ethanol accounts for almost one-fifth of energy demand from transport.

The implications for transport energy consumption are important. Brazil is a world leader in ethanol production and use from sugar cane, the world's second-largest producer of ethanol, and the world's second-largest exporter, after the United States. In terms of volume, ethanol accounts for almost half of Brazil's car transport fuels.

Concerning energy policies, the use of alternative fuels is projected to increase. Bio fuels will represent half of the country's transport sector energy needs, most being used for road transport, some in the marine transport sector, and a limited amount as fuel for aviation.

The measures to improve energy efficiency in transport are partly linked to the availability of alternative fuels to oil-based products. Brazil started to replace gasoline with ethanol in 1975 with the Brazil's National Alcohol Programme (Proalcool), which established mandatory blends for ethanol in gasoline (progressively increased to 25%).

As a result, by 1985 more than 85% of Brazil's new cars were alcohol powered, and 2 million of the total 10 million cars were fuelled completely by ethanol. Afterwards, in the 1990s, the combination of higher sugar prices and lower oil prices resulted in a supply crisis and in a return to gasoline-run cars, culminating in the deregulation of the sector in the late 1990s.

In 2003, the launch of flex-fuel vehicles (FFV) changed again the trends in energy supply. The flex-fuel is a technology that allows the vehicles to run on gasoline, ethanol or a mix in any proportion in the same tank, so that consumption of ethanol in the domestic market started to increase again significantly. At present (2010) the FFV fleet reached 10 million vehicles or approximately 42% of the light vehicle fleet in the country.

It has been acknowledged (IPEEC, 2012), however, that Brazil should consider linking the price of gasoline to the international market, reducing subsidies to gasoline and diesel, in order to control inflation. Additional measures to promote the attractiveness of ethanol price over gasoline could include reducing taxes on ethanol (which are higher than for diesel).

While the further development of the role of alternative sources of energy (ethanol and renewable) is part of the general strategy to improve energy efficiency,[27] the energy efficiency policies in transport are also focused on the following policies:

**TABLE 9**
**ON-GOING POLICIES RAISING ENERGY EFFICIENCY IN TRANSPORT IN BRAZIL**

| Title | Description | Year | Policy Type |
|---|---|---|---|
| Brazil National Climate Change Plan | Improved energy efficiency in industry, transport and buildings | From 2008 | Policy Support, Strategic planning, Regulatory Instruments |
| National Programme for Energy Efficient Use of Petroleum and Natural Gas Derivatives - CONPET | Programme to improve the management of fuels at their final use stage, e.g. engines inspections for buses and trucks | From 2008 | Policy Support, Strategic planning, Regulatory Instruments |
| DESPOLUIR program | Program launched to encompass a series of measures addressing clean fleets, vehicle maintenance (trucks), in association with transport operators, environmental management of transport operators companies (life-cycle assessment) | From 2007 | Policy Support, Strategic planning, Regulatory Instruments |
| PBE-V | Car engine labeling program | From 2006 | Regulatory Instruments, Information and Education |

Source: Author, based on IEA database.

Furthermore, infrastructure measures to reduce the road-dependent characteristic of freight transport, one of the most important challenges in the Brazilian transport system, have been also designed (IPEEC, 2012). They address the need to improve infrastructure for logistics and intermodality as well as bus rapid transit (BRT) and metro lines in urban areas.

### c) China

The importance of China in the context of the decarbonisation of the transport sector is high. China has been the fastest-growing economy among non-OECD countries and the fastest-growing consumer of transport fuels (EIA, 2011). Some recent data and projections justify the importance of the Chinese market.

- Much of the growth in China's transport energy consumption is for road use. The number of light-duty vehicles in China grew by an average of 24% per year from 2000 to 2008, and the total number of vehicles nearly quadrupled, from 22.3 million in 2000 to 86 million in 2008 (EIA, 2011).
- China's motorization level is estimated at 32 motor vehicles per 1,000 people in 2007, as compared with 820 in the United States, 552 in Europe, 595 in Japan, and 338 in South Korea. China's motorization is likely to increase strongly through 2035, although not to the levels seen in many OECD countries (EIA, 2011).
- Concerning transport infrastructure sector, from 1998 to 2008, the combined length of all China's highways increased by an average of 11.3% per year, while growth in expressways averaged 21.4% per year. Over the same period, highway passenger travel (measured in passenger-miles) and highway freight travel (measured in ton-miles) increased by annual averages of 7.7 and 19.6%, respectively.

In such a context, the energy efficiency policies can be classified in two categories:

[27] Ministry of Mines and Energy, National Plan for Energy Efficiency – Basic Assumptions and Guidelines, Brasilia, DF, 2011.

- In many sectors, detailed plans have a technology focus. In fact, the Ministry of Transport, for instance, has developed a 12th Five Year Plan for energy savings and emissions reductions with a strong emphasis on technological improvements in fuel economy for vehicles of all sorts, development and deployment of electric and other vehicles. The Plan requires parallel development with the utility sector of smart grids and intelligent transport system applications such as advanced information systems and traffic controls (IEA, 2012);
- Improve infrastructure endowment. China is in fact pursuing large-scale plans for expansion of high-speed rail and mass transit networks. Expenditure for railways was the single largest component of the government's economic stimulus package adopted in 2008. From 2009 to 2012, the government plans to invest $303.7 billion in rail construction, with plans to extend the rail network by 24,900 miles to a total of 74,600 miles by 2020. The government expects to have some 8,100 miles of high speed rail installed and 42 lines in operation by 2012 and 10,000 miles installed by 2020 (EIA, 2011).

All in all, the China Sustainable Energy Programme (CSEP, 2013):

- Supports a system of fuel-efficiency regulations that covers all vehicle types in China, gradually approaching the leading international European and Japanese levels;
- Supports the development of increasingly stringent new vehicle emissions standards and clean-fuel standards, and their timely and effective implementation;
- Promotes the rapid development and commercialization of new energy vehicles, and help them leapfrog over fossil-fuel-intensive technology and production; and
- Promotes the integration of China's road, rail, and other transport modes, and shift toward more efficient options for long-distance freight transport.

The following table (International Energy Agency Energy Efficiency Policies and Measures) summarizes the on-going policies addressing energy efficiency in transport in China.

**TABLE 10**
**ON-GOING POLICIES RAISING ENERGY EFFICIENCY IN TRANSPORT IN CHINA**

| Title | Description | Year | Policy Type |
|---|---|---|---|
| Energy saving and new energy automotive industry development plan 2012-2020 | To support the development of automotive industry that produces energy efficient vehicles | From 2012 | Policy Support, Strategic planning, Regulatory Instruments |
| Vehicle tax reduction for energy saving and new energy automobiles | Since 1 Jan 2012, reduce the vehicle tax of energy saving vehicles to a half, while the new energy vehicles are exempted from vehicle tax | From 2012 | Economic Instruments |
| Hong Kong - Tax Incentives for Environmentally Friendly Commercial Vehicles | Incentive scheme to encourage investment in environmentally friendly commercial vehicles meeting Euro V emission standards for heavy-duty and light-duty diesel vehicles | From 2008 | Economic Instruments |
| Vehicle excise tax rates | Tax rates for vehicles have been proportional to the size of car engines | From 2006 | Economic Instruments |
| Fuel-switching and Conservation to Reduce Petroleum Use | Developing alternative fuels, | From 2006 | Policy Support, Strategic planning, Economic Instruments |
| Energy Conservation in Government | Government vehicle purchases must focus on low-oil-consuming vehicles. | From 2006 | Regulatory Instruments, Information and Education, Advice/Aid in Implementation, Economic Instruments |
| Vehicle Fuel Economy Standards | Mandatory fuel efficiency standards for passenger cars from 2005. | From 2005 | Regulatory Instruments, Codes and standards |

Source: Author, based on IEA database.

### d) European Union

The general context and the key trends of the European transport sector (2000-2010) can be summarized as follows (ENERDATA, 2012). Overall, despite the improvement in energy efficiency (reduction in vehicle consumption and emissions), the overall $CO_2$ emissions are projected to growth, the share of public transport tends to decrease and the role of road transport in the freight sector is still dominant.

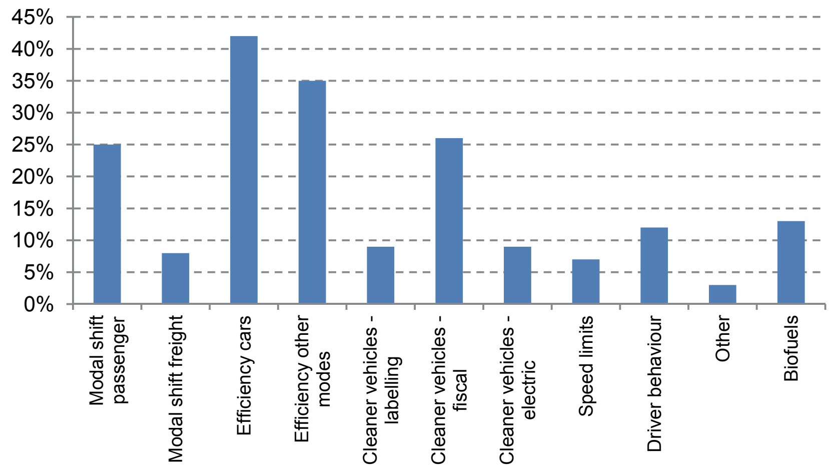
- The global economic crisis in the late 2000s had a significant impact on the transport sector, especially for freight transport, which decreased by 12% in 2009.
- Despite deterioration in the efficiency of freight transport in 2009 linked to the economic crisis, the overall transport sector was 9% more energy efficient in 2010 than in 2000. The energy consumption did not follow the reduction in traffic and only decreased by 5%.
- The energy efficiency of cars is improving on a regular basis (by 1 %/year since 2000); in 2010, cars consumed on average 0.8 liter/100 km less than in 2000 at EU level, i.e. 7.1 liter/100 km.
- The specific $CO_2$ emission of new cars has decreased by 20% (or 2.2%/year) on average in the EU since 2000. The target of 140 g $CO_2$/km stipulated in the agreement between the European Commission and the associations of car manufacturers were however only reached in 2010, instead of 2008.
- The annual distance travelled by cars has been steadily decreasing since 2000, which contributed to lower the energy consumption. However, this trend is accompanied by a considerable increase of transport of passengers (42% higher in 25 years) and changes in transport modes towards the use of faster means, such as fast trains and aviation (DG TREN, 2008). For example, the total volume of energy consumed by aviation is projected to triple in 2030 compared to 1990, despite improvements in energy intensity per unit of transport.
- The share of public transport in passenger traffic is decreasing almost everywhere, despite policies to reverse that trend; only a few countries managed to increase the share of public transport.
- At EU level, the growth in passenger traffic between 2000 and 2010 contributed to increase the energy consumption of passenger transport by 15.5 Mtoe. Energy savings have partially offset this activity effect (7.5 Mtoe). The decreasing share of public transport contributed to increase marginally the consumption by 1 Mtoe. As a result of these opposite trends, the energy consumption of passenger transport has increased by 9 Mtoe from 2000 to 2010.
- The increase in freight traffic was responsible for a consumption increase of 12.5 Mtoe between 2000 and 2010. Energy savings amounted to 3 Mtoe and have been completely offset by a modal shift from rail and water to road transport which contributed to increase the consumption by about 3.5 Mtoe at EU level. As a result, the consumption increased by 13 Mtoe between 2000 and 2010.
- The transport sector is the only end-use sector in which $CO_2$ emissions continue to increase: emissions in 2010 were 21% above their 1990 levels, and 2.5% above 2000.

In terms of energy efficiency policies and measures in transport, trends and characteristics of the most important European measures and policies are periodically monitored by the ODYSSEE-MURE project coordinated by ADEME.[28] The project is financed under the Intelligent Energy Europe Programme with the support of 29 national institutions from 25 EU Member States, Norway and Croatia, generally with co-funding from their own governments.

[28] www.odyssee-indicators.org.

The European overview provided by the project (AEA, 2012) indicates that a wide range of policy instruments are used; the most common one is fiscal measures, accounting for 28% of all measures, and are used in almost every Member State. In recent years (since 2008) there is a trend towards using fewer regulatory or normative measures, and more co-operative measures such as voluntary agreements.

**FIGURE 12**
**EUROPEAN MEASURES FOR IMPROVING TRANSPORT EFFICIENCY, DECLARED OBJECTIVES, 2008-2012**




Source: Author, based on AEA, 2012.

The most common aim of measures according to the review carried out at European level, and shown in the above figure, is to improve efficiency of passenger transport, mainly through improvements to the efficiency of cars or measures to increase the uptake of cleaner vehicles, but also through promoting modal shift. Measures are also beginning, but not predominantly, to tackle improving the efficiency of other modes, and encouraging modal shift of freight from road to other less energy intensive modes such as sea and rail.

These conclusions correspond to the review carried out by the European Commission in 2009[29], about the first National Energy Efficiency Action Plans (NEEAPS). The review found a similar pattern in terms of types of measures and aim of measures. A large number included technological measures to improve vehicle efficiency and fiscal incentives and subsides to encourage cleaner vehicles, but fewer had policies on other strategies such as modal shift and mobility management.

In the context of this report, it is interesting to stress the Commission's conclusions that called for a more comprehensive and strategic approach which captures technological, infrastructural, financial, behavioral and spatial planning measures; as only a few member States had presented clear and consistent energy transport strategies at that point in time.

### e) India

The Indian transport energy use is projected to grow, driven by economic and demographic drivers. Vehicle ownership in India is in fact a relatively new phenomenon. As a result, and due to its large population, India has very low per capita transport emissions. But the nation's vehicle fleet is growing rapidly—vehicle sales increased from 2 million in 2007 to 2.26 million in 2009—and will continue to expand significantly over the next decade.

In 2010, despite the end of economic stimulus measures introduced in 2008 in response to the global economic downturn, vehicle sales in India continued to expand strongly.

[29] Brussels, 23.6.2009 SEC(2009)889 final Synthesis of the complete assessment of all 27 National Energy Efficiency Action Plans as required by Directive 2006/32/EC on energy end-use efficiency and energy services.

India has the largest light duty vehicle fleet in the world without efficiency standards. In particular, the vehicle fleet is composed by small vehicles and two or three wheelers (EIA, 2012). This also contributes to rank India among from the least fuel˜i ntensive countries with about 6 l/100km (GFEI, 2011).

However, in view of the projected growth of car transport, the Bureau of Energy Efficiency (BEE), an agency of the Government of India, under the Ministry of Power created in March 2002 under the provisions of the nation's 2001 Energy Conservation Act, is considering mandating a 15% reduction in fuel consumption by 2020 for cars, which would result in an average fuel consumption of 5l/100 km for the new vehicle fleet. This standard would open the door to energy efficiency standards for two- and three-wheelers and heavy-duty vehicles—segments of the transport sector that consume more fuel consumption in India than passenger vehicles.

The National Action Plan on Climate Change that came in force in 2008 calls for stronger enforcement of automotive fuel economy standards, using pricing measures to encourage the purchase of efficient vehicles, and providing incentives for the use of public transport.

Other domains addressing energy efficiency in transport relate to the emission standards, production of alternative fuels, infrastructure and land use policies, as summarized in the following bullet points:

- Vehicle emission standards started to gain importance over the last decade. According to the World Health Organization, some half a million people in India die prematurely each year from diseases directly related to air pollution (Anup Bandivadekar et al, 2012). As part of India’s commitment towards cleaner fuel, 17 cities have switched to Bharat Stage 4 (BS IV) emission norms (equivalent to Euro IV), with three more cities to be added on 1 March 2012 (Amrit Raj, 2013). The plan is to extend the standard to 50 cites by 2015.
- In 2010, India launched a National Ethanol Blending Programme, establishing a 5-per cent mandatory ethanol blending standard in 20 states, and started selling blended fuel in 14 of the Programme’s states, while increasing regulated prices for ethanol;
- The development of the country’s infrastructure is among one of the key priorities for India’s government, due to the pressures on its transport system from the rapidly growing economy. To reduce bottlenecks in both urban and rural infrastructure have been seen as on factor improving efficiency and the country’s competitiveness.

In general, analysis from consultants (TERI, 2012) points out that given the current consumption patterns, although much of the fuel reduction possibility in this sector can be related to autonomous efficiency improvements of the transport modes, in the medium-long time horizon major efforts should be made to enhance rail-based movement (modal shift) and the use of public transport.

The following table (International Energy Agency Energy Efficiency Policies and Measures) summarizes the on-going policies addressing energy efficiency in transport in India.

**TABLE 11**
**ON-GOING POLICIES RAISING ENERGY EFFICIENCY IN TRANSPORT IN INDIA**

| Title | Description | Year | Policy Type |
|---|---|---|---|
| National Action Plan on Climate Change | The measures are wide ranging, targeting energy efficiency and renewable energy, as well as improved research capacity on climate change issues | From 2008 | Regulatory instruments, codes and standards |
| The Eleventh Five Year Plan | In 2007, the 11th Five Year Plan was developed and includes goals to reduce energy intensity with respect to greenhouse gas emissions by 20% from the period 07–08 to 2016–17, and increase energy efficiency by 20%. | From 2007 | Policy support, strategic planning, economic instruments |

Source: Author, based on IEA database.

### f) United States

In the context of OECD countries, the United States (U.S.) are the largest consumer of energy in transport activities. In particular, energy consumption of light-duty vehicles is relevant. Light-duty vehicles include passenger cars, pickup trucks, and light-duty commercial trucks with gross vehicle weight ratings of 8,500 to 10,000 pounds.

The transport system provides U.S. residents with high level of personal mobility – in terms of trips made and miles travelled. It has been pointed out (EIA, 2011) that the growth in energy demand for light-duty vehicles results mainly from a high increase in vehicle miles travelled per licensed driver, supported by higher levels of real disposable personal income and more moderate increases in fuel prices than have been seen in recent years.

However, it has also been stressed in a recent research by US PIRG (2013), an independent research and policy analysis organization that: "the unique combination of conditions that fuelled the driving boom—from cheap gas prices to the rapid expansion of the workforce during the Baby Boom generation—no longer exists". Confirmation of the fact that in the United States, passenger travel appears to be saturating, at least on a per capita basis, can be found in (EIA 2012).

Concerning freight transport, fuel use for heavy-duty vehicles rises as industrial output increases and more high value goods are carried by freight trucks, offset only partially by a small increase in heavy-duty vehicle fuel economy.

The recent policies in the field of energy efficiency are encouraging particularly the fuel economy standards for trucks and the current plan to extend light-duty fuel economy standards to 2025, with a doubling of fuel economy (50% cut in fuel intensity), consistent with international targets set by the Global Fuel Economy Initiative. The following table provides a complete view on the on-going recent policies addressing energy efficiency in transport.

**TABLE 12**
**ON-GOING POLICIES RAISING ENERGY EFFICIENCY IN TRANSPORT IN THE UNITED STATES**

| Title | Description | Year | Policy Type |
|---|---|---|---|
| Electric Drive Vehicle Battery and Component Manufacturing Initiative | The Electric Drive Vehicle Battery and Component Manufacturing Initiative support grants for US-based manufacturers to produce batteries and electric drive components. | From 2009 | Economic Instruments |
| Climate Showcase Communities Grants | The Climate Showcase Communities Grants programme, launched in 2009, helps communities create replicable models of sustainable community action that generate cost-effective and persistent greenhouse gas reductions while improving the environmental, economic, public health, or social conditions in a community. | From 2009 | Economic Instruments |
| Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance | Improve fleet and transport management | From 2009 | Economic Instruments |
| American Recovery and Reinvestment Act: Appropriations for Clean Energy | Grants available to support advanced battery manufacturing for facilities located in the US; -USD 300 million in additional funding for DOEs Clean Cities Program; -USD 500 million for a grant programme supporting clean energy workforce training managed by the Department of Labor; USD 100 million to support more workforce training that is managed by the DOE | From 2009 | Research, Development and Deployment (RD&D), Researc programme , Technology deployment and diffusion |
| Energy-Efficient Federal Motor Vehicle Fleet Procurement | The American Recovery and Reinvestment Act of 2009 makes available funding for capital expenditures and necessary expenses of acquiring motor vehicles with higher fuel economy, including: hybrid vehicles; electric vehicles; and commercially-available, plug-in hybrids | From 2009 | Economic Instruments |

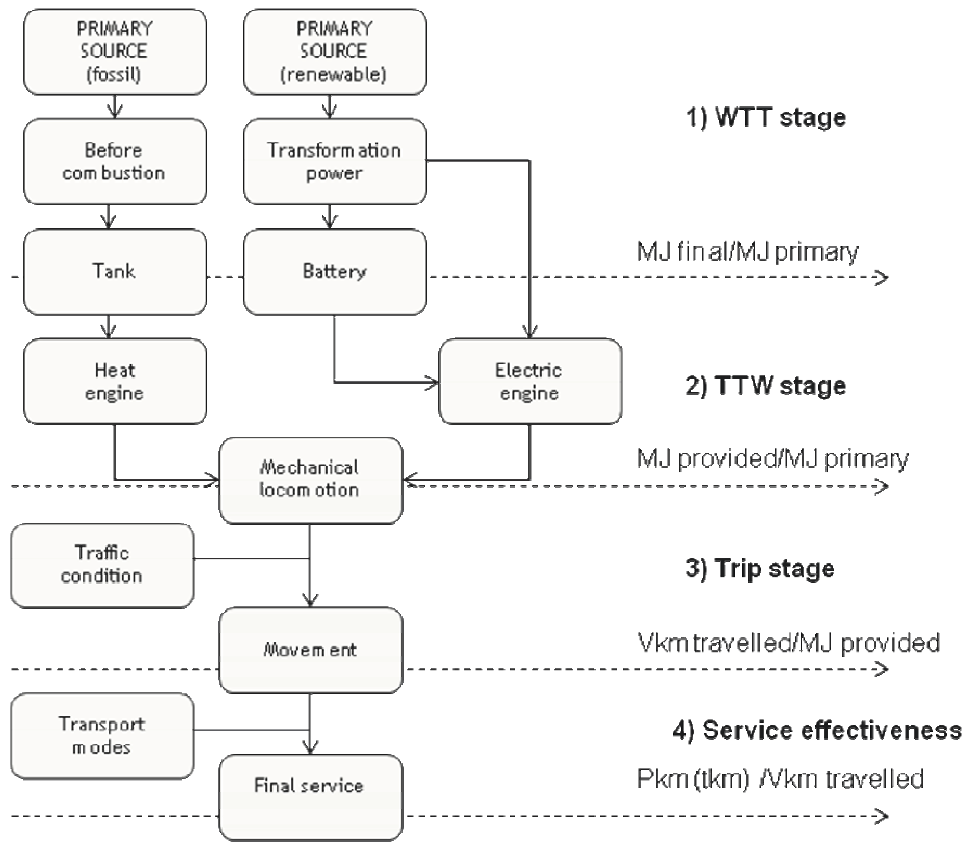
Source: Author, based on IEA database.

## 3. Emerging patterns in energy efficiency policies

Pursuing energy efficiency in transport is a complex matter, due to the fact that there are four different stages to be considered altogether, corresponding to different functional levels underlying the provision of the transport services, i.e. people or goods transported.

The following picture shows the four stages:

**DIAGRAM 8**
**STAGES IN TRANSPORT ENERGY EFFICIENCY**




Source: Author, adapted from REF-E, 2013.

The first stage corresponds to the energy transformations required to move from the extraction of the primary source to the availability of energy stored in the vehicle (this stage is often referred to by the acronym WTT = Well-To-Tank). Energy efficiency at this stage is measured by the ratio between the final energy stored and the required primary energy (expressed in Joule in the above picture).

The second stage is the process leading to mobility, corresponding to the transformations that take place in board of the vehicle for transforming the energy stored in the tank (or battery) in force traction capable of ensuring the same motion of the vehicle and its payload (this stage is often referred to by the acronym TTW = Tank-to-Wheel). The ratio between the two amounts of energy represents the energy efficiency of this stage.

These first two stages are sometimes conjointly defined by the acronym WTW (Well-to-Wheel), encompassing the overall energy consumption involved in by energy transformations and vehicle mechanical features.

The overall energy efficiency, however, is also influenced by the conditions of the transport system and the way in which transport modes are used; e.g. energy consumption spent in traffic free-flow conditions or in stop-and-go conditions, or the energy consumption spent in relation to the number of passenger or volume of tons transported. More specifically:

- The third stage is related to the trip stage, which measures the influence of traffic conditions, e.g. congestion level in non scheduled transport modes, and the relationship between speed and distance travelled along transport networks.
- The fourth stage addresses the final stage of the transport service, in which generally transport modes meeting transport demand in joint use (collective transport for passenger and goods) are more efficient in terms of energy spent per passenger kilometer or ton-kilometer.

What is important to stress, as result of the four stages, is that pursuing energy efficiency in transport means to address both the technological aspects of the energy efficiency, corresponding to the first two steps (WTW), and the socio-economic aspects of the transport system, e.g. modal split, traffic conditions, etc, corresponding to the last two stages of the process shows the stages of transport efficiency, but omits energy consumption for vehicle production (Life Cycle Assessment-LCA) and energy efficiency in transport infrastructure supply, considered both external to the transport activities.

However, the two components are deemed to play an important role in the overall energy efficiency of the sector.

PE International (2012) pointed out that there is much greater potential for decarbonisation through advances in vehicle component materials and production processes. In such a context, LCA of electric vehicles could raise methodological issues (Hawkins, et al, 2012). In fact, data availability and methodological aspects could make LCA results controversial, as stressed by ACEA (COM/2013/0196 final).

Concerning energy efficiency in infrastructure provision, IEA (2012) stressed that increasing global travel (in particular in non OECD countries) will require infrastructure provision to grow. In 2010, 40% of all travelled kms took place in non-OECD countries while having only 20% of road infrastructure stock compared to OECD countries.

The potential gains in energy savings are significant. According to case studies, greener rail stations and street lighting can reduce $CO_2$ emissions up to 0.9 Mt a year. In the field of greener and carbon-neutral airports, in Brazil, a five-year contract will save 1 million Brazilian Reals to the economy annually (World Bank (2013).

The need for a unitary and holistic approach in dealing with energy efficiency in transport activities is also confirmed by the evident relationships between the four stages of energy efficiency in transport and the Avoid-Shift-Improve (ASI) transport policy strategy, a well-established framework for sustainable transport.[30]

# 4. The case of fuel subsidies

The case of fuel subsidies deserves a particular attention among the tools for improving energy efficiency and reaching the decarbonisation of transport activities. The reason lies in the fact that fuel subsidies are meant to serve a variety of purposes: from climate change mitigation to promotion of local energy sources, industrial policies and the attainment of social issues (e.g. keeping low inflation rates).

Fossil-fuel subsidies (gasoline and diesel) and fuel subsidies in general (e.g. bio-fuels subsidies, CNG subsidies, etc) must be treated separately, due to the different impacts and implications in terms of energy policy.

## a) Fossil-fuel subsidies

International organizations (IEA, 2012, World Bank, 2013) agree that phasing out fossil fuel subsidies represents a critical step to achieve a level playing field across all fuels and technologies. It has

[30] For a broad overview of the ASI approach see www.supt.org.

been estimated (IEA, 2012) that eliminating inefficient subsidies that encourage wasteful consumption of energy and fossil fuels could reduce growth in energy demand by some 4%, even by 2020. Only in 2010 fossil fuel subsidies were estimated at USD 409 billion (with a growth of more than 37% since 2009), compared to about USD 66 billion dedicated to the development of renewable energy (IEA, 2012).

Calculations from the World Bank (2013) show, that the Islamic Republic of Iran could save USD 20 billion a year and Saudi Arabia USD 12 billion, by removing transport fuel subsidies. Poorer countries could also have major savings. If it cut its transport fuel subsidies, for instance, Myanmar could save more than $300 million.

Since 1991, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) regularly provides worldwide Fuel Price Surveys. One of its goals is to provide a worldwide comparison of fuel selling prices (and subsidies) as an instrument to evaluate energy policies in developing countries.

In 2010, comparing to a non subsidized fuel price standard identified in the USA gasoline and diesel retail prices (including industry margin, VAT and local taxes), 22 and 45 countries (accounting by 12.6% and 25.9% of the countries examined) resulted respectively as very highly and highly subsidized, resulting in lower retail prices with reference to gasoline and diesel USA retail prices (GIZ, 2011).

The list of subsidizing countries, ordered by the higher levels of subsidies, includes, for the most part, oil producer and developing countries.

In particular in developing countries low fuel prices may help domestic business, like kerosene and LPG subsidized products are used mainly by rural population in India, and therefore phasing out subsidies may turn out as politically challenging.

However, a study from the International Monetary Fund (2006), drawing on poverty and social impact of fossil-fuel subsidies analyses in Bolivia, Ghana, Jordan, Mali, and Sri Lanka pointed out that universal energy subsidies may be not a cost-effective way to protect the real incomes of poor households, since they may involve substantial leakage of benefits to higher-income groups.

As stressed by APEC (2012), given that in any case the removal of fuel subsidies may be regressive, phasing out subsidies must be part of a complex political economy of fossil-fuels subsidy reform, including well-targeted social assistance measures; e.g. budgetary savings from reduced fuel subsidies should be directed to higher priorities, such as increasing access to or improving the quality of education and health care services, improving physical infrastructure, or reducing taxes.

### b) Non-fossil-fuel subsidies

The impacts of subsidies on other non fossil-fuels are controversial. It is acknowledged that bio-fuels will play a key role in making transport sustainable up to 2050, at least in the European Union scenarios (EREC, 2010).

However, despite the fact that at world level, a growing number of countries is committing towards bio-fuels targets (Argentina, Australia, Brazil, Canada, China, Colombia, India, Indonesia, Malaysia, Mexico, Peru, the Philippines and South Africa), without support, both direct and indirect, the commercial viability of bio-fuels may be questioned (World Bank, 2013).

Case studies provide mixed signals:

- The Brazilian Proalcool program outlined a successful long-term policy that cut the cost of producing ethanol. Today the government spends about USD 2.5 billion per year on consumption subsidies and is now by far the lowest-cost producer of bio-ethanol worldwide. The industry also employs over 3 million people and contributes strongly to energy security (WEF, 2011);
- The US government subsidized bio-fuel consumers corn-based ethanol (38 to 49 cents per liter) has succeeded in positioning the US as the world's largest ethanol producer, but does not seem to have high potential to reduce $CO_2$ or oil dependency in the long term.

In general, it can be said that programs promoting energy efficiency through subsidies and incentives should have a limited lifetime; i.e. they can temporarily drive the market forward, but the effects may be rarely sustainable in the long term.

Conclusion.

Policies and measures addressing energy efficiency in transport pursue several objectives: from the improvement of technical performances at vehicle level (e.g. labeling, emission standards) to the establishment of different modal split in transport activities, e.g. shifting traffic shares to environmentally friendly transport modes (passenger and freight).

In general, the different objectives can be interpreted in the light of the A-S-I (Avoid, Shift, Improve) approach, addressing different stages of the process in which the improvement of energy efficiency in transport can be attained: the WTW stage -Improve-, the trip stage -Avoid-, through better logistics, passenger and freight, and land use policies - and the transport service stage -Shift-. A coherent and holistic strategy addressing all the stages is strongly recommended.

The current practices in OECD and non OECD countries under examination tend rather to focus on specific components, in the light of the specific challenges: technological primacy in the OECD countries and projected traffic growth in non OECD countries.

Among the policies, fuels subsidy deserves attention, due to the potential distorting signal on consumption patterns, impacts on energy market and equity.

## E. Requirements for an efficient regulation

Regulatory frameworks in the transport system design a complex bundle of instruments; both normative and economic, e.g. the overall legal, enforceable, 'command and control' type of instruments (e.g. standards), economic instruments (taxes, incentives, etc.)

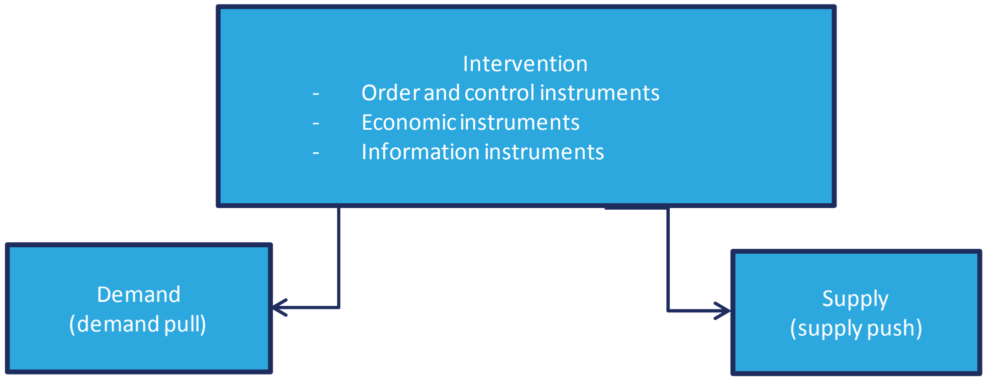
The specific mix of economic incentives and rules and regulation can be also accompanied by political instruments, as information and awareness campaign, labeling, voluntary agreements, etc, which can support the regulatory framework through the involvement of civil society (NGOs, consumer and professional associations).

The final outcome tends to influence the transport stakeholders (citizens, transport operators, industry) towards a desired end: adjusting market participants' behavior (e.g., purchasing more fuel efficient vehicles, reducing energy consumption, optimizing logistics in freight transport, changing the modal split) by establishing a system of suitable incentives and regulations.

In the field of energy efficiency, the main instruments whose specific combination determines the regulatory framework are the following:

- Command & Control instruments, setting standards in fuel consumption and emissions, as the European Union Emission Standards for Light Duty Vehicles and Heavy Commercial Vehicles (i.e., Euro II, Euro III, Euro IV, Euro V and Euro VI standards) or the Corporate Average Fuel Economy (CAFE) standards established in the United States;
- Economic instruments, influencing consumers choice, production and development of new technologies, as fuel taxes, R&D subsidies, differentiated vehicle taxes road charges, subsidies on purchases of electric vehicles or the installation of charging points, subsidies for the development of electric vehicles (e.g. battery technology), etc.:
- Information and policy instruments; as labeling, which aims at providing end-users of vehicles with clear and relevant information about the quality of the tire, and to guide them towards choosing a product which is more fuel efficient; voluntary agreement and the development of public-private partnerships.

**DIAGRAM 9**
**MAIN INSTRUMENTS IN THE FIELD OF ENERGY EFFICIENCY**




Source: Authors elaboration.

The following sections describe in turn the types of instruments, the conditions for their implementation, examples with good and bad practices, in order to provide the basis to generalize the requirements for an efficient regulatory framework in OECD and non OECD countries.

## a) Command & Control instruments

**Fuel economy standards**

Fuel economy standards are meant to reduce transport sector fuel demand through vehicle fuel efficiency improvements. Fuel efficiency is measured as distance per unit of consumption and, given the same travelled distance, it can lead to reduce consumptions and improve energy efficiency.

However, command and control policies in general focus on increasing adoption of advanced technologies but do not as such provide an incentive to operate efficiently. In fact, by decreasing specific fuel consumption, these policies can decrease the incentive to operate efficiently and increase the distance travelled (the so-called rebound effect). It has been mentioned that for every 10% fuel consumption saving, distance travelled increases by around 3% (WEC, 2011).

Furthermore, fuel economy standards may be difficult to implement, both politically (agreement with lobbying power) and technically. It has been stressed as most developing countries are found to be reluctant to introduce stringent regulatory standards because of their limited resources to enforce the stringent standards (Timislsina, 2009).

Market maturity, income level and vehicle size composition of new vehicles help to explain why at global level the fuel economy improvement appears to be mainly due to progress made in OECD countries, where average fuel consumption rates decreased by 1.5% per year between 2005 and 2008 (GFEI, 2011).

A number of countries have introduced fuel economy standards, which also help to reduce some types of emissions, such as $CO_2$, that are directly linked to fuel consumption. While European Union (EU) and Japan have the most stringent fuel economy standards in the world, the United States and Canada had the lowest standards.

**Fuel efficiency non engine standards**

The potential for improving the fuel efficiency gains through non engine components such as tires and air-conditioning systems that are often excluded from vehicle fuel-efficiency testing and requirements is significant (IEA, 2011).Governments could improve the performance of non-engine components through, for example:

- Adopt new international test procedures for measuring the rolling resistance of tires, and establish labeling and maximum rolling resistance limits for road-vehicle tires.
- Adopt measures to promote proper tire inflation levels. This should include mandatory fitting of tire-pressure monitoring systems on new road vehicles.
- Introduce energy efficiency requirements for air-conditioning systems or include the energy efficiency of such systems in fuel-economy testing.

However, the implementation of these measures requires an efficient institutional capacity to enforce the mandates, avoiding harming technological development and competition.

**Fuel quality standards**

Cleaner fuels, that have an immediate impact on both new and existing vehicle fleets, are an important component for the successful adoption of stringent vehicle emission standards and the reduction of oil-dependent energy sources.

The adoption of fuel quality standards is common in most countries around the world. Many countries, both industrialized and developing, have introduced fuel quality standards to limit sulfur content, thereby reducing oxides of sulfur and particulate matter. Moreover, several countries have introduced mandates for blending ethanol and biodiesel into, respectively, gasoline and diesel.

In general, costs and benefits associated with sulfur reduction vary from region to region, depending on the state of existing refineries, fuel quality, and emissions standards. Some countries that import petroleum products might find it hard to maintain the required quality due to the lack of their own refineries. Consequently, developing countries without their own refineries may not be in a position to enforce fuel standard related regulations.

Natural resources endowment is another important factor. Brazil decided in the 1970s that since it had ideal conditions for growing sugar cane, it had a competitive advantage. As a result, Brazil ran the ProAlcool program at a cost of ca. US$ 16 billion and today spends ca. US$ 2.5 billion per year on consumption subsidies and is now by far the lowest-cost producer of bio-ethanol worldwide (WEF, 2011).

### b) Economic instruments

**Fuel taxes and carbon pricing**

Fuel taxes and carbon pricing mechanisms can achieve an immediate impact on fuel consumption. However, they can be politically difficult to implement since they are regressive and may raise social complaints and equity concerns.

Studies show that a 10% increase in fuel price results in around a 2.5% decrease in consumption within a year and a 6.5% decrease in consumption after a few years (IEA, 2011).

Therefore, fuel taxes would produce greater immediate savings by encouraging people to drive less and, eventually, to choose more-fuel-efficient vehicles.

This instrument can be difficult to implement nationally in presence of global transport activities (aviation and international navigation), for which an international coordinate approach, and decision making, is needed, as for the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO) organizations.

**R&D incentives**

R&D subsidies and incentives are important, due to their capability to support energy efficiency technologies at their earlier state of development, reducing at the same time high risk of R&D investment.

From an administrative point of view, implementing the subsidies is relatively straightforward, but an independent and efficient system of rules and regulation is needed in order to ensure independency from political and lobbying pressures.

It is also important that governments are able to demonstrate results for their investment.

Furthermore, R&D incentives may require substantial investment, as the China case on R&D support to electric vehicle production demonstrates.

**Infrastructure subsidies**

Similarly to the R&D subsidies, infrastructure subsidies supporting investments in charging stations for electric vehicles, distribution network for natural gas stations, etc., can have great impact but are only economically efficient under a narrow range of conditions. The most important one is an administrative design which is able, on the one hand, to keep administrative costs low, and on the other, to maintain a strong incentive for competition. Public-private partnership models in such cases may be appropriate.

**Production and consumption subsidies**

Production and consumption incentives can take many forms, for example: direct financial subsidies to manufacturers or consumers for each vehicle or energy source bought or sold. For example Brazil spends ca. US$ 2.5 billion on consumption subsidies for ethanol (IEA, 2011).

As for R&D subsidies, the cost of supporting large-scale adoption may be too high for governments to afford. In such a case, fee bate policies can allow the cost of production subsidies to be transferred to consumers and industry. These policies couple a penalty for buying energy intensive technologies (fee) with a subsidy or purchasing energy-efficient technologies (rebate).

Scrappage policies, through fleet renewal, can lead to energy efficiency. The pre-conditions for a fair implementation are a well-designed administration, transparent and efficient, and the absence of long-term budget constraints.

Car and truck scrappage programs, if well designed, may be effective. The review (World Bank, 2013) stresses that the United States, as in other developed and OECD countries in the past, such as France and Norway and Chile (Cambia tu Camión y camioneta campaign, 2013), has recently implemented the Car Allowance Rebate System (CARS) or “cash for clunkers” program, which paid up to $4,500 for each energy-inefficient car (18 or fewer mpg) that was replaced with a more efficient one. Ex-post evaluation studies on welfare effects on consumers and fleet composition (e.g. Busseat al, 2012) claim that the overall outcomes are positive; from the higher than expected number of consumers applying for the program, to the old and high-mileage vehicles replaced, which did not raise prices in the used-vehicle market.

Scrappage schemes have not been implemented in developed countries only. Examples in developing non OECD countries can be found in Colombia (Enei et al, 2012), with reference to the road freight sector.

In general, the evaluation of the scheme (in particular in developing countries) relies on several factors:

- The efficient implementation and management of the program requires transparent procedures to disburse compensation in time and without misallocation. The implementation of the program in fact may raise the issue of the gap between the demand (owners willing to scrap the truck) and the supply of compensation (the owner actual receiving the resources).
- The extreme fragmentation of the freight market operators, which can represent a barrier to the development and the modernization of the entire truck fleet. Only a handful of large firms with innovative technology and financial resources could in fact provide excellent services. Therefore, the introduction of rules and regulations aiming at increase the number operators could lead to develop scale economies and truck efficiency.
- High costs and budget constraints. Car or trucks scrapping programs, however, can be seriously limited by their high cost. For instance, in the recent U.S. experience, only 30% of total passenger cars were traded in, at a cost of $3 billion. Car scrapping thus cannot be the only solution, at least over a long time, for fleet turnover.

However, it should also be considered that a well-designed scrappage program may target the most pollutant and inefficient vehicles, providing good results in a short-term horizon.

### c) Information and stakeholders' involvement

**Eco-driving**

Eco-driving relates to the practices and methods to ensure an energy efficient use of vehicles. It has been stressed (IEA, 2011), that governments should ensure that measures to increase the operational efficiency of light- and heavy-duty vehicles, such as eco-driving, are a central component of initiatives to improve energy efficiency and reduce $CO_2$ emissions.

Governments should adopt a range of measures to improve vehicle operational efficiency, including:

- Making eco-driving a required element of driver training.
- Requiring manufacturers to provide in-car feedback instruments in new cars.

**Vehicle maintenance campaign**

As declared by the spokesman on environmental affairs at Toyota[31], in France 80% of the pollution from diesel vehicles comes from 20% of the country's diesel fleet, especially those made before 2000.

Cross-country studies have confirmed the importance in targeting the small percentage of ill-maintained vehicles, responsible for most than 50% of pollutants (G. Timislsina, 2009).

Within the European Union, the member states have implemented the requirements of the Roadworthiness Framework Directive, requiring vehicle owners to comply with a compulsory vehicle inspection. In China, maintenance programs require regular inspections, which include yearly inspections, first-class maintenance, second class maintenance, and vehicle overhaul. In big cities such as Beijing, Shanghai, and Guangzhou, vehicle maintenance programs have been effective, to a large degree, in lowering vehicle emissions and consumption.

Lack of proper enforcement, and corruption, may prevent the realization of the full potential of maintenance program. The same for the lack of capacity, such as the lack of training of personnel, and poor quality test equipment, which can hinder the success of the program.

**Voluntary agreements**

Voluntary agreements can involve transport stakeholders in win-win solutions from an environmental and commercial point of view. In France, the "Charter of voluntary commitments to reducing $CO_2$ emissions" was officially launched on December 16, 2008 in association with the whole carriers representatives' organizations and 15 carriers. The objective of the $CO_2$ charter is to improve the energy performance of the transport sector, in particular road freight (and limiting $CO_2$ emissions) and provide companies with a reliable, coherent methodological framework, recognized at national level.

**Public-Private partnerships**

Public-private partnerships may be important to accelerate the development and deployment of new technologies. A broad range of partnership types are available, depending on the type of technology and market (WEF, 2011).

- Partnerships with relatively few players are effective at research, development and pilot-scale trials.
- Narrow-based, high investment partnerships are effective at developing infrastructure and bringing technologies to the market.

[31] The Economist " Green wheels" April 20th 2013.

- Broad-based partnerships have a role throughout the technology lifecycle – starting with conducting feasibility studies, policy lobbying and developing standards, and moving to address market failures caused by lack of information.

For example, in the broad-based partnerships, the US SmartWay program which built an accreditation scheme to reduce fuel consumption in the road freight industry. The scheme involves both carriers (companies which provide and hire trucks) and shippers (companies which create the demand for freight services).

Carriers can become members if they commit to monitoring and improving their fuel use and shippers can become members if they commit to sourcing at least 50% of their goods through SmartWay member carriers (WEF, 2011). Shippers may benefit from increased transparency in their sourcing and from gaining a way to react to consumer's environmental concerns. Carriers benefit from increased visibility and capture market demand.

Another example is the German Initiative for Natural-Gas-Based Mobility, which aims to significantly increase the share of natural gas and bio methane in the German fuel mix and raise the number of natural gas-powered vehicles.[32]

The Initiative for Natural-Gas-Based Mobility brings together well-known companies active along the entire value chain of the energy and transport sectors.

- Car manufacturers: Daimler, Fiat, Iveco Magirus, Opel, Volkswagen Group, VDIK – Association of International Motor Vehicle Manufacturers.
- Petroleum industry: BP / Aral, Shell, UNITI – German Federal Association of Medium-Sized Oil Companies.
- Gas suppliers: erdgas mobil, Wingas.
- Biogas industry: VERBIO.
- Gas engineering: figawa – German Federal Gas and Water Industry Association.
- ADAC.
- Public stakeholders: Dena (coordination and communication), BMVBS (patronage).

An important pre-condition for the effectiveness of these instruments (voluntary agreements and public-private partnership) is the presence of a public and strong independent agency; e.g. ADEME for the French case, the Environmental Protection Agency (EPA) in the American case and the Federal Ministry of Transport, Building and Urban Development (BMVBS) in the German case. The independent agencies, from the stakeholder's pressures and lobbies, must provide a consistent support, being able to lead the program with the whole transport industry actors and develop tools, methodologies which can act as important enablers.

## F. The role of regional integration

Among the requirements for an efficient regulation, the one related to the role of regional (inter-country) integration must be stressed. Integration of energy and transport sectors lays the foundations to create a network of infrastructure, whose extension spreads across national boundaries.

For instance, in the energy sector, regional power system integration is considered, especially in developing countries, as an important strategy to help provide reliable, affordable electricity to their economies and citizens (World Bank, 2010). The benefits from international integration are expected to stem from an increased electricity generation cooperation and trade between countries that can in

32 For info: www.erdgasmobilitaet.info/en/home.htlm.

fact enhance energy security, bringing economies-of-scale in investments, facilitating financing and enabling greater renewable energy penetration.

Concerning the transport sector, international integration in transport infrastructure is generally acknowledged as a vehicle to reach economic development and energy efficiency. For example, the importance of international cooperation on transport infrastructure provision is recognized by Asian and Pacific countries through several cross-border transport infrastructure projects (ESCAP, 2006), and in the European Union the TEN-T program (EC, 2007) has identified a core network of trans European transport infrastructure in order to establish a single, multimodal network that integrates land, sea and air transport networks throughout the Union.

The implications in terms of energy efficiency are relevant: it has been stressed that favoring large-scale inter-country integration of several transport modes may lead to improve the overall energy efficiency of trips, i.e. reducing institutional barriers, excessive border tolls, etc., that can induce travelers and freight to detour to roads that are longer (with higher energy consumption) but quicker to travel (World Bank, 2013).

Furthermore, in some transport modes, i.e. maritime and aviation, transport activities and industry are fundamentally global in scale, leading to the presence of international bodies, as the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), in which the decisions about global measures and policies for improving energy efficiency are taken. These organizations coordinate the contributions of individual countries and can be considered as examples of regulation through inter-country integration. Besides, with reference to the international regulation of the GHGs emissions in the aviation sector, the European Union provides currently the only example of a region that target aviation $CO_2$ emissions through a regional (inter-country) mechanism: the CO2 cap-and-trade system (ICCT, 2012).

However, behind the trend towards international cooperation (structural, economic or political), it is quite common to consider the degree of cooperation-integration as one of the key factors to shape the future of transport and energy scenarios. But, at the same time, it is also considered as one of the key source of uncertainty (WEC, 2010).

In fact, despite the potential benefits arising from major international integration are generally acknowledged, e.g. facilitating the exchange of resources (labor, capital, raw materials, or financial) and technologies, it remains unclear which politics/economics-related barriers could be erected to defend private, public, or even national interests.

With reference to the transport energy efficiency, the following barriers and opportunities to major international integration can be identified:

### a) Barriers

**Political barriers.** The Shift and Avoid components to improve energy efficiency in transport, implemented essentially at local or regional (sub-national) level could not be dealt with effectively at supra-national level. In European laws, the principle of subsidiarity specifically addresses this issue, stating that central (national or supra-national) authorities should have a subsidiary function, performing only those tasks which cannot be performed effectively at a more immediate or local level, ensuring that decisions are taken as closely as possible to the citizens.

**Economic barriers.** Dearth of financing and economic downturn may hamper the commitments towards international projects. In the European funding schemes for the pan-European TEN-T infrastructure projects, for example, the national sharing part of funding is regularly under strain and at risk of being rescheduled in presence of national economic and financial problems, like the emblematic case of the Italian-France high speed rail link Turin-Lyon, part of the TEN-T Priority Corridor 5.

**Technical barriers.** Transport and energy infrastructure may be developed at different stages at country level. Therefore, the physical integration may be problematic. In order to harmonize different systems, the regulatory mechanism may become more complex and costly for operators and regulators: for example, in the energy sector, after a major shut-down of the synchronous system following a disturbance in Italy in 2003, the UCTE (Union for the Co-ordination of Transmission of Electricity, the European organization of national transmission centers operating bodies) required participating transmission system operators (TSOs) to sign a Multilateral Agreement legally enforceable in the European Court of Justice.

### b) Opportunities

**Institutional and political.** To establish official mechanisms of coordination among national member’s ministries of transport, energy and environment, that in many cases have traditionally worked separately, can facilitate the generalization of institutional best practices. It has been stressed, in fact (APEC, 2009), that often the greatest barrier to effective policymaking on energy-efficient transport is the lack of clear jurisdiction for a given program, or the lack of communication among agencies regarding their particular needs and goals.

**Capacity building.** Particularly in developing countries, relevant potential for improving energy efficiency comes from capacity building initiatives (e.g. IPEEC – International Partnership for Energy Efficiency Cooperation). Several and interlinked objectives can be pursued: a) to raise awareness among senior government leaders on the benefits, opportunities and feasibility of implementing energy efficiency policies, b) to build the capacity of government staff and consultants to evaluate, design, and implement high-quality energy efficiency policies, c) to assist developing and middle-income countries in identifying gaps in existing energy efficiency policies ; and to support strengthening of national energy efficiency policies through activities such as policy assistance networks and energy efficiency action planning.

**Technological development.** Particularly in developed countries, international cooperation in large energy related capital-intensive research topics which are far from commercialization and too expensive for a single country to undertake on its own, may be beneficial. Examples of international technology collaboration include bilateral agreements; multilateral technology-oriented partnerships, such as the International Partnership for the Hydrogen Economy; and regional multi-technology frameworks, such as the Asia Pacific Partnership, EU Framework Programmes, European Research Area Networks and Nordic Energy Research (EIA, 2012).

**Standardization.** Technical standards represent an important area to gain major benefits from international cooperation. In fact, most of the transport energy efficient measures cannot be effectively implemented without the adoption of technical standards to define and measure energy efficiency performance and without standardized methodologies to support the implementation of energy efficiency practices. The following domains can be identified:

- Standards for vehicle fuel consumption tests to take into account more realistic driving conditions and different regional usage patterns (for example, driving in congested urban areas is the most common road vehicle trip in developing countries).
- Fuel consumption test procedures, which need to be extended and adapted to cover hybrid vehicles.
- Standards covering the other major components of vehicles (and their operating conditions) which have significant impact on fuel consumption. Particular importance should be given to standards covering metrics and testing of tire rolling-resistance, as well as air conditioning and other in-vehicle sub-systems.

From the above list of barriers and opportunities it can be derived that the degree to which regional integration is part of a specific national regulative framework depends on national circumstances. The process of deepening regional integration in national legislation is not predictable; design, approach, and phasing of regional integration should be adapted to local realities, with considerable room for flexibility and adjustment as conditions and attitudes may change.

In general, developing countries may benefit from regional integration in terms of capacity building, circulation of best practices, institutional and normative solutions, developing common methodologies for data collection and metrics.

Developed countries, relying on fully integrated and competitive markets, may mainly benefit from international cooperation in technology and R&D projects and standardization.

## G. Conclusion and recommendations

The following table summarizes the most important pre-conditions underlying the key components of the regulatory framework.

**TABLE 13**
**THE TRANSPORT ENERGY EFFICIENT REGULATORY FRAMEWORK COMPONENTS**

| | | Requirements | | | | |
|---|---|---|---|---|---|---|
| Regulatory framework components | Examples | Market Development | Natural resources | Institutional capacity | No Public Budget constraints | Equity issues |
| Command and control mechanisms | Fuel efficiency standard | √ | | √ | | |
| | Fuel efficiency non engine standards | √ | | √ | | |
| | Fuel quality standards | | √ | √ | | |
| Economic mechanisms | Fuel/carbon taxes | | | √ | | √ |
| | R&D incentive | | | √ | √ | |
| | Infrastructure subsidies | | | √ | √ | |
| | Production and Consumer incentives (e.g. scrappage) | | | √ | √ | |
| Information and stakeholders involvement | Eco-driving , consumer education, labeling | √ | | √ | | |
| | Voluntary agreements | | | √ | | |
| | Public-private partnerships | √ | | √ | | |
| | Vehicle Maintenance campaign | | | √ | | |

Source: Authors elaboration.

Not surprisingly, institutional capacity is an important pre-condition in all the components, both to be applied in developing and developed countries. Public administrations play a key role in shaping and influencing the transport markets in general and in particular the framework for improving energy efficiency. They can influence travel decisions in favor of transport modes that are not energy efficient. Setting appropriately fuel taxes, prioritization of funds and R&D incentives (e.g. subsidies for infrastructure) they can encourage markets that favor energy efficient solutions, favoring public-private partnerships, as the recent German initiative on Natural Gas-based mobility demonstrates.

In search for the optimal mix of regulatory framework components, it must be considered that command and control mechanisms, economic incentives and information campaigns are not mutually exclusive, given that they address different purposes. Different countries could thus give priority to different measures depending upon their needs and institutional capacity to implement the regulatory framework.

Since most developing countries are particularly concerned about budget constraints, economic incentives and subsidies to infrastructure, R&D, producers and consumers, must be carefully considered.

Equity issues could also play a role when fuel taxes/fuel subsidies must be regulated or removed.

Command and control instruments, e.g. fuel economy and non-engine standards have been adopted mainly in developed OECD countries, due to their difficult implementation and relationship with industry and consumer reaction. On the contrary, fuel quality standards, supported by natural resources endowment (e.g. bio-fuel) may be significant to reduce oil-dependency in developing countries.

Furthermore, time factor and cost-efficient issues can also influence the decision about the most appropriate mix of components. For example, fuel economy and fuel standards may take years to realize their impacts, to the extent that fleet renewal depends on the rapidity with which more efficient vehicles make up a larger share of fleet (ICCT, 2013). Economic mechanisms, e.g. fuel taxes and vehicle scrappage can target the objective more rapidly, if well designed.

In general, both in developed and developing countries, the regulatory framework towards energy efficiency should also include policies that promote shifts of passengers and freight to more efficient modes and to adopt land use policy that consider the implications for transport and energy demand.

# III. The mobility perspective – the A-S-I approach for improved energy efficiency in mobility: Avoid, Shift and Improve

## A. Introduction

*"Nearly 5 million new cars are added each year to the fleet of motor vehicles, while tens of millions of old and highly polluting vehicles continue in service (...). While cleaner technologies can help, it is vital to also focus on mass transport issues in cities and to plan sustainable cities."*

*Luis Alberto Moreno, President of the Inter-American Development Bank at Bogota, 2011.*

There is indeed a wide range of known measures to reduce energy consumption of mobility and with that its environmental impact. Their scope can vary from the utilization of new technologies and intelligent logistics or mass transit in public transport to the promotion of energy efficiency in urban planning or behavioral changes or to the application of market policy instruments like e.g. fuel taxation. The variety of measures can be broadly classified into technical (technology oriented) and policy (market-based) instruments. This chapter reviews and analyses the scope and possible impact of the technical instruments contained in the measures put forward by the first Regional Forum on Sustainable Transport in Latin America.

As referred to in the previous chapters, the most common approach to classify measures that increase energy efficiency and/or reduce GHG-emissions in transport is the "Avoid - Shift - Improve" approach (ASI). It is built on three pillars:

- Enabling users to **avoid** motorized trips through smarter land use and logistics planning → Increase **system efficiency;**
- **Shift** the transport of goods and persons to more efficient transport modes[33] → Increase **travel efficiency**; and

[33] For passenger transport: e.g. mass public transport, walking or cycling for freight transport: e.g. rail or water transport.

- **Improve** the efficiency of transport systems by improving vehicle, fuel, and network operations and management technologies. → Increase **vehicle efficiency** (SloCaT, 2013).

Above dimensions of efficiency in transport, i.e. system, travel or vehicle efficiency can be related to GHG-efficiency, energy efficiency and, to a less extent, efficiency in terms of traffic safety or pollutants like NOx, SOx or particulate matter.

Current levels of energy efficiency in above dimensions significantly vary between economies and between regional and urban contexts. In fact, the indicators for system efficiency, travel efficiency or vehicle efficiency can differ from a few % points to factor of 10 as illustrated in the next figure at the example of urban passenger transport. Among others the level of energy efficiency depends on the level of urbanization, income, trade intensity, efficiency and utilization of technologies, region or city layout and environmental awareness of consumers.

**TABLE 14**
**ENERGY EFFICIENCY INDICATORS IN TRANSPORT IN DIFFERENT ECONOMIC CONTEXTS**

| Indicator | US cities | Western European Cities | High income Asian cities | Latin American cities | African cities |
|---|---|---|---|---|---|
| System efficiency | | | | | |
| Passenger transport energy use per capita (MJ/person) | 60 034 | 15 675 | 9 556 | 7 283 | 6 184 |
| Private individual mobility (pkm/capita) | 18 200 | 6 321 | 3 971 | 2 966 | 2 711 |
| Urban density (person/km2) | 1 490 | 5 490 | 15 030 | 7 470 | 5 990 |
| Travel efficiency | | | | | |
| Modal split of all trips | | | | | |
| Non-motorized modes | 8.1% | 31.3% | 28.5% | 30.7% | 41.4% |
| Public transport | 3.4% | 19.0% | 29.9% | 33.9% | 26.3% |
| Motorized private modes | 88.5% | 49.7% | 41.6% | 35.4% | 32.3% |
| Energy use per public transport passenger-km (MJ/pkm) | 2.13 | 0.83 | 0.48 | 0.76 | 0.51 |
| Vehicle efficiency | | | | | |
| Energy use in private passenger vehicle-kilometer (MJ/km) [a] | 4.6 | 3.3 | 3.3 | 3.7 | 3.7 |
| Energy use per public transport vehicle-kilometer (MJ/km) | 26.3 | 14.7 | 14.4 | 16.9 | 9.5 |

Source: Author, based on GIZ, 2011.
[a] Note that the share of cars and two- or three-wheelers has an influence on this indicator. It is preferable to assess automobile and two- and three-wheeler vehicle efficiency separately (GIZ, 2011).

From an energy efficiency point of view African, cities perform very well, i.e. energy consumption in transport per capita is only at 6.200 MJ per person. However, this is first of all a result of low overall mobility and a high share of non-motorized transport. With rising incomes and economic development energy consumption in transport in contemporary transport patterns will increase. However, the example of high income Asian cities shows that there is a potential to partly decouple the development of these variables, i.e. energy use per capita is "only" 30% higher than in Africa and 85% less than in US cities.

Especially for emerging economies there still is an opportunity to choose a low energy development path in transport. The consequent implementation of ASI-measures can boost energy efficiency for both passenger and freight transport (see next box for an example on freight) and as a result reduce dependency on oil and oil imports.

**BOX 6**
**INTEGRATED PLANNING FOR FREIGHT TRANSPORT IN EUROPEAN UNION[a]**

The European Commission White Paper on transport of 2011 defines a strategy towards competitive and resource-efficient transport systems for freight, defining targets for AVOID, SHIFT and IMPROVE strategies.

Optimizing the performance of multimodal logistic chains (AVOID and SHIFT)

Promoting the use of more energy efficient modes of transport at a larger scale, facilitated by efficient and environmentally friendly freight corridors (SHIFT)

Instigating a 50% shift in longer-distance freight journeys from road to other modes (SHIFT)

Instigating a 40% use of sustainable low-carbon fuels in aviation (IMPROVE)

Achieving at least a 40% cut in shipping emissions (IMPROVE)

By means of this strategy the European Union shall achieve 60% reduction in $CO_2$ emissions and a comparable reduction in oil dependency until 2050.

Source: UNCTAD, 2012.

[a] Fuel switch is a strategy for improving GHG-efficiency, not necessarily energy efficiency. Please see sub-section on IMPROVE strategies for further discussion.

In June 2011 at the “Foro de Transporte Sostenible” in Bogota, the first Regional Forum on Sustainable Transport in Latin America, high-level policy makers and representatives of national transport and environment agencies agreed to 24 objectives for sustainable transport Regional Forum on Sustainable Transport in Latin America 2011. The definition of sustainable transport includes much more than just low energy consumption. It is the provision of services and infrastructure for the mobility of people and goods needed for economic and social development and improved quality of life and competitiveness. These services and transport infrastructure provide secure, reliable, economical, efficient, equitable and affordable access to all, while mitigating the negative impacts on health and the environment locally and globally, in the short, medium and long term without compromising the development of future generations" (Bogota Declaration, 2011).

For those objectives of the Bogota declaration, which increase energy efficiency of both passenger and freight transport, proven ASI-measures will be presented in the following sections. Section 2.2 presents the measures related to avoiding motorized trips and reducing travel distances, Section 2.3 contains the measures related to shifting the transport of goods and persons to the most efficient transport modes and Section 2.4 describes the measures related to improving technology and management of transport services. Each section also assesses the effectiveness of the analyzed measures. Section 2.5 provides a cost-benefit analysis for ASI strategies and the concluding section (2.6) offers a general summary and a set of policy recommendations.

**BOX 7**
**ENERGY EFFICIENCY VS. GREENHOUSE-GAS-EFFICIENCY IN TRANSPORT**

Measures, which increase energy efficiency in transport, usually reduce GHG-emissions, too - due to the fact that more than 90% of transport fuels are from fossil origin. As a result both the reduction of the national energy bill and the mitigation of climate change are important drivers for improving energy efficiency in transport.

Measures that increase GHG-efficiency also increase energy efficiency as long as there is no fuel switch to alternative fuels involved. The production of alternative fuels in most cases uses more energy than the production of fossil fuels for each MJ produced. I.e. the switch from fossil fuels to alternative fuels usually increases energy consumption. However, a fuel switch to alternative fuels can still mitigate climate change and reduce the national energy import bill.

Whereas developed economies in public discussion seem to prioritize mitigation of climate change higher than improvements in energy efficiency, it is crucial for both developed and developing economies to reduce the dependency of transport on oil. The 2008 oil price hike showed that increased prices of transport affect the prices of almost every product that is transported. For low-income producers (e.g. small farmers) transport costs can have a high influence on their margins. For low-income consumers, transport costs have a high influence on their access to education, jobs or health care. It is therefore positive to see more and more political decision makers recognizing the high importance of energy efficiency in the transport sector to both climate change mitigation and economic and social development.

Source: Author’s elaboration.

# B. AVOID motorized trips and reduce travel distances

Avoiding transport without negatively affecting economic development can be achieved by a) improved planning and management of logistics and passenger transport, b) strategic prioritization of energy efficiency in urban planning and transport infrastructure construction and c) the consequent use of modern information and communication technology. These measures form the core of the three first objectives of the Bogota Declaration.

## 1. "Increase the efficiency of transport and distribution of goods through urban and interurban intelligent logistics systems and specialized logistics infrastructure" (Objective 1)

With increasing economic activity there usually is an increased demand for transport of goods, which results in increased energy consumption. Policy-makers are recognizing freight transport as a significant and growing concern.

The amount of necessary tonne-kilometres (tkms) can be reduced by local sourcing and decentralization of warehousing. However, energy efficiency of these measures needs to be further investigated, especially with regard to the trade-off between energy consumption in transport and in decentralization[34]. I.e. energy consumption for building and operating the additional warehouses has to be considered, too – not to speak of the trade-off in costs.

Tkms can further be avoided by increasing vehicle utilization, i.e. avoiding empty or semi-empty truck tours. 13% of truck-kms in international transport and 27% in national transport in the European Union run empty - 36 to 48% in India, about 50% in China (McKinnon, 2012). Improved vehicle utilization can be achieved by intelligent load management, optimized routing, reduced packaging, improved transport scheduling or even transport collaboration between different companies. Transport collaboration is an effective and economic measure, where two or more companies jointly plan their transport routes and schedules to increase lorry utilization and share cost benefits (see following box for an example).

**BOX 8**
**TRANSPORT COLLABORATION BETWEEN COMPETITORS**

As part of the EU-project "CO3 – Collaboration Concepts for Co-modality" collaboration was achieved even between competing companies. In central UK Nestle and United Biscuits increased truck utilization by jointly operating one route instead of two individual routes: "We compete on the shop shelf, not in the back of a lorry." a company representative concluded. The collaboration on that route resulted in savings of 280,000 truck-kms per annum.

Source: McKinnon 2013.

Bilateral or multinational cooperation on the planning, construction and operation of cross-border transport corridors has the potential to reduce energy consumption by a) avoiding tkms by shorter routes for multinational bus, truck or train transport or b) avoiding idling in border queues. On the other hand shorter trade routes or reduced travel times can induce transport volumes, resulting in increased energy consumption.

By means of intelligent logistics systems (ILS), logistic operators can AVOID tkms or IMPROVE energy efficiency per tkm. It is difficult to find a proper definition on ILS or a clear differentiation to Intelligent Transport Systems (ITS). Most definitions refer to ILS as an increased use of information technology in logistics planning and operation. ILS-measures that avoid tkms can involve e-freight initiatives and the concept of bundling freight flows on common platforms for information and business exchange.

[34] Especially as far as the transport of perishable goods or food is concerned.

**BOX 9**
**AVOIDING TRANSPORT BY USING INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IN FREIGHT TRANSPORT IN CHINA**

The Chinese company Henan Anyang Modern Logistics Information Development has helped trucking companies in Anyang city (Henan Province) to reduce the empty mile percentage from 53% in 2006 to 38% in 2008. They in 2006 established an online logistics information platform that provides freight information exchange services. It has since expanded to the entire province with more than 50,000 deals made per month and with average savings per month of 43.9 million kilometers, equivalent to 8.8 million liters of fuel.

Source: UNCTAD 2012.X.

Specialized logistical infrastructure[35] can be one way to bundle freight-flows and thus reduce tkms. ERTRAC (2011) recommends more research, innovation and policy development to adequately resolve remaining difficulties. Focus should be laid on business models, service platforms & databases, ICT & protocols and modularized goods carriers & vehicles. The Inter-American Development Bank (2013) highlights the importance of embedding the planning of specialized logistics infrastructure in urban and regional land use planning.

## 2. “Integrating the concepts of land use and accessibility, and using strategic planning tools for urban and regional development” (Objective 2)

In order to reduce necessary travel distances at urban or regional level, urban and regional planning is critical. Especially for growing cities it is of major relevance as it defines the distances and infrastructure of future urban and regional transport. Once constructed, settlement structure and infrastructure are expensive to change. Policy makers of emerging economies are therefore recommended to recognize the long-term effect of planning during policy design for transport.

With regard to infrastructure planning the science community recommends a shift away from the traditional “predict and provide” principles as “they do not solve transport problems”. Instead they conclude that “specific interventions in terms of land use regulation and (...) are much more effective in the long run economic, social and environmental terms” (GIZ 2011). In fact, Litman (2013) concludes that more transport infrastructure for inefficient modes like passenger cars induces more transport on these modes rather than making it more efficient.

Obviously, the further people have to travel for shopping, jobs, etc. the higher is the energy consumption. Increasing the population density in growing urban areas should from an energy efficiency perspective be a central concern in urban and regional transport planning – accompanied by the appropriate transport infrastructure development.

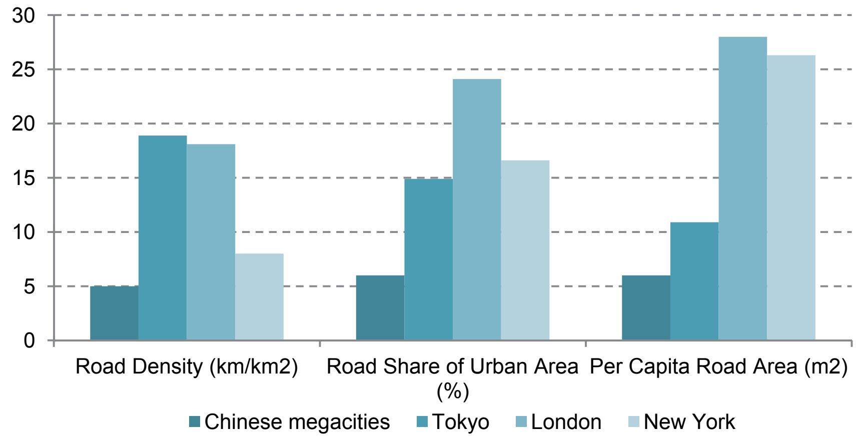
With growing distances demand for motorized transport modes like cars is increased. Walking and cycling as the most energy efficient modes become less attractive for users. According to World Bank (2012) demand for cars “in Germany decreases significantly with good access to shopping centers, cinemas, and theatres. In the United States, car ownership decreases with the distance to the nearest bus stop. In Hamilton, Canada, the number of cars per household decreases as the number of bus stops within 500 meters of residences increases.” Distances can be further reduced by mixed land use, i.e. mixing working and living areas (GIZ, 2012).

A second important measure to avoid transport is to limit the expansion of road area in cities or to reduce it. Petersen (2004) shows that in the developed economies a significant share of valuable city

[35] Specialized logistic infrastructure are defined areas, where one or more operators perform activities related to logistics, transportation, handling and distribution of goods, basic functions and activities techniques for value-added merchandise trade nationally and internationally. This can be ground transportation or distribution logistics areas, air cargo centers, logistics zones, ports, dry ports and multimodal logistics areas IDB (2013). "CO-L1090: Program to Support the National Logistics Policy.”

space is dedicated to roads, which are used by energy-intense transport modes, i.e. by motorized vehicles. Road share of urban area in London is four times higher than in an average Chinese megacity.

**FIGURE 13**
**INTERNATIONAL ROAD SPACE COMPARISON**

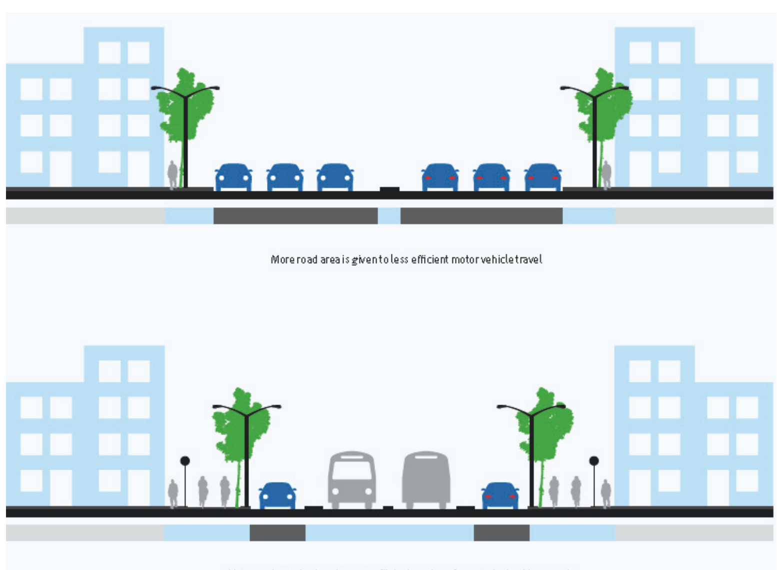



Source: Author, adopted from Petersen (2004).

As a result necessary travel distances between homes, offices and commercial places are increased. This is important especially for growing cities as it is very costly to change inefficient space utilization once an urban settlement has been constructed. While energy consumption is less for transport in trains, buses, trams, on bicycles or on foot in comparison to transport in vehicles, these modes are also more space-efficient. It is therefore in-efficient to dedicate most space to car infrastructure, i.e. roads.

Aside the infrastructure space efficiency the vehicle space efficiency varies greatly for different transport modes, too. The next figure illustrates this fact and its consequences for urban life quality.

**IMAGE 1**
**ROAD AREA ALLOCATION FOR ENERGY-INTENSIVE AND ENERGY EFFICIENT TRANSPORT**




Source: ITDP, 2013.

**IMAGE 2**
**THE AMOUNT OF SPACE REQUIRED TO TRANSPORT THE SAME NUMBER OF PASSENGERS: CAR, BICYCLE, AND BUS**

Source: Wright and Fjellstrom, 2003.

The immense variety of potential measures and tools for improved land use cannot be covered here. Examples of land use planning measures are given in Petersen (2004) and the Transit-Oriented Development (TOD)-Standard of the Institute for Transportation & Development Policy (ITDP 2013). Policy measures to improve planning in this respect include capacity building for urban planning and creation of organizational structures that regulate and enforce settlement plans.

Dense regional planning is also an effective energy efficiency measure for freight transport -. Minimizing transport distances is not only reducing energy consumption and costs for freight transport. It reduces the risk of traffic jams and by that enables increased just-in-time delivery, too. This in turn saves costs for storage of inputs and outputs.

## 3. "Increase the virtual interaction between people using information and telecommunication technologies" (Objective 3)

The widespread use of video conferencing, electronic mail and telephone are further measures to avoid both transport and costs. The movement of IT-companies towards remote areas illustrates that certain businesses already prefer excellent communication infrastructure over good transport infrastructure.

With the availability of high-quality communication infrastructure, information and knowledge can replace "capital and energy as the primary wealth-creating assets". "Within this new economy, the long held association between car use and wealth is being challenged. It appears that the amount of travel needed to support each pound of economic activity is now able to fall as a result of ICT" (Halden 2006).

Continuing the trends of working from home office can further contribute to a less intense growth in passenger transport demand (see box). Halden (2006) suggests a very positive future potential of teleworking of up to 11% reduction in travel demand (see box). Kahn Ribeiro et al. (2007) conclude for the U.S. context that it is difficult to find empirical results of the effectiveness of teleworking. They cite a 2005 *macro-scale study in the USA that suggests a reduction in annual vehicle-km by zero to 2%* (Choo, Mokhtarian et al. 2005).

**BOX 10**
**E-WORKING IN SCOTLAND AND USA**

In 2006, 13.5% of working adults in Scotland spent at least some of their working hours at home. E-working, based on current patterns of economic activity and capabilities of current technology, could “achieve reductions of up to 11% in travel demand in the Scottish context.” However, high take up of e-working in Scotland “is associated with: low population densities, the need for security by working from dispersed locations, fiscal incentives, and the prevalence of managerial, professional and administrative jobs.”

Source: Halden 2006.

**Effectiveness of AVOID-measures**

It is difficult to find examples of AVOID measures with quantitative data on the achieved reductions in energy consumptions. The following table illustrates some of them in different economic contexts.

**TABLE 15**
**EXAMPLES FOR EFFICIENCY IMPROVEMENTS OF AVOID-MEASURES IN DIFFERENT CONTEXTS FOR BOTH FREIGHT AND PASSENGER TRANSPORT**

| Measure | Context of the measure/Country | Resulting improvement in energy efficiency | Source |
|---|---|---|---|
| Information services for freight companies | Online logistics information platform that provides freight information exchange services for trucking companies in Henan province, China | Reduction of empty running from 53% in 2006 to 38% in 2008. Average savings per month of 43.9 million kilometers or 8.8 million liters of fuel. | UNCTAD, 2012 |
| Transport collaboration | Collaboration of two competing companies in central UK | 280,000 truck-kms per annum | McKinnon, 2012 |
| Teleworking | Teleworking in USA | 1998: reduction of at most 1% of total household vehicle-km<br>2005: reduction of vehicle-km by 0–2%. | Kahn Ribeiro, Kobayashi et al., 2007 |

Source: Author based on sources mentioned.
[a] Please note that the examples are based on the best available information. In the cases in which at the time of production of this report the final evaluation results were available, the results presented are achieved results in cases where implementation is on-going the ex-ante estimated results are presented.

Increasing energy efficiency by avoiding transport is not only effective but for most measures also very cost-efficient compared to SHIFT or IMPROVE measures. Strategic urban and regional planning can lay the basis for energy efficient transport as it will define the mobility patterns, distances and infrastructure for many decades or centuries to come. This is of immense importance, especially for growing economies with expanding cities not only for improved sustainability in transport, but for sustainable development in general.

## C. SHIFT the transport of goods and persons to the most efficient transport mode

Travel-efficiency, i.e. the energy consumption per km travelled, can be improved by shifting transport from energy-intensive modes, like airplanes or cars, to energy efficient modes like (public) mass transit (trains or buses) or non-motorized transport. The SHIFT strategy forms the second pillar of the ASI-approach. There are five objectives in the Bogota Declaration which belong to the shift strategy; the first two are discussed together in the following subsection.

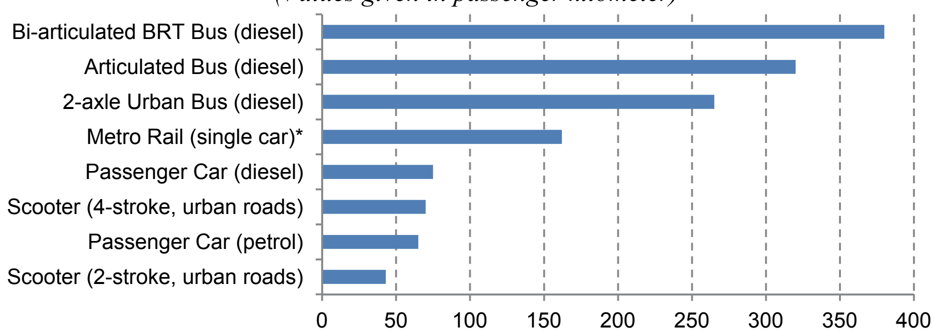
## 1. "Promote increased use of maritime, river, and railway modes (…), through strategic investments (…), as well as the promotion of intermodal logistics management" (Objective 4) and "Promote the use of more sustainable modes of interurban passenger transport, (…) offering alternatives to private cars and air transport" (Objective 6).

Switching transport from energy-intensive to energy-efficient transport modes like railway or river transport has a high potential for reduction of energy consumption. This method can be applied to freight or passengers (up to 91 and 69 % respectively, according to IPCC (2013)). In the following effective measures for passenger transport and later freight transport are presented.

A variety of examples for shift measures, ranging from demand management, financial instruments, regulation, supply of alternative to supply of information, exist for urban transport, as illustrated in table 15.

The graphic illustrates energy consumption for various modes in urban passenger transport for a theoretical occupancy rate of 100%.

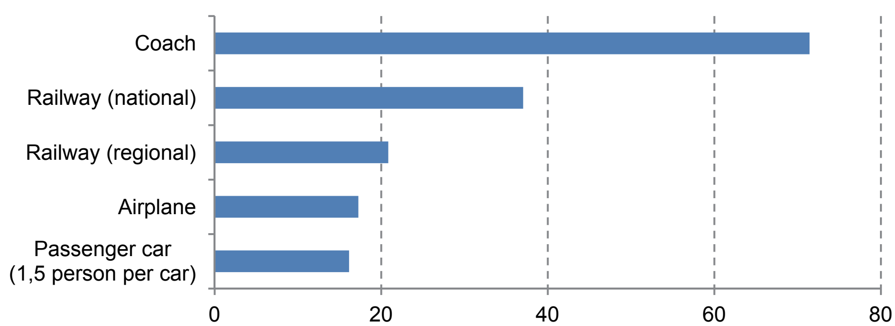
**FIGURE 14**
**HOW FAR CAN I TRAVEL ON 1 LITRE OF FUEL IN URBAN TRANSPORT?**
*(Values given in passenger kilometer)*




Source: Author, adapted from DENA 2009.

Please note that 'fuel efficiency' on bicycle or on foot can be even higher depending on speed, weight and weather conditions. For regional, national and international travel above portfolio is augmented by additional modes: airplanes, railway and coaches.

**FIGURE 15**
**ENERGY EFFICIENCY OF DIFFERENT MODES IN REGIONAL TO INTERNATIONAL TRANSPORT - A GERMAN EXAMPLE[a]**




Source: Author, adopted from DENA 2009.
[a] Values in figure limited to tank-to-wheel data. Calculation basis: passenger-kilometers calculated with average occupancy rate in Germany, i.e. 1.5 persons per passenger car. 1 liter gasoline fuel is calculated to be equivalent to ca. 9 kWh.

Above the values only show energy intensity of the rolling vehicle stock, i.e. energy-consumption from tank—to—wheel. Additionally, energy consumption of constructing vehicles and corresponding infrastructure, maintenance and vehicle dismantling should also be taken into account. Energy consumption for construction of infrastructure can be a dominating factor in a comparison between energy efficiency of Metro or high-speed train networks to bus rapid transfer roads. However, it can be difficult to find correct and context-specific data on complete life-cycle energy consumption.

As mentioned before, a variety of examples for shift measures in urban transport has been identified by GIZ (2013):

**TABLE 16**
**SHIFT MEASURES FOR URBAN TRANSPORT**

| Classification | Measure |
|---|---|
| Demand Management | Corporate travel policy |
| | Changing facilities and bicycle stands at workplace |
| | Job tickets |
| | Car-free travel packages for tourists |
| | Car sharing |
| | Rideshare matching |
| Financial instruments | Parking pricing |
| | Congestion charge |
| | Pay at the pump surcharges |
| | Subsidized public transport fares |
| Regulation | Environmental zone |
| | Plate restrictions |
| | Vehicle quota |
| | Traffic cells and diverters |
| | Speed restrictions |
| | Car free days |
| | Parking supply restrictions |
| | Maximum parking requirements |
| | Road space reallocation |
| | Bus priority |
| | Bus lanes |
| Supply of alternatives / Regulation | Expansion of the public transport network |
| | Park and ride facilities |
| | Bus rapid transit |
| | Comfortable stations and vehicles for public transport |
| | Integration of public transport infrastructure (connect) |
| | Bicycle lanes, road signage and maps; green wave |
| | Bicycle parking; bike & ride facilities |
| | Shared bicycle services |
| | National cycling plan |
| Information | Improved rider information |

Source: Author, adapted from GIZ, 2013.

Examples for interregional or interurban energy efficient modal shifts in passenger transport are Bus Rapid Transfer (BRT)-Systems (from passenger car or van to bus; e.g. in Latin-American or Asian Mega-Cities) or high-speed train networks (from passenger car and airplanes to trains; e.g. in Europe or Japan.[36].

[36] Costs are an issue here: Investments for Germany's high-speed train ICE are approx. US$48 million per km; Korea's is around US$40 million per km, China's high-speed train cost approx. US$24 million per km of line (Kuei-ju, 2013).

Special attention should be laid on smoothly connecting complementary mass transit systems—augmenting consumer value and acceptance by reducing total travel time for passengers or goods and hence increasing demand for such services. Examples could be mass transit stations, e.g. for trains, which effectively connect to other mass transit modes, like e.g. BRT-systems, or efficient feeder modes like bikes or car sharing. One example of poor inter-modal connection practise was the lack of feeder transport to the Bangkok Skytrain, which added to the disappointing initial ridership (World Bank 2012).

Because of its intermodal character[37] car sharing can be regarded as energy efficient transport, even when the energy efficiency of a shared car is essentially the same as of a private car. Car sharing is a prerequisite for strategies to reduce private vehicle ownership, while still providing residents with a personal motorized transport option for occasional use. Users are expected to use energy efficient transport modes more often than owners of private cars (see box). Energy consumption for car production in this case is less, too.

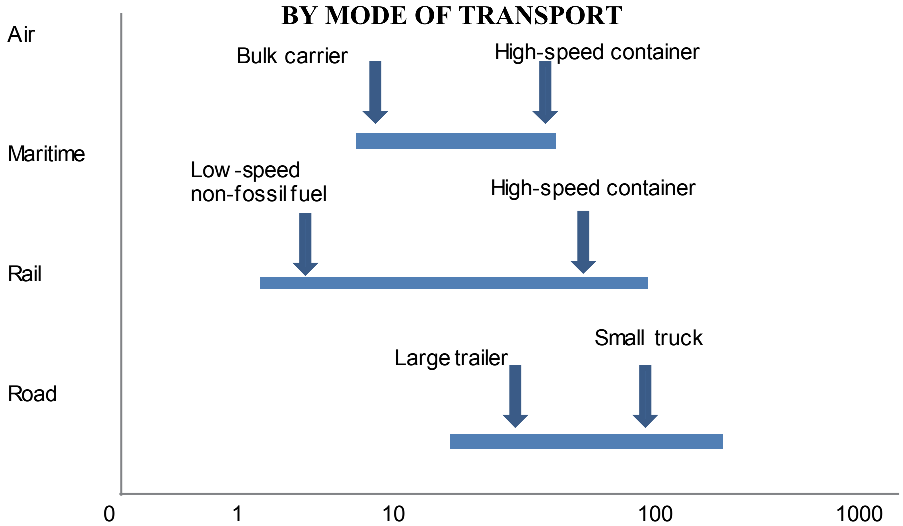
**BOX 11**
**CAR SHARING IN PRACTICE**

The city community “Stellwerk” in Germany has 60 private cars per 1,000 residents (i.e. 6% car ownership) and a car sharing membership rate of 67% of households. One car sharing vehicle is provided per 44 residents, compared to a national car ownership rate of about one vehicle per two inhabitants in Germany. When car sharing is bundled with transit passes as offered in Freiburg/Germany and Zurich/Switzerland reduced car ownership and with it energy efficient transport is further encouraged.

Source: ITDP 2013.
Note: Compared to less than 0.6 per cent on national level.

Similar to passenger transport energy intensity between freight transport modes differs significantly. Airplanes are the most energy-intense mode, followed by vans, trucks, inland shipping, coastal and sea shipping. Rail and pipeline form the most energy efficient freight transport modes. The intergovernmental panel on climate change (IPCC) visualizes the immense differences in carbon-intensity between these modes, which in current fuel mixes roughly translate to energy intensity.

**DIAGRAM 10**
**COMPARISON OF CARBON-INTENSITY PER TON-KM IN FREIGHT TRANSPORT BY MODE OF TRANSPORT**




Source: IPCC in UNCTAD, 2012.

According to the European energy efficiency model “EcoTransIT” energy consumption for freight transport in e.g. Germany is 3 to 4 times on truck higher than on train (EcoTransIT Consortium 2013). However, in order to be able to switch freight from road, appropriate infrastructure for railway

[37] Car sharing might also be considered to be classified as an AVOID measure, if the use of car sharing reduces individual car use and car purchase.

or shipping and a connecting infrastructure are needed. Connections enable competitive transport from the first to the last mile. Efficient interconnection of rail, bus and waterways is key to energy efficient logistics—and in many cases cost-efficient, too.

Energy efficiency in freight transport can be important factor for competitiveness – especially in economies with unsubsidized fuel prices. However, due to high initial investments (sunk costs) and unfavorable risk profiles, suppliers will hesitate to invest in rail infrastructure or interconnecting logistic systems. This is the case especially if the infrastructure can also be used by competitors. Infrastructure provision hence demands long-term strategic investment decisions by governments. Private stakeholders will be willing to co-invest under the provision of long-term stable and attractive policy frameworks, e.g. in public private partnerships.

**BOX 12**
**MODAL SHIFTS FOR IMPROVED ENERGY EFFICIENCY IN FREIGHT TRANSPORT IN INDONESIA**

The Government of Indonesia has introduced comprehensive policies that aim at promoting sustainable freight transport systems and reducing the transport burden on roads. Policies include

a) A shift towards greener modes of transport such as rail and short sea shipping (where ferries can carry out roll-on/roll-off operations)

b) Development of rail-based logistics in Jakarta to relieve congestion caused by freight movements

Source: (UNCTAD, 2012).

The increased demand for just-in-time delivery (JIT) in industry is potentially increasing energy intensity as trips have to be made more often and with reduced cargo per trip. To increase energy efficiency or GHG-efficiency McKinnon (2012) advices logistic companies to either relax JIT-delivery regimes in coordination with the customer or switch transport to smaller vehicles or low carbon modes (e.g. from truck to vans or from vans to freight bikes). For successful JIT-delivery these vehicles can even be slower than before the SHIFT.

## 2. "Promote and preserve the use and safety of pedestrian and bicycle transportation, as an integral part of efficient sustainable transport systems" (Objective 5)

According to World Bank (2012) the "use of non-motorized modes may decline with economic growth, but even in developed countries, they can still represent a significant share of travel if they are well integrated with other transport modes". Measures, which promote non-motorized transport (NMT) or active transport, i.e. walking and cycling, are among the most cost-efficient measures for energy efficient urban transport. This is in contrast to their oftentimes limited representation in discussion of policy frameworks or public budgets for urban transport.

However, walking and cycling are not only very energy efficient transport modes but also very dangerous ones (World Bank, 2012). In order to increase energy efficiency of transport by means of transport, the safety of pedestrians and cyclists needs to be prioritized in policy making around the globe. New York City, USA is probably the most famous site, where infrastructure for cars is recently converted to pedestrian areas and bicycle lanes (see box).

**BOX 13**
**TRANSFORMING ROADS TO SPACE FOR NON-MOTORIZED TRANSPORT IN NEW YORK CITY**

Since 2009 roughly 2.3 miles of Broadway have been modernized in favour of non-motorized transport in order to provide much needed pedestrian infrastructure and actually reduce gridlock and improve area-wide travel times. NYC's department of transport removed vehicle traffic lanes, limited turns and closed the entire street to vehicles in places. Pedestrian plazas with street furniture were created at several places. Bike lanes were added, in many places separated from vehicular traffic.

Box 13 (conclusion)

Outcomes included:

- Point to point travel time improved in all direction but one: up to 17%.
- Motorist and passenger injuries decreased by 63%
- Pedestrian injuries decreased by 35%.
- Pedestrian volumes increased by 11% in Times Square and 6% in Herald Square, and the pedestrians in those locations lingered longer.
- Bicycle volumes increased by 16% on weekdays and 33% on weekends.
- Median speed for trips on all modes taken on 18th Street within the project area (6th Avenue to Irving Place) improved by 14%.
- 74% of area survey respondents liked the new traffic configuration and 20% of business owners/managers thought that it had improved business, while none stated that it adversely affected their business

Source: Adapted from Ullman, 2013.

In markets like Europe, North America or China cycling undergoes a renaissance as sportive life styles and electric bicycles (E-bikes) are becoming more popular. The yearly market for e-bikes in China for examples has grown to 21 million bikes per year in the past decade (World Bank, 2012) with more than 180 million e-bikes being used at the end of 2012 (Bloomberg 2013).

**BOX 14**
**CYCLING ON THE GLOBAL AGENDA FOR ENERGY EFFICIENT TRANSPORT**

"Half of all trips in cities are short and within cycling distance. The protection (and revitalization) of cycling in Asia and the promotion of cycling elsewhere have to become an ingredient in comprehensive mobility plans to mitigate GHG emission in developing country parties of the IPCC. Cycling bears substantial significance for avoiding emissions, poverty alleviation and development. The earlier cycling expertise is brought into transport and urban planning processes, the larger the long term benefits from a cycling inclusive transport system will be. The post 2012 framework should lever government investments in planning for such systems. We can build upon the transition in transport strategy by, among others, the multilateral development banks. Local, national or international strategies and plans should be translated into Nationally Appropriate Mitigation Actions (NAMAs) to become a stimulus for most of the developing country parties to take up planning for cycling. The Global Cycling Coalition aims at contributing to SLoCaT's work program on this".

Source: SLoCat, 2013.

Strengthening the role of non-motorized transport (NMT) is also contributing to improved air quality, road safety and social development. Because NMT allows for equal access to jobs, doctors, etc., it is especially important to improving the life of poor people. In growing economies and growing cities with intensifying transport demand it is therefore worthwhile to discuss the social aspects of walking and cycling. One example where this discussion was missed is illustrated in the following figure. It shows the demonstration in India following a ban of Rickshaws in Old Delhi in 2006.

**IMAGE 3**
**RAISING AWARENESS FOR EQUAL ACCESS TO TRANSPORT INFRASTRUCTURE**


Source: ITDP, 2013.

## 3. "Promote measures to discourage increased share of private motor vehicles (…), through Transport Demand Management" and "Promote behavioral changes (…) through information and education of the population" (Objectives 8 and 9)

Opposite to previous shift objectives these two objectives focus on measures that affect the demand-side rather than the supply-side of the transport market.

There are various definitions for Transport Demand Management or Mobility Management (MM). According to the European Platform on Mobility Management (EPOMM) this "is a concept to promote sustainable transport and manage the demand for car use by changing travelers' attitudes and behavior. At the core of Mobility Management are 'soft' measures like information and communication, organizing services and coordinating activities of different partners. Soft measures most often enhance the effectiveness of 'hard' measures within urban transport (e.g., new tram lines, new roads and new bike lanes). Mobility Management measures (in comparison to 'hard' measures) do not necessarily require large financial investments and may have a high benefit-cost ratio". (EPOMM 2013).

**BOX 15**
**MOBILITY MANAGEMENT IN PRACTICE**

One positive example from Munich, Germany, is the cost-free information program on transport and mobility for every person or family that moves to the city. It includes an information package (per e-mail), a motivating phone call, a detailed conversation, sometimes test tickets and personal sales efforts for public transport services.

Source: Landeshauptstadt München, 2013.

Target groups for urban MM include municipality officials, public or private employers and employees. Measures include travel planning, information campaigns and events, promotion of carpooling and car sharing systems, education and training, site-based measures, utilization of telecommunications and flexible time organization as well as supportive, integrating actions, e.g. changes in company fleets or company travel guidelines towards bikes and trains.

## 4. Effectiveness of SHIFT measures

The following table illustrates examples of SHIFT measures and their effectiveness in different economic contexts.

**TABLE 17**
**EXAMPLES FOR EFFICIENCY IMPROVEMENTS OF SHIFT-MEASURES IN DIFFERENT CONTEXTS**

| Measure | Context of the measure/Country | Resulting improvement in energy efficiency | Source |
|---|---|---|---|
| Shift of passenger transport to Bus Rapid Transfer | BRT Bogotá, Colombia: TransMilenio Phase II to IV | 53% (equivalent to 80,128 tonnes $CO_2$-equivalent per year) | IPCC, 2013 |
| Shift passenger transport from small and medium buses to cable cars | Cable Cars Metro in Medellin, Colombia | 69% (equivalent to 17,172 tonnes $CO_2$ equivalent per annum) | IPCC, 2013 |
| Shift of freight transport to train | Modal shift from road to train for transport of cars in India | 91% (equivalent to 23,001 tonnes $CO_2$ equivalent per year) | IPCC, 2013 |
| Introduction of city tax | Introduction of a city tax in Stockholm, Sweden in 2006 (incl. parallel reduction in public transport fares; residents of the city centre voted in favor of the tax). | 2.7% reduction in $CO_2$-emissions (about 42,500 tons/year) [b] | Eliasson, 2009 |
| Employer travel reduction strategies (Transport Demand Management) | Introduction of a law in state of Washington, USA requiring travel plans in its most urban areas for employers with 100 or more staff. | Percentage of employees who drove to work in the targeted organizations reduced from 72 to 68% (affecting about 12% of all trips made in the area). | Rye, 2002 |

Table 17 (conclusion)

| Measure | Context of the measure/Country | Resulting improvement in energy efficiency | Source |
|---|---|---|---|
| Travel-feedback programmes (Transport Demand Management) | Introduction of travel-feedback programmes in residential areas, workplaces and schools in Japan[c] | Car use was reduced by 12% and $CO_2$ emissions by 19%. | Fujii and Taniguchi, 2005, in Kahn Ribeiro, Kobayashi et al., 2007 |

Source: Author´s elaboration.

[a] Please note that the examples are based on the best available information. In the cases in which at the time of production of this report the final evaluation results were available, the results presented are achieved results in cases where implementation is on-going the ex ante estimated results are presented.

[b] “The system is shown to yield a significant social surplus, well enough to cover both investment and operational costs, provided that it is kept for a reasonable lifetime: investment costs are recovered (in terms of social benefit) in about four years.”Eliasson, J. (2009). "A cost–benefit analysis of the Stockholm congestion charging system." Transportation Research Part A: Policy and Practice 43(4): 468-480.

[c] Travel-feedback programmes with a behavioural plan requiring a participant to make a plan for a change showed better results than programmes without a plan.

## D. IMPROVE technology and management of transport services

The third pillar of the ASI-approach is the improvement of vehicle efficiency, i.e. energy efficient operation of existing vehicle technology, development and marketing of new vehicles, market introduction of clean fuels, regular vehicle inspections, information, and communication services. For example, GIZ (2012) recommends several IMPROVE measures for urban passenger transport, some of which are included in the Bogota declaration and are discussed in the following sub-sections.

**TABLE 18**
**IMPROVE MEASURES IN URBAN TRANSPORT**

| Measurements | |
|---|---|
| Eco Driving for employees of public or private organizations/businesses | Electric car technology |
| Green procurement policies for purchase of energy efficient cars of public and private fleets | Procurement of low carbon vehicles |
| Eco Driving lessons in driving schools | Active traffic management |
| Vehicle Fuel Economy Standard | National motoring package |
| Cap Systems for manufacturers | Speed reduction on trunk roads |
| Energy efficiency labeling for vehicles | Widespread implementation of travel plans |
| Energy-saving vehicle components and accessories, light-weight construction | Freight best practice |
| R&D in energy efficient technologies and vehicle design | Financial instruments |
| Eco Driving for employees of public or private organizations/businesses | |

Source: Author, adopted from GIZ, 2012.

Three objectives of the Bogota declaration call for IMPROVE measures in passenger and freight transport.

### 1. "Promote the increased use of cleaner vehicles and fuels, and greater energy efficiency and emission control measures in all transport modes" (Objective 10)

In order to improve GHG and energy efficiency of vehicles there are three main strategies, as depicted in the table below. Further improvement of conventional vehicles, admixture of alternative fuels and market introduction of alternative fuel vehicles (AFV). These measures apply to all passenger and freight vehicles including ships, public transport vehicles, trucks, passenger cars, 2-wheelers and airplanes.

**TABLE 19**
**MEASURES TO IMPROVE ENERGY EFFICIENCY AND GHG-EMISSIONS IN MOTORIZED VEHICLES**

| Reduction of fuel consumption: | Mixture of low carbon fuels: | Alternative fuel vehicles (AFVs): |
|---|---|---|
| Electrification of power trains | Ethanol (E5/E10) | Compressed or liquefied natural gas or biomethane (CNG or LNG) |
| Light weight construction | Biodiesel (B7) | Eethanol (E85 to E100) |
| Optimization of auxiliaries | Hydrated vegetable oils (HVOs) | Liquefied petroleum gas (LPG) |
| Aerodynamics | Biomass-to-liquid (BTL) | Electricity and hydrogen from low-carbon sources |
| Result: | | |
| Climate and energy efficient vehicles | | |

Source: Author, adapted from Peters and Weller, 2012.

However, many of above measures to improve vehicle efficiency have to be motivated by demand-side or supply-side policy instruments. With regard to passenger cars ambitious fuel economy standards and fuel taxes[38] have in some countries motivated car manufacturers to develop, produce and market vehicles with increased fuel economy.

Even in countries with similar vehicle offer the consumers will make very different purchase decisions with respect to the fuel economy of their new car. I.e. consumers purchase in different car segments and engine configurations. As a result of these differences in consumer behavior, fuel efficiency in France in 2011 was 14% higher than in Germany. This is partly because of the much stricter $CO_2$-related bonus-penalty-vehicle taxation in France. Typically, national fleet fuel efficiency will be higher in countries with high fuel costs or high taxation of $CO_2$-intensive vehicles. Some appropriate policy measures are presented in the following.

**Fuel economy standards** are one effective supply-side policy instrument. However, without policy measures, which increase demand for energy efficient vehicles these standards, can be very costly not only for producers but also economies. Accompanying demand-side measures can include fuel pricing, GHG-based vehicle taxation, green public purchase, improved consumer information, e.g. by means of regulated vehicle labeling or tire labeling.

**Fleet renewal schemes**, also called car scrapping schemes, some of which were introduced in Europe and USA during 2009 financial crisis, can be regarded as less cost-efficient policy instruments. Evaluation of these schemes has shown that they performed very poor in terms of fuel economy improvements with respect to their immense costs. With net societal costs ranging from 300 to 2,235 million € in the case of the countries below such schemes can therefore not be recommended for copy. However, it would be worthwhile to investigate, how much improvement would have been possible at these costs, if the focus would have been on energy efficiency rather than on preservation of jobs in the automotive industry during crisis.

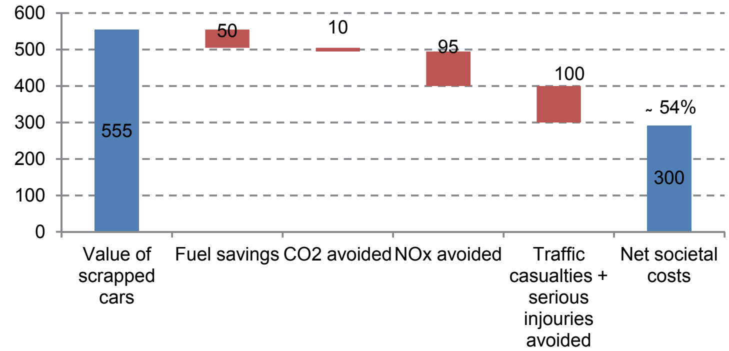
For trucks and buses as well as other modes numerous fuel economy measures can be applied, which typically yield a 1–5% fuel saving (McKinnon 2007). These measures include:

- providing drivers with training in fuel-efficient driving;
- offering incentives for fuel-efficient driving;
- purchasing more fuel-efficient vehicles;
- reducing the vehicle power rating to match load weight and topography;
- reducing vehicle tare (empty) weight;
- improving the vehicle's aerodynamic profiling;
- raising standards of vehicle maintenance (see next sub-section);
- imposing tighter speed limits;
- ensuring correct tire pressures (McKinnon 2007).

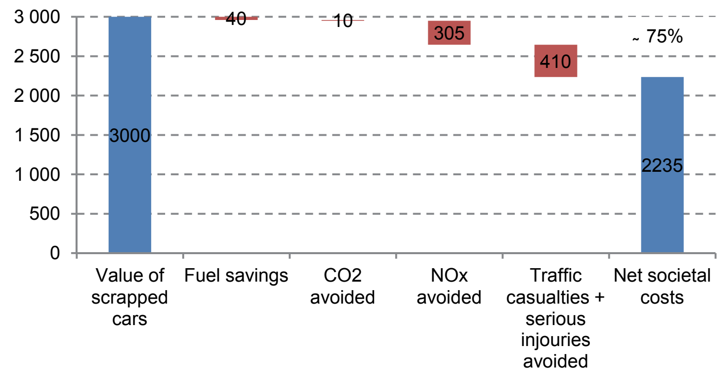
[38] This was supported by improved consumer information, environmental awareness and rising oil prices.

**FIGURE 16**
**COST-EFFECTIVENESS OF THE FRENCH, GERMAN AND UNITED STATES FLEET RENEWAL SCHEMES**
*(Car scrapping initiatives)*

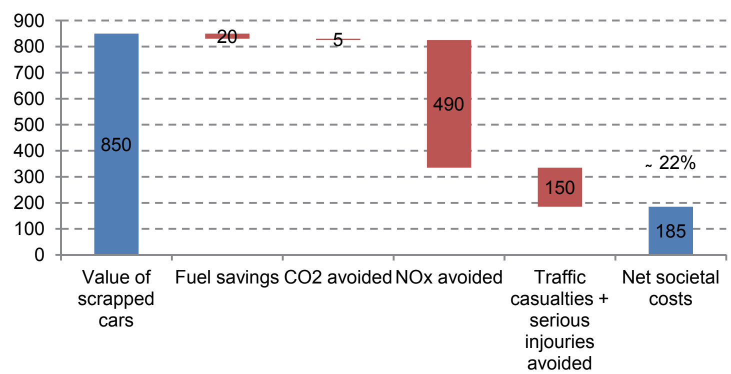
A. France "Prime a la Casse"




B. Germany "Umweltprämie"




C. United States "CARS" program




Source: Author, adapted from Fraga, 2013.

Hybrid-power trains in buses are capable to reduce fuel consumption by up to 30% depending on the travel profile but cost about 25 to 30% more to purchase[39]. Depending on the mission profile of the truck or bus the degree of recommended electrification can vary from hybrid vehicles to full electric vehicles, i.e. trolley bus or battery-electric bus or truck.

[39] Feng and Figliozzi (2012) quote purchase prices of US$958,000 for a 60ft hybrid diesel bus and US$737,000 for a 60ft diesel bus in USA, which equals a price premium of about 30 per cent. Fuel efficiency gain for the hybrid bus in this case was about 11 per cent.

The UK Government Freight Best Practice Programme collects and communicates best-practice examples for energy efficient or GHG-efficient trucking (DfT 2013). According to McKinnon (2007) this programme is a very cost-effective measure with public costs of about 8 Pounds per tonne $CO_2$ reduced.

For rail, the following measures are recommended: Reduction of train weight can be achieved by aluminum car bodies, lightweight bogies and lighter propulsion equipment. Regenerative braking can generate electric energy, which via the electricity network can power other trains, thus reducing energy consumption. However, the further away other trains are, the less effective is this measure. In the future, this measure can be improved by on-board energy storage devices, which buffer the energy until needed. Higher efficiency in propulsion systems might be achieved in the future by means of superconducting on-board transformers and permanent magnet synchronous traction motors.

With regard to shipping UNCTAD (2012) states that technology and fuel improvements "could achieve some energy efficiency and reduce GHG emission intensity rates ($CO_2$/ton-mile) by 25-75% below the current levels". Measures may include slow steaming, improved design, engine efficiency improvements and fuel switch. Central for improved energy efficiency in aviation are lightweight materials, improved engines, aerodynamics and construction.

For all modes but airplanes vehicle efficiency can further be improved by eco-driving, i.e. training of drivers on how to operate the vehicle in a more energy efficient manner. Investigations from driver trainings in Germany and UK showed long-term fuel economy improvements of approx. 10% (IE Europe 2009).

So called clean vehicles or alternative fuel vehicles (hydrogen fuel cell or battery-electric vehicles) repeatedly attained high media attendance in the past but failed and fail to conquer relevant market share. As a result they did not contribute to energy efficiency improvements in transport. Instead, main efficiency achievements in vehicle fleets resulted and continue to result from reducing fuel consumption of conventional vehicles. This trend is likely to continue unless there are major changes towards higher oil prices or more ambitious policy frameworks to support market introduction of clean vehicles.

**BOX 16**
**THE POTENTIAL OF ALTERNATIVE FUELS FOR INCREASING GHG-EFFICIENCY AND ENERGY EFFICIENCY**

Alternative fuels (AF) including biofuels are a vivid part of the public discussion on energy efficient transport. They are applied as admixture to conventional fuels or in dedicated alternative fuel vehicles (AFVs). However, while most AFs reduce GHG-emissions only few reduce energy consumption. Energy efficiency is only increased if the energy conversion process in the AFV is more efficient than for the comparable fossil fuel vehicles. Examples include hydrogen fuel-cell vehicles or electric vehicles.

However, it might be sensible to promote AFVs in order to reduce dependency on oil-based fuels or reduce GHG-emissions. While energy consumption e.g. of CNG-engines is higher than of diesel engines, compressed natural gas (CNG) in comparison to diesel is quite GHG-efficient and can be further optimized by blending in GHG-neutral biomethane. Similar to their effects in light-duty vehicles (LDVs) alternative fuels can improve GHG-balances for heavy-duty vehicles (HDV) and buses, but again this will with the exemption of fuel-cell and battery-electric vehicles not have any positive influence on energy efficiency.

Political decision makers should strive towards leveraging alternative fuels to their maximum by increasing the energy efficiency of transport prior to the use of AFs in transport. In other words: The impact of corn-based ethanol in U.S. road transport could be multiplied if it would be combined with strict AVOID, SHIFT or IMPROVE measures. At the end it is a question of resources (e.g. biomass) and price: As long as it is cheaper to reduce energy efficiency than blending in alternative fuels efficiency measures should be prioritised. To correctly determine the price of alternative fuels one should keep in mind the demand from other sectors as heating or electricity production.

Source: Author's elaboration.

Political coordination of market introduction of AFVs can be one policy measure that would improve market take-up.

## 2. "Work to establish or improve technical vehicle inspection regimes, and to progressively implement safety standards, and standards to reduce atmospheric emissions." (Objective 12)

Regular vehicle inspections, while central for vehicle safety, can also improve energy efficiency, e.g. by regularly checking and servicing tires, engine and oil. The effectiveness of vehicle inspections can further be increased by including customer advisory services on eco-driving, purchase of energy efficient tires, vehicle maintenance (incl. low-viscosity engine oil and regular tire pressure checks) or even vehicle purchase. The latter is a chance for car manufacturers: In order to oblige with fuel economy standards while keeping costs low they can incentivize their dealers to sell energy efficient cars or car models rather than energy-intensive ones.

## 3. "Promote the adoption of Intelligent Transport Systems such as electronic tolls, transport control centers and user information in real time..." (Objective 13)

In this last section on vehicle efficiency the potential of energy efficiency improvements by means of intelligent transport systems (ITS) is presented. ITS make use of information and communication technology (ICT) to:

- optimize utilization of existing infrastructure for cars, trucks, airplanes or public transport
- operate vehicles more energy efficient or
- increase consumer value in public transport by introducing electronic real-time information services in public transport.[40]

**TABLE 20**
**EXAMPLES FOR ICT-BASED ENERGY EFFICIENCY MEASURES IN TRANSPORT**

| | Passenger | Freight |
|---|---|---|
| Rail | Telematic applications that increase attractiveness of trains, e.g. providing passengers with information before and during the journey, reservation and payment systems, luggage management and management of connections between trains and with other modes of transport | Telematic applications including information systems (real-time monitoring of freight and trains), marshalling and allocation systems, reservation, payment and invoicing systems, management of connections with other modes of transport and production of electronic accompanying documents. |
| Road | Priority for public transport, e.g. at traffic lights | |
| | Electronic fee collection, multi-modal travel information, traffic information incl. feed-in to navigation systems, and set and enforce speed limits. Fuel efficiency falls significantly as car, van or trucks speeds are pushed above optimal levels. Reducing car speed from 100 km/h to 80km/h can save 21% on CO 2 emissions (IE Europe, 2009 cited in Porter, Fitzpatrick et al., 2009). | |
| Inland Navigation | Harmonized information services; river information systems | |
| Maritime | Vessel traffic management including information exchange, e.g. European Vessel Traffic Monitoring and Information System (VTMIS) | |
| | Improved terminal layouts at harbors, which reduce distances and as a result energy consumption | |
| Air | Air traffic control, e.g. Single European Sky ATM Research (SESAR) | |
| Multimodal | Multimodal Journey Planners | |

Source: Author with data from EC, 2013.

However, according to Lenz (2011) the scientific community was not able to quantify with current methodologies positive effects of ICT on mobility. If at all positive, then these effects on mobility would be marginal.

An exemption from that reasoning would be the findings of Jelinek et al. (2002) with regard to ICT-improved air traffic management (see box).

[40] This is a SHIFT measure.

**BOX 17**
**ENERGY EFFICIENCY IMPROVEMENT IN AIR TRAFFIC MANAGEMENT**

On 24 January 2002 the European Air Traffic Management RVSM (for Reduced Vertical Separation Minimum) was implemented in the EUR RVSM Airspace, i.e. most of Western and Central Europe. It provided six additional flight levels between 29,000 feet (FL290) and 41,000 ft (FL410) inclusive and hence improved capacity and routing. A Eurocontrol study (Jelinek et al., 2002), which compared fuel consumption before and shortly after the implementation showed that total fuel burn was reduced by between 1.6–2.3% per year for airlines operating in the European RVSM. Malwitz et al. (2009) estimated that the introduction of that system in the U.S. reduced fuel burn per distance travelled by 2 to 3%.

Source: Kahn Ribeiro, Kobayashi et al. 2007.

However, total energy consumption from aviation since introduction of RVSM has increased—one reason probably being the capacity increase, which RVSM provided over the old system.

## 4. Effectiveness of IMPROVE measures

The following table illustrates examples of IMPROVE measures and their effectiveness in different economic contexts.

**TABLE 21**
**EXAMPLES FOR EFFICIENCY IMPROVEMENTS OF IMPROVE-MEASURES**

| Measure | Context of the measure/Country | Resulting improvement in energy efficiency[a] | Source |
|---|---|---|---|
| Fuel economy standard | Introduction of a new car fuel economy standard for light duty vehicles (passenger cars) in 1995 in Japan | 19% until 2004 | World Bank, 2012 |
| Introduction of clean vehicles | Replacement of fossil fuel powered scooters by electric scooters in various cities and regions of India (recent CDM-Project) | Reduction in GHG-emissions will be about 69% or 24,563 tonnes $CO_2$ equivalent per year. | IPCC, 2013 |
| Eco-driving including speed reduction | Promotion of safe and fuel efficient driving to HGV drivers in Scotland (SAFED initiative) | 10% | Fraser and Anson, 2010 |
| | Reduction in maximum speed for trucks from 65 mph to 60 mph in USA | up to 8% | Ang-Olson and Schroeer, 2002 in McKinnon, 2007 |
| | Ecodriving training for drivers of passenger cars in Germany and UK | 20.7 and 22.5%[b]. Long-term improvements after training of approx. 10%. | IE Europe, 2009 |
| | Container ships lowering their speed from 26 to 18 knots (“slow-steaming”) | 30% | Dekker, Bloemhof et al., 2012 |
| Capacity increase in aviation | Introduction of Reduced Vertical Separation Minimum (RVSM) in Europe and USA | 1.5 to 3.0% per flight-kilometer | Jelinek, Carlier et al., 2002, Malwitz, Balasubramanian et al., 2009 |

Source: Author´s elaboration.

[a] Please note that the examples are based on the best available information. In the cases in which at the time of production of this report the final evaluation results were available, the results presented are achieved results in cases where implementation is on-going the ex ante estimated results are presented.
[b] For the drivers whose training took place on public roads, the average reduction was 16.8%. Slightly faster speeds were achieved.

It is important to note that for achieving substantial improvements in energy efficiency in transport the technological possibilities of IMPROVE measures will not be enough. World Bank (2012) states that “economic measures, such as pricing, regulation, and the availability of multimodal transport systems, are also essential”.

## E. Cost benefit Analysis for ASI-strategies

Often less prioritized in public discussion on energy efficient transport but of significant importance is the costs of efficiency measures. There is little information on cost/benefit-ratios available for transport. Furthermore it is difficult to cite general cost/benefit-ratios for ASI-measures as they will be heavily influenced by the economic, geographic and political context. However, in general it can be said that improve measures, like market introduction of clean cars, which enjoy high popularity in governments and media often come at a higher cost for public budgets than shift or avoid measures. Some economic instruments like energy pricing can even pay for themselves from the moment of implementation.

Clearly, costs of AVOID measures like e.g. dense urban planning or mixed land use vary immensely in relation to their date of implementation. Their costs are low when the cities are still growing and there is room for planning. Once the city and infrastructure is built, it is much more expensive to increase population density, decrease road area or mix office and living quarters.

As indicated above measures that promote non-motorized transport can be very cost-effective, especially if indirect benefits are included. World Bank (2012) calculated benefit/cost-ratios of selected NMT measures of 1.5 to 4 and amortization periods of less than one year (see table below).

**TABLE 22**
**COST—BENEFIT ANALYSIS FOR SELECTED MEASURES ON NON-MOTORIZED TRANSPORT**

| Test interventions | Total benefits | Benefit components | Total cost | Cost components | B/C ratio |
|---|---|---|---|---|---|
| Walk way improvement along corridor in Morogoro | US$14 400 per year | Saving travel time | US$18 000<br>US$4 200/year | Repair culverts<br>Walkway construct<br>Build bridges | 3.4 |
| Raised zebra-crossing in Dar es Salaam and Morogoro | US$4 350 per year | Avoiding costs of accidents | US$4 500 per zebra-crossing<br>US$1 000/year | Raised zebra-crossing | 1.45 |
| NMT bridge in Dar es Salaam | US$6 000 per year | Saving travel time | US$11 000 per bridge<br>US$1 500/year | Bridge<br>Cost reduction because of community participation | 4 |

Source: Author, based on World Bank, 2012.

Johnson et al. (2010) show that energy efficiency measures in transport can in some contexts yield higher direct benefits than costs, e.g. from energy-savings. In the investigated Mexican context this would be the case for optimizing bus systems and rail freight, introducing regular vehicle inspections, urban density programs, BRT-systems and promoting non-motorized transport. Direct benefits for these measures ranged from US$40 to 90 per tonne $CO_2$, which are very high values. Improve and shift measures would in this case be more cost-effective than avoid measures.

Depending on the context it is sensible to pay attention to political costs, too. They can weigh more than the financial costs, e.g. for unpopular avoid measures like increase in parking fees or reduction of public parking space, introduction of road toll or abolishment of fuel price subsidies. Political costs can be reduced by designing policy instruments in a way that voters understand that their benefits exceed their costs. Examples include the positive poll for the introduction of a city toll for Stockholm city centre or the positive polls in New York City after reallocation of road space to pedestrian areas and bike lanes.

While implementation of some ASI-measures appears very expensive in a short term there are substantial benefits associated to it in the mid and long term in comparison to the current situation– not taking into account the additional benefits from mitigated climate change or increased safety or equal access to jobs and education. IEA (2012) concluded for such a long term perspective that future investments to build and maintain inefficient transport modes and infrastructure would be significantly higher than investments for energy efficient transport. In an ambitious scenario to limit climate change to additional 2 degrees Celsius (2DS) US$50 trillion could actually be saved in transport until 2050 compared to a less ambitious 4 degrees scenario (4DS) (see box and figure below).

**BOX 18**
**GLOBAL ENERGY EFFICIENCY POTENTIAL FROM INVESTMENTS IN ENERGY EFFICIENCY MEASURES IN TRANSPORT**

"Despite increases in expenditures on rail, High-Speed-Rail (HSR) and Bus-Rapid-Transfer (BRT) infrastructure in the Two-Degrees Scenario (2DS), cumulative global land transport infrastructure spending decreases by nearly USD 20 trillion over the four degrees scenario (4DS) estimates. The bulk of those savings come from reduced roadway investment and maintenance costs, which account for nearly USD 15 trillion of total projected savings. Parking reductions also save roughly USD 10 trillion over 4DS spending levels, while rail expenditures (including HSR) increase by nearly USD 3.5 trillion. BRT network additions under the 2DS add another USD 350 billion over 4DS spending levels (only one˜tenth of the increased rail costs).

In fact, ETP 2012 estimates show that global vehicles, fuels and infrastructure expenditures to 2050 are nearly USD 515 trillion in the 4DS. Transport expenditure estimates in the 2DS, including more expensive trains and buses, amount to roughly USD 465 trillion – representing net savings of USD 50 trillion, or USD 30 trillion in savings in vehicle and fuel expenditures and USD 20 trillion in infrastructure savings as identified in this analysis."

Source: Citation IEA, 2012 in SLoCat, 2013.

## F. Summary and recommendations

Demand for transport is rising and with it so is energy consumption. Current energy-efficiency measures are outpaced by increased transport demand. The Bogota declaration for sustainable transport in 2011 also was a major step towards energy-efficient transport. Likewise many governments defined ambitious political goals for energy efficiency in transport. Serious implementation now needs to follow. The consequent implementation of ASI-measures can decouple economic development and energy consumption in transport by improving system efficiency, travel efficiency and vehicle efficiency.

Reductions in energy consumption also result in reduced GHG-emissions. However, measures to reduce GHG emissions do not always reduce energy consumption, but sometimes even increase it (e.g. fuel switch to alternative fuels). Policy makers have to decide, whether they aim for a) energy efficient transport, b) mitigation of greenhouse gas emissions from transport or c) transport with low consumption of crude oil- based fuels. The impact of limited alternative fuels on climate change mitigation should be leveraged by adopting energy-efficiency measures first and only then applying the alternative fuels to a more energy-efficient transport system.

Policy makers are advised to plan and implement measures for energy-efficiency with a long-term planning horizon. In this case most presented measures can generate direct financial benefits – besides environmental, health and social improvements. Depending on economic contexts the cost-benefit ratios of ASI-measures vary. Political costs for implementation of unpopular measures can be reduced by creating attractive benefits in exchange and by educating voters on their and future generations' benefits and co-benefits and including stakeholders in the policy design process.

As this report focuses on the technical instruments, it is recommended to in a next step consolidate the existing knowledge on policy instruments, both temporary and permanent, for implementation of ASI-measures. The wide range of available regulatory, financial, informing and coordinating policy instruments should be presented for both demand and supply side of the market. Among the financial instruments, focus should be laid on pricing instruments, like e.g. carbon pricing, as it can provide the necessary basis for financing energy efficiency measures (World Bank 2012).

Often energy-efficiency measures are not implemented because of a lack of finance rather than a lack of technical knowledge or political will. It therefore is crucial to consolidate international knowledge on existing financing instruments for necessary investments in energy efficient transport, too. The reports from International Transport Forum 2013 (OECD) and World Bank (2012) provide a good basis for future investigations. The consolidation of best-practice examples would be recommended.

# IV. Understanding market-mechanisms for development of markets for energy efficient mobility

## A. Introduction

For successful market introduction of energy efficiency measures policy makers need to be aware of the underlying mechanisms and characteristics of the transport market. This chapter presents fundamental academic knowledge from public economics with relevance to policy design in the transport market.

Subject to limited financial resources at either the government or the consumers' level, public policy makers need to be aware of the gap between what is technologically possible and what is economically feasible, i.e. attractive and cost-efficient to consumers. For successful market introduction of energy efficient services or technologies in transport the understanding of a) the needs and economic situation of the targeted consumer groups (demand) and b) the competition from already established transport services (supply) is key.

There is an imbalance in both public discussion and research on energy efficiency technologies in transport between a) the evaluation of their theoretical efficiency potential and b) the evaluation of their marketability and competitiveness to established transport, the latter being much less pronounced than the first of the two. As a consequence, market introduction of many efficiency technologies fails or can only be competitive on the market with continuous subsidies. This section therefore presents proven academic concepts from the fields of public economics and innovation strategy that allow for a better understanding of market characteristics and competition in transport. It shall increase chances for successful implementation of efficiency measures or policies in transport. The main underlying questions are:

What are the forces for market development in transport? Which factors influence demand and supply for energy efficient transport services? Under which conditions should policy makers intervene in the transport market?

In the following section, firstly key concepts of innovation theory will be applied to the transport market (sections 3.2), using the example from market introduction of clean vehicle (section 3.3), followed by a discussion of the factors that influence supply (section 3.4) and demand (section 3.5) and their elasticity in transport (section 3.6). The section finishes with the introduction of the concept of market failure and ways on how to apply it to the transport sector (3.7). Examples from market introduction of clean vehicle, incl. alternative fuel vehicles (AFVs) or electric hybrid vehicles, are used to demonstrate the applicability of the presented concepts to real-world challenges in transport markets.

## B. Key concepts for market introduction of new products or services

Innovation is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 1995). Examples for innovations in energy efficiency in transport could be mass transit systems for urban transport, intelligent logistic systems, clean vehicles or mobile navigation systems that make biking or walking more attractive.

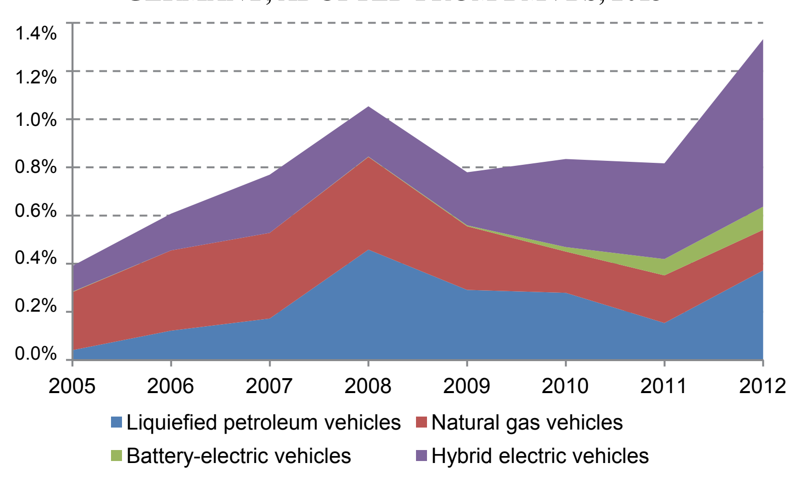
The overall spread of an innovation or the process by which an innovation is communicated through certain channels over time among the members of a social system, is called Diffusion (Rogers 1995). It is the direct or indirect outcome of a planned, systematic effort designed to make a program or innovation more widely available. The rate, at which a new product, service or technology wins market share from competing products, is the market penetration rate. In order to halt the continuous growth in energy consumption in transport the market penetration rate of energy efficient transport services needs to be increased significantly.

**BOX 19**
**UNSUCCESSFUL MARKET INTRODUCTION OF CLEAN VEHICLES**

At the example of the German vehicle market it can be shown that some innovations in transport have immense difficulties to gain relevant market share. Clean vehicles are still not able to reach relevant market share - despite substantial financial incentives from the government, existing reliable technologies and environmental consumer awareness. As seen in the following figure, market share of clean vehicles was only 1.3 per cent (40,000 vehicles) in 2012, i.e. far from reaching the mass of consumers. Their contribution to improved energy efficiency or GHG efficiency in transport remains marginal.

Source: Author´s elaboration.

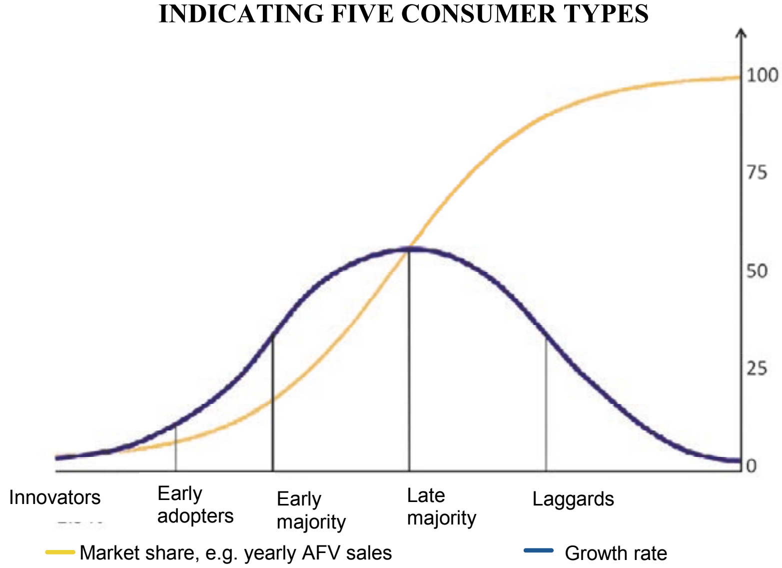
**FIGURE 17**
**DEVELOPMENT OF CLEAN VEHICLE REGISTRATIONS IN NEW VEHICLE FLEET IN GERMANY, ADOPTED FROM BMVBS, 2013**




Source: Adopted from BMVBS, 2013.

The diffusion of a new technology, plotted in an x-y-diagram of units sold (or market share) over time has similarities with an S-curve shape. Distinctive groups of consumers purchase the new technology subsequently, i.e. innovators, early adopters, majority and laggards (Rogers, 1995).[41]

**FIGURE 18**
**DIFFUSION OF INNOVATION OVER PRODUCT LIFE CYCLE, INDICATING FIVE CONSUMER TYPES**




Source: Koen, 2011.

Depending on the specific consumer group, willingness-to-pay for energy efficient transport varies. Willingness-to-pay is highest for the group of “innovators” and decreases gradually towards the group of “laggards”.[42] Mock at al. (2009) and Mock and Schmidt (2009) see the maximum willingness to pay more for GHG-efficient vehicles at 20% for the “innovators”. Market introduction of initially more “expensive” products or services should hence first target the innovators (R&D and demonstration phase), later the early adopters (early and niche markets) and finally the majority of consumers (mass market). It is crucial to identify the “innovators” for the targeted transport market or market segment to be able to design effective policy instruments. The next box gives a good example of effectively identifying and targeting “innovators” in the vehicle market.

**BOX 20**
**PUBLIC VEHICLE PROCUREMENT AS A DRIVER FOR INNOVATION IN ITALY**

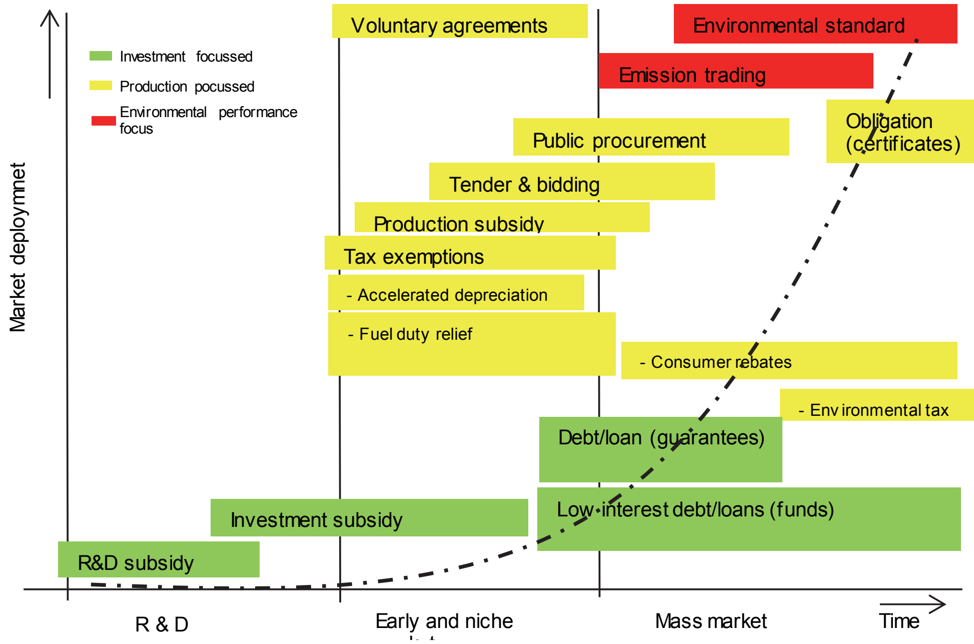
Within the clean vehicle market the Italian government identified the public fleets to be the “innovators”. Purchase behavior of public fleets is easily adjustable by means of regulation. In order to increase market penetration rate in these fleets public fleet owners are obliged to preferably purchase clean vehicles rather than the cheapest vehicle option. Some Italian municipalities even go further and regulate their purchase department to only purchase goods or services from organizations that use clean vehicles. These measures also affect the private or commercial vehicle market as public fleets sell these vehicles after some years, allowing the technology to penetrate these market segments at a much lower price Premium.

Source: Peters, 2011.

Timing, type and duration of policy instruments should be carefully planned along the S-curve and in accordance to the preferences and needs of these target groups. Preventing free-rider effects this strategy is not only more cost-efficient than an all-at-once approach but additionally allows for staged “investments”. This way, policy makers can check for progress in market introduction before commencing with further investments. See next diagram for an example of fade in and fade out of different policy instruments along the S-curve for market introduction of clean technologies in transport.

41 Rogers (1995) suggests different sizes of these groups as seen in the figure.
42 Consumers’ evaluation of willingness to pay is also including convenience costs for e.g. higher health risks or travel time.

**DIAGRAM 11**
**POLICY INSTRUMENTS ALONG THE S-CURVE**




Source: Brunzeck, van Bree et al., 2010.

Uncertainty and interdependence are inherent in the process of technological change in transport and need to be considered during policy design. These characteristics, coupled with positive feedback cycles, can contribute to the emergence of ‘‘technological lock-in’’, which prevents a market from adopting a new technology like e.g. AFVs. Sources of positive feedback for the “lock-in” include economies of scale, economies of scope, effect of learning or technological interrelatedness (Yarime 2009). An example for such a lock-in can be found in the vehicle market (see following box).

**BOX 21**
**TECHNOLOGICAL LOCK-IN IN THE LIGHT-DUTY VEHICLE AND VEHICLE FUEL MARKETS**

There are more than 14.000 filling stations in Germany established for conventional vehicles, consumer information is high, service station staff is trained and conventional vehicles are very affordable (from 7,000 Euro per new car). Conventional fuel pumps cost less than half compared to natural gas stations and less than 1/10 compared to hydrogen filling stations. Furthermore fuel pumps for alternative fuels compete for space at filling stations with fuel pumps for diesel or gasoline and even with car wash facilities. Market entry for new competing fuels and the complementary vehicles can hence be described as technologically “locked-in”.

Source: Author´s elaboration.

However, governments can overcome such “technological lock-in” by means of specifically designed policy instruments that properly address the needs of consumers and/or suppliers. The following example is illustrating the differences that political market intervention can make on technology development.[43]

[43] It has to be noted that differences in market development also are a result of other factors like technological maturity, vehicle and fuel availability and fuel prices.

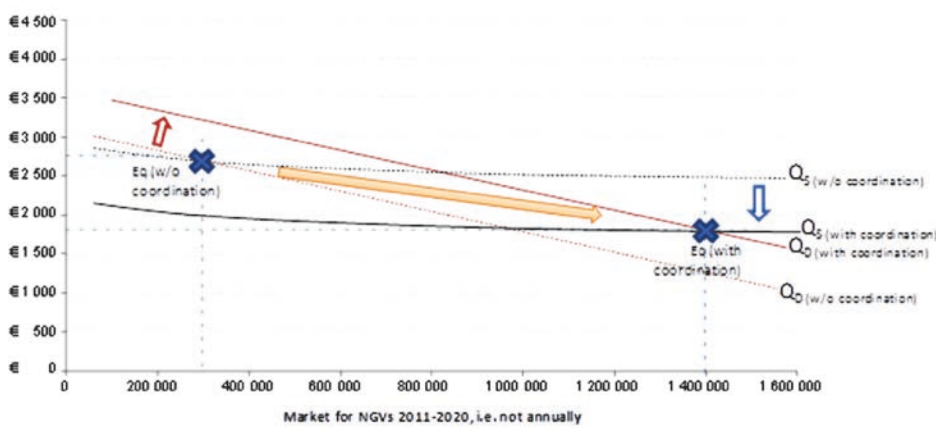
## C. Comparison of market development of clean technologies in selected economies at the examples of natural gas vehicles (NGVs)

Success of market introduction of NGV technology around the globe varies literally from top to flop. The figure below shows the shares of NGVs in total vehicle populations in different countries. Countries such as Argentina, Sweden or Italy are demonstrating that rapid market penetration of that technology is possible. Opposite to that, diffusion of NGVs in Japanese and German economies is slow. The share of NGVs in vehicle population in Sweden in 2010 was three times higher than in Germany, i.e. 0.6 vs. 0.2%, despite rather similar consumer tastes and vehicle offer. In Argentina in 2010 a share in population of already 16% had been achieved, i.e. 80 times higher than in Germany. The technology in has reached mass market in Argentina, partly due to retro-fit option.

The case of NGV development in Argentina shows how an organic growth can be achieved without much public funding but intensive coordination and high prices on conventional fuels. By means of government coordination a shared vision or plan among stakeholders should be created and a coordinated expansion of infrastructure and vehicles pursued in accordance to it. This is supported by Yarime (2009, p.2) who advocates an active role of government for "keeping the expectations and incentives of the relevant actors transparent and by encouraging honest and candid dialogues among the participants".

It can be shown how willingness to supply Qs increases as a result of coordination, i.e. car manufacturers are willing to offer NGVs at a lower price premium over gasoline vehicles. This becomes possible as uncertainties and risks for consumers and suppliers are reduced and improved supply-side incentives are negotiated.

**DIAGRAM 12**
**PRICE OVER QUANTITY DIAGRAM OF TRANSITION OF NGV-MARKET TO A HIGHER EQUILIBRIUM BY MEANS OF GOVERNMENT COORDINATION**

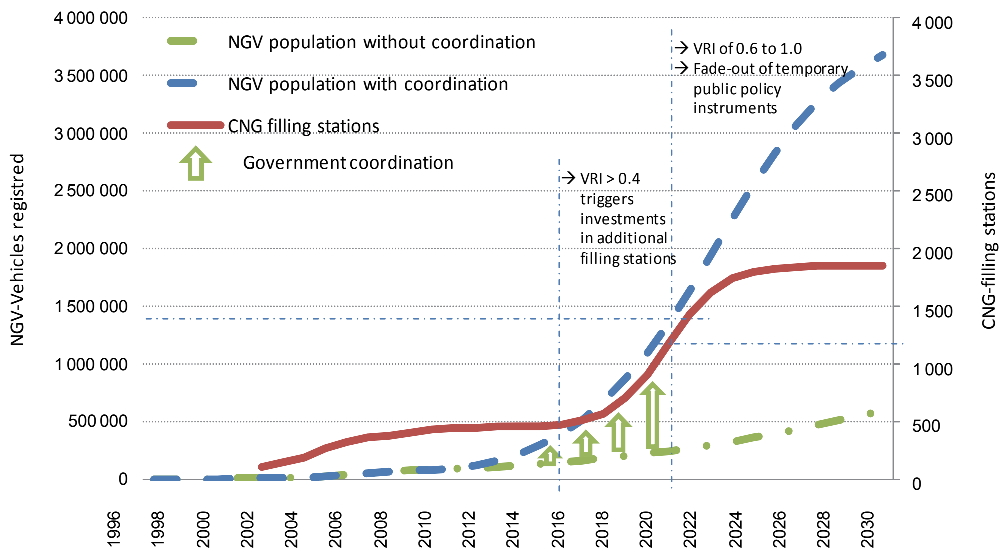



Source: Peters, 2011.
Note: Future vehicle numbers exemplarily based on DENA, 2010.

The following figure shows how this coordinated transition to higher numbers of NGVs and filling stations (blue and red lines) could take place over time in comparison to a scenario without coordination, i.e. business as usual (green line).[44]

[44] The figures in that graph have not been derived from a scenario process. They are instead estimations of Peters meant to visualize a possible process rather than providing a prognostic and are based on the following assumptions: Target population of 5 million NGVs in 2050, i.e. 10 per cent of total vehicle population; no changes in external factors, e.g. prices of crude oil, fuels and gas.

**FIGURE 19**
**PROJECTION OF TRANSITION OF NGV-MARKET TO HIGHER MARKET PENETRATION BY OVERCOMING COORDINATION FAILURE OVER TIME**




Source: Peters, 2011.

Note: VRI (Vehicle to refueling station index): VRI >0.4 or >0.6 translates to more than 400 or 600 vehicles per filling stations.

In this example, government would overcome the “chicken-egg-dilemma” between NGVs and Compressed Natural Gas (CNG) filling stations. Vehicle sales would increase faster than the number CNG of filling stations resulting in growing station utilization. However, during this time investments in infrastructure are still high as filling stations are built at attractive locations, i.e. at highly frequented roads or motor ways, while other stations are abandoned. From 2015, NGV-population would be high enough to speed up investments in new stations, i.e. market forces start functioning. Station profitability would increase up to 2020, the point in time when temporary public financial instruments would be obsolete and should fade out.

The case also demonstrates rather well that in order to make well-coordinated policy interventions, it is essential to plan and estimate well the consequences of the measure taken. These will depend on the respective context of a country and has to be aligned with other government priorities (e.g. decreasing dependence on one source of energy, stimulating local economy, budget consolidation, etc.).

In order to achieve successful market development consumers’ willingness to demand energy efficient transport has to be increased. Additionally, willingness of industry and businesses to supply such transport services can be raised as well. The next two sub-sections summarize the relevant factors that have to be considered in policy design for achieving these objectives.

## D. Factors that affect the consumers’ willingness to demand

No different from other sectors, factors that increase consumer demand in transport are consumers’ needs and preferences, income development, price of substitutes and complements and expected price development.

## 1. Needs and preferences

Consumers are willing to pay a certain price for every transport product or service, which meets their needs or preferences. The better the fit the higher is their willingness to pay. Needs and preferences change over time depending on changes in society, level of consumer information, communication or technological development. For example, with increased information on the positive health effects of walking and cycling demand for these transport modes in safe environments will increase.

## 2. Income development

Willingness to demand depends on the income and the income development of consumers, too. Demand for normal goods, e.g. new vehicles, will rise with increasing income – relatively to demand for inferior goods, e.g. old and polluting second-hand vehicles or gas-powered-vehicles.[45] The opposite happens at decreasing income. The recession in Argentina fuelled the number of vehicle conversions to natural gas as people were looking for ways to lower their fuel costs (NGV Global, 2011).

## 3. Price of substitutes and complements

Rival products that offer the same use or benefits for the consumer, e.g. going by express train or by plane, are substitutes. When people start shifting from e.g. high-speed train to airplane, prices for train tickets have to be lowered (at constant supply) in order to keep market share. Example: Natural gas in the transport sector is a substitute for other fossil fuels, especially diesel. Both fuels and their complementary vehicles are attractive to consumers with high yearly mileage, e.g. drivers of logistic companies or sales people. Subsequently NGVs are substitutes for diesel vehicles.[46]

An example of poor practice between substitutes in transport with respect to energy efficiency is given in the next box.

**BOX 22**
**POOR PRACTICE IN TAXATION OF SUBSTITUTES**

Whereas jet fuel is not subject to a fuel tax in Germany, rail companies have to pay tax on the used electricity or diesel (Reutter, 2011). This of course affects cost competiveness and hence consumer purchase decisions on competing routes. As a consequence, energy consumption and GHG emission on these routes are higher than what they would be in a scenario where jet fuel would be taxed as high as rail fuel.

Source: Author´s elaboration.

Products that are purchased jointly, e.g. airplanes and aviation fuels, are called complements (Begg and Ward, 2007). In a complementary market, a market is not created when the market for its complement is missing. For complements a growing demand for one product will at constant supply increase prices for its complement, too. Examples:

- A growing demand in airplanes will result in a growing demand for kerosene.
- Lower fuel prices will increase willingness to demand inefficient vehicles and decrease willingness to demand efficient vehicles. Simulations have shown that increased fuel prices could nonlinearly magnify the impact on vehicle fleet efficiency (Eppstein, Grover et al. 2011). The same would result from GHG-linked prices for parking, city access, road use (toll) as seen e.g. in Sweden.
- The provision of bike parking or safe bicycle lanes will increase demand for bikes.

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[45] In high-income countries biomethane-powered NGVS would because of their improved GHG-balance probably be considered normal goods rather than inferior goods.

[46] Electric vehicles (EV) are not considered a direct substitute for NGVs. Because of high battery costs for a similar vehicle price EVs offer a much shorter driving range or less vehicle space. Peters, D. (2011). Evidence for Market Failure at Introduction of Alternative Fuel Vehicles in Europe and Development of Mitigating Market Support Stategies.

## 4. Expected price development

If consumers expect falling prices for a product or its complement, they hold back consumption. To keep operations going, vendors can then be forced to reduce prices.

Examples: Expectations for a discontinuation of fuel tax reductions for clean fuels will reduce demand not only for the fuel itself but also for the complementary AFVs. Anticipation of rapid expansion of alternative fuel filling stations network, which equals anticipation of reduced convenience costs, will increase demand for AFVs.[47]

Demand-side factors for vehicle purchase decisions are illustrated in the following box.

**BOX 23**
**DEMAND-SIDE FACTORS FOR VEHICLE PURCHASE**

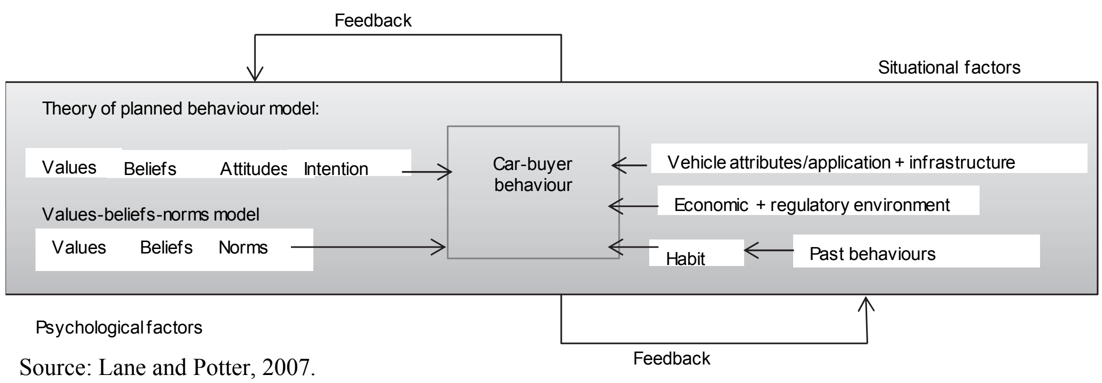
Vehicle purchase decisions involve a high cognitive effort. Vehicle size, safety and price are ranking at top priority of buying criteria to consumers. Environmental issues are also often considered important, however at almost no willingness to pay an additional charge (Mock, Hülsebusch et al. 2009). The figure illustrates that psychological factors, like values and beliefs, influence car-buyer behaviour as well as situational factors, e.g. vehicle characteristics and economic environment. Experience with past purchasing decisions also affects decision-making for future decisions (feedback loop).

According to research from Mock et al. (2009) a completely rational and price oriented vehicle consumer would first choose a size category and filter for general compulsory requirements, e.g. driving range. At a second step he would choose from within the resulting vehicles those with lowest total cost of ownership (TCO) for his individual driving characteristic, e.g. for his yearly driving range and time until buying new vehicle. TCO in this case would include all relevant costs, such as vehicle purchase price, annual ownership tax and costs for fuel. Only at a last step the consumer would look at $CO_2$-emissions and choose the vehicle variant with lowest CO2 emission well-to-wheel (WTW).

It is evident that the vehicle purchase decision often is made on a non-rational basis, e.g. when buying an excessively large vehicle due to prestige reasons.

Source: Mock, Hülsebusch et al. 2009.

**DIAGRAM 13**
**FACTORS INFLUENCING CAR-BUYER BEHAVIOUR**




Source: Lane and Potter, 2007.

# E. Factors that affect producers' willingness to supply

Every day investment decisions are made by among others vehicle manufacturers, infrastructure providers and transport businesses for or against development, production or marketing of energy efficient transport products or services. Their willingness to supply depends on costs of inputs, productivity and competition.

[47] Obviously this is only true when total cost of ownership of alternative fuel vehicles will be lower than for conventional vehicles.

### 1. Costs of inputs

The lower the total costs of inputs, i.e. the sum of variable and fixed cost (labor, raw materials, etc.), the higher is the producers' willingness to supply at a certain price.[48] Example: Willingness to supply battery-electric vehicles is among others heavily depending on the costs of electric batteries. As battery costs are declining slower than expected, willingness to supply battery-electric vehicles stays lower than for conventional vehicles.

### 2. Productivity

An increase in productivity enables an increase in supply at a given price. Productivity depends on know-how and technology involved and the speed of their change. As a consequence production costs for energy efficient transport products decrease with growing experience. Example: Car manufacturers are for a certain price willing to supply more inefficient conventional vehicles than efficient H2-fuel cell or battery-electric vehicles as they in the past 100 years have increased productivity for conventional vehicles.

### 3. Competition

Competition depends on the amount of competitors in the market, market structure and market growth. It results in decreasing prices as companies try to outbid each other (Porter, 1980). Especially prior to the introduction of subsidies for market introduction policy makers should be sure that the supported efficiency technology will in the future become competitive to existing technologies.

The following box summarizes examples for key factors for willingness to supply energy efficient or GHG-efficient vehicles.

**BOX 24**
**EXAMPLES FOR POLICY INSTRUMENTS THAT ADDRESS ABOVE FACTORS FOR SUPPLY**

Manufacturer subsidies for research and development or production of energy efficient transport services;

- Regulation on fuel economy: at non-compliance costs increase directly because of penalty fees and indirectly because of loss in image (e.g. marketing costs);
- Taxes like value added tax, vehicle registration tax, etc.; taxes on complementary products, e.g. fuel tax;
- Infrastructure subsidies or mandates for construction of fuel pumps for gas vehicles (CNG or LNG filling stations) or charging points for electric vehicles.

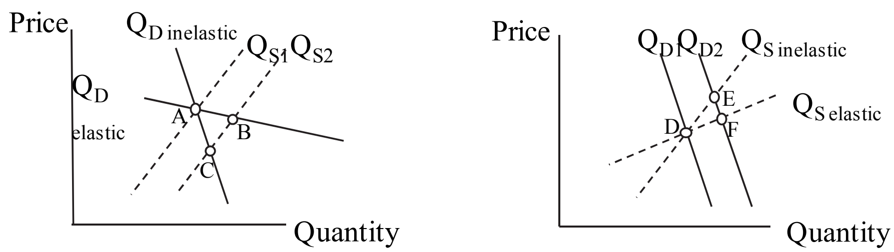
Source: Peters, 2011.

## F. Elasticity of demand and supply

The responsiveness of demand and supply to above factors is called elasticity (see Begg and Ward, 2007). At inelastic demand a change in supply will have a high impact on price and little impact on quantity demanded (point A to C). At elastic demand the impacts are just opposite (point A to B). A change in demand will result in greater change in price and less change in quantity supplied at inelastic supply (point D to E) than at elastic supply (point D to F).

[48] Scale effects, i.e. by means of increased output, will only reduce average total costs until the point where marginal costs to produce one more unit are higher than average cost.

**DIAGRAM 14**
**IMPACT OF CHANGE IN DEMAND $Q_D$ ON SUPPLY $Q_S$ OF VARIOUS ELASTICITY (LEFT SIDE); IMPACT OF SUPPLY CHANGE ON DEMAND OF VARIOUS ELASTICITY (RIGHT SIDE)**




Source: Peters, 2011.

The price elasticity for demand in transport is the ratio between relative change in transport (e.g. change in overall passenger-kilometers or average annual fuel consumption) and the relative change in a specific user price (e.g. fuel price, purchase price of a vehicle). For road fuel use, the long term fuel price elasticities are generally about -0.6 (Goodwin, Dargay et al. 2004). That means that if the real price of fuel rises by 10% and stays at that level, according to Goodwin et al. (2004) the result is a dynamic process of adjustment such that the volume of fuel consumed will fall by over 6% in the longer run. Certainly, price sensitivity of consumers differs with their available income but these figures indicate a high potential for increased energy efficiency in road transport by means of increased fuel taxes.

## G. Market failure

Market failure is a concept within economic theory wherein the allocation of goods and services by a free market is not efficient[49] (Ledyard 2008). The existence of market failure can be used as a justification for government intervention in markets (Arrow 1969, Gravelle and Rees 2004), e.g. in transport markets. Stiglitz (2000, p. 77) distinguishes the following market failures:

- Failure of competition
- Undersupply of public goods
- Externalities
- Incomplete markets, and within it coordination failure in complementary markets
- Information failures (imperfect information, underinvestment in R&D, principal-agent issues and bounded consumer rationality)

Portney (2003) suspects that difficulties of introducing fuel saving technologies in the U.S. vehicle market are caused by at least four types of market failure or market failures (see Box 20). As a means to increase energy efficiency or GHG-efficiency in transport markets policy makers should look for and mitigate these forms of market failure.

49 Not efficient (in the sense of Pareto efficiency) means that there exists another conceivable outcome where a market participant may be made better-off without making someone else worse-off (Ledyard, 2008).

**BOX 25**
**EXAMPLES FOR MARKET FAILURE IN THE VEHICLE MARKET**

According to Portney (2003) several market failures prevent the adoption of technologies for improved fuel economy or GHG efficiency, which even would pay for themselves: For example, consumers may undervalue future savings in gasoline purchases because they lack information during vehicle purchase, "have short horizons, or are uncertain about future fuel prices. In addition, the automobile industry might be viewed as oligopolistic, in which case profit-maximizing manufacturers could undersupply vehicle attributes (like fuel efficiency) even when potential buyers would value them. Others, however, view the new vehicle market as efficient, aside from the externalities."

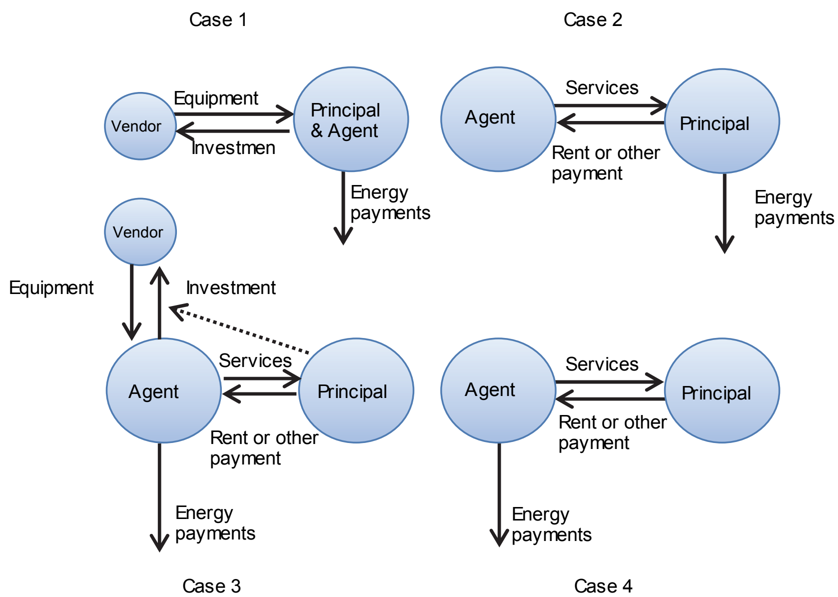
Source: Author´s elaboration.

The different types of market failure and their application to the transport sector are described in the following paragraphs.

## 1. Market failure Nº 1: Principal-agent issues

Principal-agent (P-A) problems typically arise in situations where two parties engaged in a contract have different objectives and possess different levels of information. The general arrangement is that a principal hires an agent for acting on his behalf but can only imperfectly monitor the effort of the agent. The market result is likely to be inefficient as the agent does not bear the full consequences of his actions. Four cases of this market failure can be distinguished (see next figure).

**DIAGRAM 15**
**THE FOUR CASES OF PRINCIPAL-AGENT ISSUES**




Source: IEA, 2007.

The empirical literature provides ample evidence that markets for energy efficient products are fraught with P-A problems. However, Vernon and Meyer (2012) as well as Graus and Worrell (2008) are the only empirical studies on energy-related P-A problems in the transport sector.

**BOX 26**
**EXAMPLES FOR P-A-PROBLEMS WITH REGARD TO ENERGY EFFICIENCY IN THE TRANSPORT MARKET**

Vernon and Meyer find that up to 91 per cent of total trucking fuel consumption in the US is plagued by P-A problems because shipping firms and/or drivers lack incentives to invest in fuel saving technologies or to avoid fuel-wasting practices. Graus and Worrell in turn show that unconstrained driving behaviour of company car drivers raises total fuel use in the Netherlands by more than seven per cent.

In the German NGV market P-A problems arise in at least two settings. Firstly, current laws on company car taxation lead to a distortion of price signals. Secondly, public purchasing departments often do not incorporate environmental considerations in their buying decisions. See Peters (2011) for more information.

Source: Peters, 2011.

The consequences of buying decisions effected by P-A problems extend beyond the time of the car ownership of the company or public fleet. 92% of company cars in Germany are sold to private consumers after a time period of six years, which is required for full depreciation. As company cars spend on average another four years in private ownership, a bullwhip effect arises, through which the results from the incentive structure within one market are transmitted through the whole market.

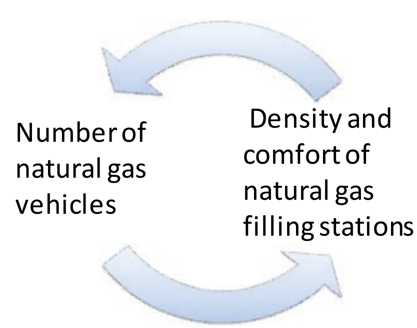
The German government has addressed the problem that this incentive structure distinctly counteracts efforts to promote energy efficiency by means of a legislation which envisages a preferential treatment in company car taxation for EVs.

## 2. Market failure Nº 2: Coordination failure in complementary markets

Coordination failure exists in market introduction of complements (Stiglitz, 2000, p.89), i.e. when strong complementarities among parts of a market exist and there exists a lack of coordination among these parts. Without sufficient penetration of both goods in such a market,[50] the purchase and use of one of the complementary goods becomes highly inconvenient for consumers. In other words “it produces high convenience costs” (Meyer and Winebrake, 2009) and will not be competitive against other products.

The vehicle market offers a good example for this failure: Consumers of AFVs evaluate the costs of getting fuel before buying a vehicle, including convenience costs. I.e. they evaluate the density of filling stations for that particular alternative fuel. The higher the density of filling stations and the lower the fuel price the higher is consumers’ demand for vehicles of these kinds. Achtnicht et al (2008) and Melaina and Bremson (2008) even showed that consumers are willing to initially pay extra for the development of the infrastructure. On the other side, infrastructure investors request a minimum amount of vehicle users that will refuel at their stations before investing. This creates a causal loop or feedback loop (see next diagram).

**DIAGRAM 16**
**NATURAL GAS VEHICLE-INFRASTRUCTURE CAUSAL LOOP DIAGRAM**




Source: Peters, 2011.

[50] Meyer and Winebrake (2009) speak of a complementary goods system.

The 2013 draft directive of the European Commission on the construction of infrastructure for alternative fuels is among others justified by that market failure. Member states shall be mandated to develop and implement a national policy framework that will result in a minimum coverage of fuel infrastructure for hydrogen fuel cell vehicles, NGVs and battery-electric vehicles.

## 3. Market failure Nº 3: Failure of competition

Failure of competition exists when there are one or few dominant firms in the market with few rivals, i.e. a monopoly or oligopoly (Begg and Ward 2007).[51] Dominant firms can prevent new entrants or substitutes from entering the market. A monopoly of a dominating technology in the market is described by literature as a “technological lock-in” as described before. Portney (2003) perceives the automotive industry as oligopolistic, i.e. not competitive. The recent market introduction of NGVs in Europe by the main car manufacturers (or OEMs for Original Equipment Manufacturers) can be seen as an argument against this hypothesis. See Peters (2011) for more information.

## 4. Market failure Nº 4: Imperfect information

Imperfect information is a market failure that arises when consumers misperceive the benefits of a good over other alternatives (Anderson, Parry et al. 2010).[52] *“A number of government activities are motivated by imperfect information”* and *“by the belief that the market, by itself, will supply too little information”* (Stiglitz, 2000, p. 83). In an ever growing product range of vehicle models and engines it is nearly impossible for consumers to find the most energy efficient and affordable vehicle-engine configuration for their mobility pattern, either because they are not aware of the existence of that configuration or they lack the necessary information to its energy consumption in comparison with others, e.g. in terms of fuel consumption. An example for imperfect information in public transport could be the lack of information on availability, comfort or punctuality of buses and trains, esp. for new inhabitants of a city.

## 5. Market failure Nº 5: Bounded rationality

Simon (1957) points out that people mostly are only partly rational. All remaining actions happen based on emotional/irrational decisions. Bounded rational agents, e.g. vehicle consumers, experience limits in formulating and solving complex problems and in processing information.[53] Consumers optimize their decisions but imperfectly (Howarth and Sanstad 1995).

For example, many consumers do not know how to calculate the total cost of ownership of vehicles (incl. energy consumption) and therefore decide only boundedly rational.[54] One could argue that many consumers decide partly rational in a purchase decision between a car and a yearly pass for public transport, too. To mitigate or even make use of this market failure, policy makers should invest in e.g. government-supported image campaigns for energy efficient transport modes.

## 6. Market failure Nº 6: Negative externalities and undersupply of public goods

*“Externalities are the effects of consumption, or production, on third parties”* (Begg and Ward 2007, p. 180). This type of market failure can lead to a difference between interests of private individuals

[51] In a monopoly or oligopoly situation, the market equilibrium will no longer be Pareto optimal. Pareto optimal or Pareto efficient refers to resource allocations that have the property that no one can be made better off without someone being made worse off (Stiglitz, 2000).

[52] Decisions in transactions, where one party has more or better information than the other, are based on an information asymmetry. Principal-agent issues (section 0) can be caused by information asymmetry.

[53] Processing here refers to receiving, storing, retrieving and transmitting. They employ the use of heuristics to make decisions rather than a strict rigid rule of optimization (Williamson, 1981). Consumers make rational decisions subject to constraints on their attention, resources and ability to process information, including transaction costs.

[54] This would be the case e.g. in a comparison between a cheap but inefficient and an energy efficient but also more expensive vehicle.

and society and an inefficient production or consumption of goods and services from the perspective of society. *"If production, or consumption, by one group reduces the wellbeing of third parties, then a negative externality has occurred"* (Begg and Ward 2007, p. 180).

Example: Road extension can reduce the wellbeing of households at the road because of induced traffic (e.g. because of emissions and noise) and other households because of its effects on climate change. A frequently cited but less frequently implemented policy option for mitigation of this type of market failure is internalisation of all external costs in purchase decisions. An example would be the EU public purchase directive for clean and energy efficient vehicles that proposes a guideline to include a) total cost of ownership incl. fuel costs and b) a monetarization of emissions of NOx, $CO_2$, SOx and particulate matter over expected vehicle life in the comparison of offered vehicle options.

Another example is the underinvestment in R&D: Given the fear of spill-over effects, i.e. of the inability of a seller to exclude non-buyers from using a product anyway, can cause underinvestment in R&D. This happens when a researcher or e.g. a car-OEM cannot capture enough of the benefits from success to make the research effort in e.g. energy efficiency technologies worthwhile (Jaffe 1996). Policy makers can mitigate that market failure with among others strict and duly enforced copy-right regulations.

## H. Summary and recommendations

Effective and cost-efficient improvement in energy efficiency in transport markets as in any other market is determined not only by the availability of innovative energy-efficient technologies. It is determined by the way on how policy makers and businesses create functioning markets, i.e. create sufficient supply and demand, for these technologies.

Main factors that affect producers' willingness to supply are costs of inputs, productivity and competition. Main factors that affect consumers' willingness to demand are their needs and preferences, income and income development, price of substitutes and complements and expected price development. For improving supply and/or demand for energy efficient products or services in transport, policy makers should first aim at understanding the specific market condition and only then design policy instruments, which target the most relevant factors for suppliers or consumers.

Many transport markets are subject to the existence of market failure, mainly negative externalities, principal-agent issues, imperfect information and bounded rationality. Market introduction of energy efficient technologies in affected markets will either fail or become inefficiently expensive to the economies. Lessons-learned from market failure in vehicle markets and the resulting slow market introduction of alternative fuel vehicles are in many cases transferable to other transport markets. The main market failure in markets for alternative fuel vehicles is the coordination failure in complementary markets.

Once policy makers are aware of the existence of market failures in their target market they can design specific public policy instruments that mitigate them and hence allow for a fast and cost-efficient replacement of energy-intensive technologies in transport markets.

# V. The engine of global trade —energy efficiency in shipping

## A. Introduction

While many energy efficiency studies focus on the energy performance of road transport, given its dominant share in the world oil consumption, maritime shipping —the engine of global trade— has undoubtedly an important role in the efforts to achieve energy efficiency in the transport sector.

To help explore the shipping's performance and potential is this area, this Chapter offers an overview of key parameters to consider in order to improve the fuel efficiency of shipping, such as ship design for energy efficiency (section 4.2), effects and barriers of the energy efficiency measures in shipping (section 4.3) and the experience of the existing policies and incentives (section 4.4). In doing so, it also offers insights on the energy efficiency of the maritime transport in comparison to other transport modes.

There is a strong pressure on the transport sector to increase the fuel efficiency. While many other sectors show decreasing $CO_2$ emissions, transport is expected to have increasing emissions in the future. Shipping represents at present about 3% of the global anthropogenic $CO_2$ emissions, but its share is expected to increase in the future as a result of increased transport in combination with difficulties in implementing effective fuel efficiency measures and difficulties in replacing fossil fuels.

In Latin America and the Caribbean maritime transport is responsible for over 90% of all international freight movements in terms of volume and thus the most important facilitator for the region's participation in the global market place (Wilmsmeier and Hesse, 2011). The sector and more specifically energy efficiency in this sector has received little attention from governments in the region. However, the search of competitiveness of the region in international trade and increasing costs for marine fuels have put pressures on the industry to be more fuel efficient. As fuel efficiency is inevitably linked to air emissions, successful measures and policies to improve energy efficiency will have positive implications for the regions emission levels.

Research in the field of alternative power sources, technical-, operational-, and structural energy saving measures for shipping exist. However, there are gaps between present knowledge and implementation of available energy efficient measures among shipping companies (Styhre and

Winnes, 2013). As in many industries there remain a number of measures that would improve fuel efficiency in shipping that are not implemented despite known cost-efficiency. This situation can be referred to as an energy efficiency gap. There is also an extensive taxonomy of barriers to explain the non-adoption of measures. Sorrell et al. (2004) summarized barriers as risk, imperfect information, hidden costs, and access to capital, split incentives, and bounded rationality.

Initiatives within the International Maritime Organization (IMO) have resulted in an addition to MARPOL Annex VI on prevention of emissions of $CO_2$ which entered into force 1st January 2013. An energy efficiency design index (EEDI) value, which relates the mass of $CO_2$ emissions per transport work to ship size, should be produced for all new ships. The EEDI of a specific ship is compared to a reference line that dictates the maximum allowed limit. The reference line is different for different ship types. In addition, the added regulation requires a so called "ship energy efficiency management plan" (SEEMP). A SEEMP should function as an operational tool to improve energy efficiency. Goods volumes transported at sea are, however, predicted to rise, and absolute reductions in fuel consumption and $CO_2$ emissions from the industry are not expected despite the new regulations (Bazari and Longva, 2011; Anderson and Bows, 2012).

In addition to the work on reducing fuel consumption and $CO_2$ emissions from shipping there are regulations being implemented regarding other pollutants which have implications also for costs. Emissions of sulphur dioxide ($SO_2$) and particulate matter (PM) are regulated through the sulphur content in the fuel. There is a direct proportionality between $SO_2$ emissions and the sulphur content and a connection between PM emissions and sulphur content has also been established. The background to these regulations is problems with acidification ($SO_2$) and health risks (PM). However, in the future explicit PM regulations, like there are for other diesel engines, may be needed to further mitigate the health risks with ship exhausts. The sulphur regulations mean that the maximum allowed fuel sulphur content is 0.5 % from 2020, down from 3.5 % that is allowed today, and further, in special areas (Sulphur Emission Control Areas – SECAs) the limit is 0.1% from 2015. Today these areas comprise the North and Baltic Seas, the English Channel and the coasts outside USA and Canada. The other pollutant that is regulated is nitrogen oxides, $NO_X$, where emissions limits have been somewhat tightened for engines installed after 2011. There is also a further restriction coming at some time in the period 2016 – 2021, but only for special $NO_X$ emission control areas, currently only the waters outside USA and Canada.

This chapter contains an overview of important parameters to consider for improving the fuel efficiency of shipping. Further, other emissions are discussed together with a comparison to other transport modes.

## B. Ship design for energy efficiency

Technical measures that cost-efficiently reduce fuel consumption have resulted in highly efficient marine engines and power trains, optimised flow profiles around hull, rudder and propeller, and innovations like the bulbous bow. Still, it is not unusual for individual ships to consume up to 30% more fuel than necessary due to imperfect designs, badly used propulsive arrangements, or poorly maintained status on hull and propeller. High expectations on improved energy performance from technical improvements are also found in a report for the Marine Environmental Protection Committee of the IMO where a potential to reduce $CO_2$ emissions per transport work by 10 to 50% from design measures is estimated.

Knowledge of fuel saving potentials from technical measures related to hull and propeller geometry, hull construction, propulsion machinery, auxiliary machinery and equipment, heat recovery, cargo handling, and alternative energy sources are in general good within the industry. There is a long tradition of development and research within these areas and improvement potentials are estimated to reach, in average, a few % fuel savings for each category. A remaining challenge is to increase knowledge of how the different technical systems on a ship affect each other. Such knowledge is needed in order to increase recovery of waste heat or efficiently reduce electricity use on-board, that are highly potent measures for the overall energy economy.

Ships have long lifetimes and modifications and retrofits to existing ships are in a life cycle perspective more expensive than for new designs. A ship design process starts with a mission analysis that outlines the types of goods to be transported and how it will be loaded and unloaded, routes, service time, etc. Based on these requirements a conceptual design phase starts, the dimensions and layout of the ship are determined and powering needs are decided. The conceptual design phase consists mainly of technical feasibility studies in order to conclude if the mission requirements can be translated into reasonable technical parameters and still produce a seaworthy ship. This is followed by an increasingly detailed design and refined ship characteristics.

Energy efficiency decisions are to a large extent included already in the conceptual phases of the ship design process. Among the most important parameters for ship energy efficiency are the main dimensions of the ship; length, breadth, depth and displacement. Small changes in these parameters can result in big changes in energy need. The operational phase is by far the most energy demanding period of a ship's lifecycle. A well-defined operational profile from the early stages of design is a promising way to develop an energy efficient ship of high quality. Design for operations should therefore also be prioritised over a less costly construction at the yard from an energy efficiency perspective. Optimization efforts can be counteracted by yards' requirements on a cost efficient construction. The yards do not necessarily have a life cycle approach and are not always able to change an existing design, or the changes are very costly to the owner. It is difficult for the ship owner to possess the skill and the power to plan for life cycle costs under such conditions.

Fuel prices have long been rising and the fuel costs' share of the total costs has increased. Further, environmental regulations that demand the use of low sulphur fuels will result in even higher fuel costs for ship operators, markedly for operators active in the Emission Control Areas where requirements are strictest. As fuel prices increase the interest in energy saving measures within the industry grows. The ships constructed today are likely to sail the oceans in the 2040s and energy efficient solutions will during the lifetime of these ships most likely be more valuable than ever before.

## 1. Alternative fuels

A few liquid fuels that can replace oil for ship propulsion exist and are in different stages of development; from pilot project to commercial implementation. Liquefied natural gas (LNG) has a potential to replace oil in a large share of the fleet. LNG has previously been used as a fuel for LNG carriers but is being introduced in other segments of the fleet. Natural gas is a fossil fuel and will like the traditional fuel oil contribute to the increasing $CO_2$-levels in the atmosphere. However, lower emissions of sulphur dioxide and nitrogen oxides also make LNG an option for ships in the emission control areas where marine gasoil is the only other fuel alternative available today unless abatement technology is installed. Further, the reserves of natural gas are expected to last longer than those of oil (EIA, 2009). Two other issues that are likely to hold back the development of LNG use are the costly engine retrofits for existing ships, which makes LNG an option primarily for new builds, and the additional space requirements for LNG storage. LNG is stored in specially designed pressurised tanks on board and requires approximately 2.5 to 4 times more storage space than conventional fuel oils. The lack of infrastructure for LNG in many ports also hinders the use of this fuel.

Once a ship has been constructed for operations on LNG the option to use liquefied biogas is open. Biogas and natural gas are made up of the same hydrocarbon molecules (mainly methane) and are only different in the sense that they are of different origin; natural gas is a non-renewable resource from the earth's crust while biogas is from renewable sources, typically produced by fermentation of biomaterial such as food and sewage. LNG can be combusted in dual fuel diesel motors, where a small amount of diesel oil is injected simultaneously with the gas. LNG can also be used as only fuel in Otto engines, similar to methanol engines – another fuel discussed for marine use.

Methanol is an alcohol that potentially could bridge to a fossil fuel free future although it is today mainly produced with natural gas as feed stock. Methanol is a liquid at room temperature and does not require pressurized tanks. Methanol as marine fuel is at a trial stage. Another option is synthetic diesel that can be produced by the Fischer-Tropsch method or similar processes from basically any hydrocarbon raw material; natural gas, biogas, coal or biomass. Synthetic diesel is, however, not yet beneficial to use neither from energy efficiency nor from a cost point of view (Bengtsson et al., 2011). Another fuel that can be used directly in diesel engines is dimethyl ether (DME).

The Marine Environmental Protection Committee of the IMO forecasted that HFO will be completely replaced by distillate oils and LNG by 2020. In a scenario analysis, it is assumed that 5% of tank ships and 5-10% of coastal shipping will be fuelled by LNG by 2020 and that these figures will rise to 10–20% for tankers and 25–50% for coastal shipping by 2050. In 2050, only minor shares of synthetic diesel are expected to have been introduced to the marine fuel market (Buhaug et al., 2009).

## 2. Operational measures

A variety of measures of utterly different characters are needed to reach successful and sustainable reductions of the amount of fuel used per tonne transported goods between ports of origin and destination. Logistic measures, including slow speed operations, higher capacity utilization, and route planning are important ones, as well as communication measures for improved port call efficiencies and changed behavior, for example renewed incentive structures within and between organizations. Communication and behavioral aspects are important for successful implementation of all measures, primarily during operations.

The operational energy efficiency measure with the highest potential is slow steaming (Buhaug et al., 2009). As the relationship between ship speed and fuel consumption per unit time is approximately cubical, a minor speed reduction can have a great influence on fuel consumption. Slow steaming is an attractive option in times of economic recession with an overcapacity of ships, but the effects of slow steaming cannot be expected to be equally big as the economy turns and shipping service is more requested (Lindstad et al., 2011). Suggestions to maintain slow speed operations in the international fleet in order to reduce $CO_2$ emissions from ships include fuel taxes (Cariou, 2011; Corbett et al., 2009) and regulated speed restrictions for ships (Faber et al., 2012; Lindstad et al., 2011).

Another measure to increase ships' energy efficiency is to increase port efficiency, which means that the turnaround time of the vessels in port can be reduced. With shorter time in port, the speed at sea can be reduced with preserved transport service. Johnson and Styhre (2013) investigated the possibilities of reducing speed at sea for short sea bulk shipping by decreasing unproductive waiting time in port. The results show that the two largest sources of unproductive time in port are waiting time at berth when the port is closed, and waiting time at berth due to early arrival. With 1-4 hours of decreased time per port call, the potential for increased energy efficiency was 2-8%.

In a discussion on ship energy efficiency measures it is important to stress the different premises for liner shipping and tramp shipping. Liner shipping provides regular services between specified ports according to timetables and usually carries cargo for a number of cargo owners, while tramp shipping is irregular in time and space. Ships in liner traffic have in many cases been subject to careful logistic arrangements, including long term cooperation with few ports and developed fixed time tables and designated berths. Ships in tramp traffic will seldom have dedicated berths and port slots and will most often visit several different ports, which all have specific procedures and administration related to a port call.

Different ship types have different energy needs. A relevant example for the Latin American market is the transport of reefer cargo. Reefer cargo transported in specialized reefer vessels or in refrigerated containers, demands extra energy for cooling. About 20% of the energy needed to transport food in refrigerated containers is due to refrigeration need. Low freight rates has hit reefer companies hard as container ship operators have used the potential to load containerized reefer cargo to fill idle capacity in their ships. The on-going cargo shift from specialized reefer vessels to container ships is likely to continue; there are no specialized reefer vessels on order and new built containerships increase their capacity for refrigerated cargo.

# C. Effects and barriers

A number of energy efficiency measures in shipping are cost efficient. Eide et al. (2011) estimate that it is feasible to avoid approximately 400 million tonnes of $CO_2$ emissions by only using cost efficient measures in 2030. Over the last several years, marginal abatement cost curves (MACCs) have been used to identify the cost efficiency in measures. However, published MACCs project different abatement potential, which can be explained to a large extent by the fact that they use different emission baselines, different sets of measures and different assumptions about future fuel prices (Faber et al., 2011a). The fuel prices used by Eide et al. (2011) were 350 USD/tonne heavy fuel oil and 500 USD/tonne marine distillate. With higher prices (the price today for marine distillates is over 600 USD/tonne); it is obviously possible to reduce even more $CO_2$ emissions while at the same time reducing costs. MACC curves are very sensitive to assumptions such as discount rates, investment costs, vessel service life and annual transport work (Kesicki and Ekins, 2012). The analysis of measures includes highly aggregated data on efficiency and costs, and does not include important aspects as revenues that can be expected from speed increases. Also, the MACC analysis does not grasp all the costs that a ship owner and a ship operator perceive with a certain technology. Perceived risks associated with new technologies, which can be referred to as technological risks, are highly important reasons to why implementation rates are slow. Other barriers to implementation are found to be of institutional or financial character (Faber et al., 2009).

Institutional barriers inherent in organizations of actors in shipping influence the implementations of fuel saving measures. Measures that overcome institutional barriers are believed to have significant potential to reduce emissions, but are generally hard to develop and implement (Eide et al., 2011). Typically two or more counterparts in shipping have to work together in order to implement these measures and increase efficiency. As already pointed out, tramp shipping have a more extreme situation than liner shipping in these issues as these ships are subject to agreements between ship operators and charterers which may limit the implementation of technical and logistic measures (Faber et al., 2009). For example, the contracts between a ship charterer and a ship operator in tramp shipping will stipulate who pays for the fuel at different times during the ship's journey. Special contracts, charter-parties, are used, which state the conditions for the use of a vessel during the period of chartering. The agreements contain a number of clauses that in different ways include the voyage, the cargo to be transported and the time frame. There are also clauses on performance and guarantees for speed and bunker consumption and regulations of delays. Such clauses can affect energy efficiency since they provide incentives to save fuel to varying degrees. In a voyage charter party agreement, there can even be an incentive for the crew or ship owner to sail at high speed since the charterer pays rent for the ship in port, demurrage.[55] In economic recessions, the demurrage can be even higher than freight earnings for the ship operators. Thus, a voyage with demurrage may be a more attractive option for the individual operator than to sail at a reduced speed and save bunker.

In general, ships also have a second hand value that does not reflect investments in energy efficient equipment. Faber et al. (2011b) refers to low second-hand values, and prices to charter a ship that does not reflect the ship's energy efficiency, as highly important institutional barriers to the implementation of energy efficiency measures in the ship industry.

Further, an important factor that affects the ability to implement energy efficiency measures is associated with transaction costs and difficulties of allocating costs and profits between different companies for an investment that benefits multiple stakeholders (Kesicki and Strachan, 2011). Consequently, there is an additional, non-negligible cost associated with the measures, which can have the effect of capital not being allocated to the business where it is most needed. Smith (2012) points out that low charter prices and high fuel prices are effective drivers for energy efficiency efforts among shipping companies. This partly explains the ship operators' recently increased interests in energy efficiency in shipping.

[55] Demurrage refers to the period when the charterer remains in possession of the vessel after the period normally allowed to load and unload cargo (laytime).

## 1. Shore side electricity

The time a ship spends in port is usually considered as insignificant when it comes to the total fuel consumption of a ship. However, emissions of pollutants, as well as noise, can be significant problems for the city where the port is located, and these emissions will potentially affect a larger number of people compared with emissions at sea. There are some specific measures that can be applied in ports and there is also a possibility of influencing the ship's performance through differentiating the port fees.

The fuel consumed for ships at berth is mostly used for electricity production in order to run facilities on board for passengers and crew such as air condition, cooking, light, and also, e.g., for pumps to load and unload cargo on tanker ships. This means that ferries and cruise ships together with tankers use relatively more fuel at berth compares to other ship types.

One alternative for the ships is to use shore-side electricity at berth. There is so far no widespread use of this technology but a number of ports have facilities and ships in liner trade connect to shore-side electricity. There are a number of practical issues, such as different voltage and frequency for the current, investment costs, and crew availability for the actual connection, that have hampered the development. Further, the low bunker fuel prices until a few years ago made it possible to produce electricity on-board at a low cost.

If shore-side electricity is a good measure when it comes to reducing $CO_2$ emissions depend entirely on how the electricity is produced; for coal power electricity the $CO_2$ emissions may increase while they will be reduced significantly with hydro- or wind-power. The main asset with shore-side electricity is, however, to reduce the emissions of pollutants like particles and $NO_X$ in populated areas.

## 2. Modal comparison

Shipping has in general been able to maintain an image of an environmental-friendly mode of transport. In some ways this is correct; shipping is for most cases relatively fuel efficient, it can ease problems with road congestion, it uses relatively little land and there are relatively few accidents. However, there are also significant problems; high emissions to air of noxious substances such as $NO_X$, $SO_2$ and PM as well as polycyclic aromatic compounds and other toxic organic substances; emissions to water of oil and toxic hull paints; and the introduction of alien species with ballast water discharge in sensitive environments.

In order to illustrate the different emissions to air of $CO_2$, $NO_X$, $SO_2$ and PM, as well as the fuel consumed, between different transport modes, some example calculations are carried out. It should be noted that there are of course other important issues that will differ between the transport modes, such as impact on water, congestion, accidents, infrastructure, etc. However, the problems with emissions of climate gases and air pollutants are major issues for the transport sector.

The calculations are carried out from a South American perspective for a transport of 1000 tonnes of cargo between Manaus, Brazil and either Buenos Aires, Argentina or Santos, Brazil. For shipping this means that the international rules apply, i.e., a maximum fuel sulphur content of 3.5% and, for ships constructed after 2000, Tier 1 $NO_X$ levels. It is here assumed that the fuel sulphur content is 2.7%. Two ships are studied: one container ship of 10 000 dwt and a bulk ship of 60 000 dwt. For trains,[56] the emissions are for the most part unregulated in South America. It is assumed that the train is pulled by a diesel engine with emissions typical for unregulated large diesel engines. The truck regulations in South America vary from country to country, but generally newer trucks follow approximately the Euro III emission standard. Also the sulphur limits for diesel fuel used by train engines and trucks varies over the continent. A diesel fuel with 500 ppm, which can be regarded as a common quality, was chosen for the calculations.

Of great importance for the results is the capacity utilization, i.e., the load factor. It is assumed that the truck, the train and the container ship carries containers that are filled up to 75% of the

[56] There does not seem to be good train coverage for these hauls but the train is included in order to illustrate its potential.

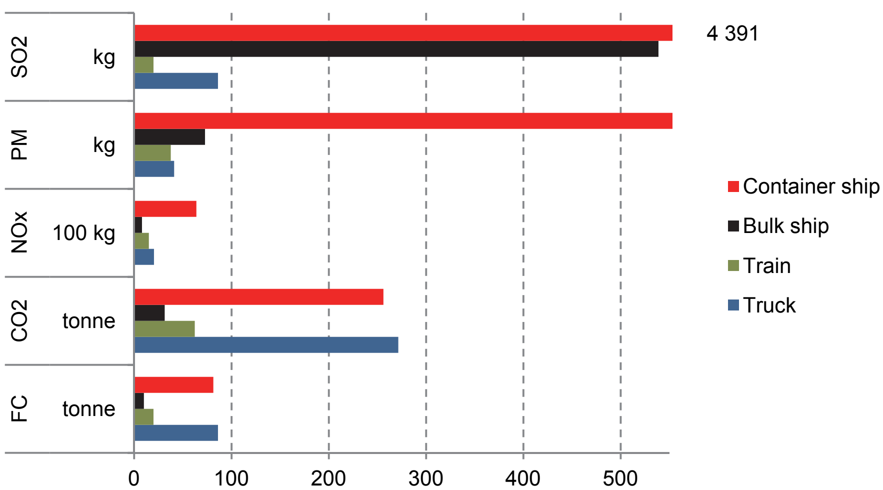
maximum weight capacity. In addition, the ships and the train are assumed to have load factors of 75% when it comes to the number of containers that are loaded.

The results can be seen in the next figure. One can immediately note the difference between the two ships, with much lower emissions for the bulk ship. This is due to the larger size, but also to bulk ships being more efficient due to lower speed and that a higher fraction of the deadweight is cargo compared with a container ship. The fuel efficiency is highest for the bulk ship transport and lowest for the truck. The train has relatively high fuel efficiency and is clearly more efficient than the container ship. The $CO_2$ emissions are directly proportional to the fuel efficiency in these examples, the reason being that the assumed fuels have similar $CO_2$ emissions related to the energy content in the fuels. The $NO_X$ emissions are highest for the container ship. This is related to the low degree of abatement normally found for ships. Also the train shows relatively high emissions of $NO_X$ which is due to that train diesel engines normally are unabated. For PM the different alternatives show similar emissions in this example except for the container ship with much higher emissions. The ships have high emissions of $SO_2$, which is due to the high sulphur content in the marine fuel.

It should be noted that these results are merely an example. By choosing other types of vessels, with other sizes and different exhaust abatement equipment, the picture becomes modified.

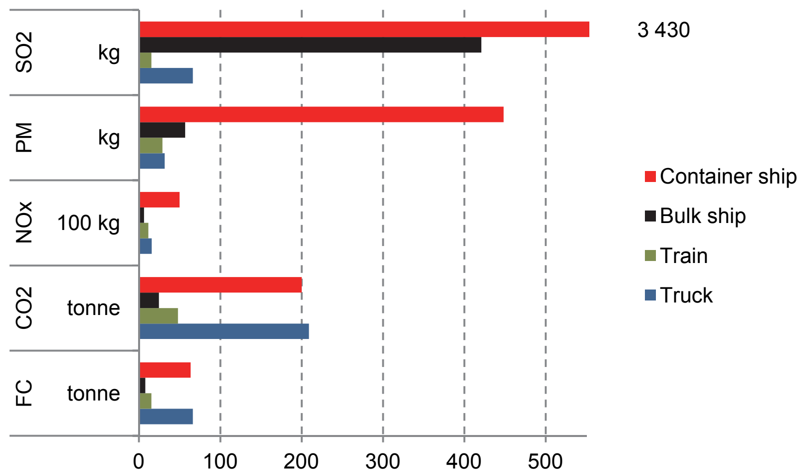
The next figure illustrates how the emissions would be reduced if the ships both use marine gasoil with 0.1% sulphur rather than heavy fuel oil, and comply with the Tier 3 $NO_X$ regulations; and for the truck, if it follows the Euro V emission standards and uses diesel with 10 ppm sulphur. One can note that the fuel efficiency and thus the $CO_2$ emissions are unaffected by these measures. The $NO_X$ emissions are significantly reduced for both vessels and for the truck as are the PM emissions. The $SO_2$ emissions are drastically reduced due to the lower fuel sulphur contents.

**FIGURE 20**
**RESULTS FROM EMISSION CALCULATIONS FOR TRANSPORTING 1000 TONNES OF GOODS BY DIFFERENT VESSELS AND VEHICLES FOR MANAUS TO BUENOS AIRES**




Source: Author´s elaboration.
Note: Note that the $SO_2$ value for the container ship is outside the scale.

**FIGURE 21**
**RESULTS FROM EMISSION CALCULATIONS FOR TRANSPORTING 1000 TONNES OF GOODS BY DIFFERENT VESSELS AND VEHICLES FOR MANAUS TO SANTOS**




Source: Author´s elaboration.
Note: Note that the $SO_2$ value for the container ship is outside the scale.

## D. Policies and incentives

Efforts to improve conditions for nature and man have appeared on the political agenda for decades. Environmental sustainability is discussed on local, regional and global levels to improve living conditions for present and future generations. Combustion of fossil fuels has since the industrial revolution caused a net increase in atmospheric $CO_2$ contents that impacts our climate. Air pollution of ozone, $NO_X$, $SO_2$ and particles has more direct impact on human health and is mainly of local and regional concern. International agreements and conventions such as the Kyoto Protocol on climate change and the Convention on Long-range Transboundary Air Pollution (CLRTAP) have been established in cooperation between several nations. These forums however, do not comprise shipping and environmental regulations for air pollution from international shipping originate from conventions governed by the IMO.

As discussed in this chapter there are several technical and operational measures that may increase fuel efficiency for shipping. In order to reduce the fuel consumption and $CO_2$ emissions of the sector, or at least to make the increase lower, it is important both that these measures are applied and that there is a further technical development as well as new business models where fuel efficiency comes high on the agenda.

Another way to increase the fuel efficiency of transport is to transfer shipments to sea from other modes. However, as is obvious from the data in the figures above, this may come at the expense of increased emissions of noxious substances such as particles and nitrogen oxides. It thus seems essential that a modal shift toward sea transportation is accompanied by measures for reducing the emissions to air from ships. This can be accomplished by technical measures such as low sulphur fuel and exhaust abatement technologies. However, since these measures come with a cost, a prerequisite for their introduction is that suitable policy measures are introduced.

There are a number of policy options available to increase the fuel efficiency and/or lower the emissions of noxious gases. As increased fuel efficiency and reduced $CO_2$ emissions go hand in hand, these are largely motivated by the need to limit impact on climate. At present there are only few such policy measures in place. The already discussed regulations decided by IMO regarding EEDI and SEEMP are the only sharp examples. The EEDI regulations will put pressure on designing more fuel efficient ships in the future and the SEEMP will hopefully highlight operational measures that can be used for better fuel efficiency. However, in view of the expected increase in trade the total fuel consumption within shipping is still expected to increase in the future. In Europe, there are also discussions about including shipping in an existing system with carbon credit trading for land based sources. The first measure is to monitor the fuel consumption in the European trade. Similar systems have already been decided for aviation. Another idea is an international levy for $CO_2$ emissions where the fees collected may be used for investments in technology to mitigate $CO_2$ emissions from shipping or from other sectors.

There are also examples where ports are differentiating port fees with $CO_2$ emissions being one parameter (for discussion on differentiation of port dues see Wilmsmeier, 2012). Further, different initiatives for procurements also take $CO_2$ emissions into account. Organisations offer information on environmental performance of ships to cargo owners who then can factor in environmental performance in procurement. One inherent difficulty is how to measure fuel efficiency. In order to take operational measures into account the fuel efficiency is often expressed as fuel consumed per transport work performed in tonne-km. This measure will vary between different types of ships and requires a transparent system of bookkeeping of cargo, distances and fuel consumed, much of which often are regarded as secret business information. Unfortunately the most straight forward policy option to stimulate a development towards higher fuel efficiency, a fuel tax or levy, seems difficult to realise in the current international climate. Further, national or local taxes are more or less totally obstructed by international laws governing international shipping.

For emissions of noxious gases the policy situation is somewhat more versatile. Clearly, as can be seen from comparing the results for situation A and B in the figures above, significant reductions in emissions can be obtained from using low sulphur fuel and from using abatement equipment. For the sulphur content in marine fuel the decisions taken in IMO will result in significantly reduced emissions of SO2 in the period 2015-2020. Further, this will also result in significantly reduced emissions of particulate matter.

There are also regulations at hand for $NO_X$, but only the Tier 3 regulations will result in any significant reduction of the emissions. However, these will only be applied to few regions of the world and, further, since they only apply to new engines there is an effect on emissions only when old ships are replaced by new ones. All this indicates that if a significant reduction in $NO_X$ emissions from shipping is requested – and there are many environmental and health risk reasons to do so – other policy instruments need to complement the IMO regulations.

One example is the $NO_X$-tax used in Norway since a few years. The inclusion of ship emissions in the national $NO_X$-tax system was made in order to achieve the Norwegian $NO_X$ emission goals determined from an international agreement between 51 states on reduction of environmental impact from air pollution – the Gothenburg protocol. Ship owners have to pay a tax for each kilogram of $NO_X$ that is emitted and the money is placed in a fund. Ship owners can apply for grants for investments in abatement technology for their ships from the fund. Although the tax only applies to routes within Norwegian waters, this system has been a success in terms of investments in new technology. Technologies of different characters are supported, such as LNG engines or selective catalytic reduction (SCR) after-treatment. The success of the Norwegian $NO_X$ fund system proves high potentials to include domestic shipping in schemes for emission reduction in response to international agreements. Domestic shipping is seldom a large contributor to pollution but the effects of increased use of abatement technologies can be expected to result in more mature technologies that subsequently are more easily adopted in larger segments of the fleet. Another example is the environmentally differentiated fairway due that is used in Sweden in the last two decades, which originally was combined with financial support for investments in abatement technologies. This also has the drawback of only being applied to Swedish waters, but has stimulated the use of SCR and other measures in a fair number of ships.

There are also a number of systems with environmentally differentiated port fees and procurement initiatives aiming at reducing emissions. However, the actual impact on emissions from these is unclear. An issue here is that the stimulus needs to be large enough to overcome the costs for abatement systems, as well as the institutional barriers discussed above. Thus, as a consequence, transport service buyers must be ready to pay more in order to reduce the environmental impact of their transports.

Including emissions from ships in mandatory or voluntary schemes in ports can also be a way to comply with national and local air quality standards in port cities. Many cities have large difficulties to keep concentrations below ceiling levels of typically PM, ozone and $NO_X$. Annual concentrations of PM10 in several South American urban areas surpass national standards, as well as those established in the global air quality guidelines recommended by World Health Organization (Pan American Health Organization, 2007). Also ozone and $NO_X$ can despite sometimes scarce reporting be concluded to exceed air quality standards in many Latin American cities (Maggiora and Lópes-Silva, 2006). $NO_X$ is a precursor to ozone and smog incidents; $NO_X$ in sunny environments will in reactions involving hydrocarbon species cause ozone formation. Initiatives that reduce $NO_X$-emissions from ships' auxiliary engines running at berth, by installation of shore side electricity and exhaust treatment, can thus be a valuable step in improving air quality.

All in all, the existing regulations on emissions to air from ships need complementary efforts in order to accomplish significant absolute reductions. The expected increase in transport demand will likely increase the contribution to air pollution and global warming from shipping, while regulations on land continue to efficiently reduce land based emissions. There are a number of examples of voluntary incentive systems for ship operators that sometimes have proven highly successful. Such efforts have mainly been used on national levels and been very different in character. As exemplified in this study, shipping is a fuel efficient means of transport. The potential in shipping to provide both fuel efficient and low polluting transport, however, relies on more wide spread use of existing abatement techniques. Further, although the fuel efficiency in shipping is already high, there is still potential for further improvement, which will be a competitive advantage in a future with expected high fuel prices. Measures to improve fuel efficiency have been identified in a variety of fields, from pure technical measures to measures aiming at changing incentive structures within the business. With fulfilled potentials, ships will offer transport with high competitiveness for a sustainable development.

## E. Conclusions

In Latin America and the Caribbean initiatives and incentives to improve energy efficiency in the shipping sector are rare and the region follows behind other regions' in the world. ECA's in LAC have not been implemented despite significant ship traffic in vulnerable areas such as the Caribbean and coastal zones. Further, measures to promote modal shift from road to sea at national and sub-regional levels are absent (Brooks, Sánchez and Wilmsmeier, 2013). Thus potentials for greater energy efficiency, particularly in long distance transport are note converted into savings and better performance. The possibilities for energy efficiency provided in this report depict an array of how the countries in the region can move towards greater energy efficiency in shipping and also how to improve efficiency of the transport system overall.

# VI. A regional perspective

## A. Consumption and energy intensity

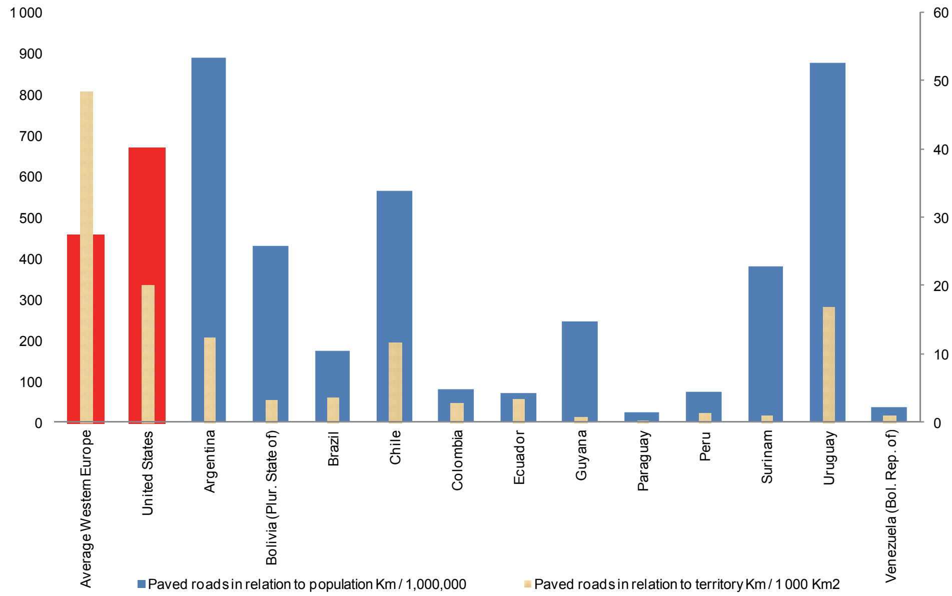
The vast continent of Latin America, with its rough terrain and tropical rainforests, has always posed a challenge in terms of transport. A brief look back at its history confirms this. The powerful pre-Colombian civilizations that held sway across large areas of the region had extensive roadways and a good communications network, but they did not use wheeled vehicles (even though they did use wheels for their children's toys). Perhaps this was because the steep slopes and valleys which they had to cross did not lend themselves to this mode of transport but instead called for the types of engineering works that have only recently become feasible.

Latin America's current stock of transport infrastructure—which is unevenly distributed and is of widely varying quality—amounts to an average of around 0.82 km of paved roadways and 0.22 km of railway lines per 1,000 inhabitants (ECLAC, 2011). This falls short of potential needs and demand, even under the assumption that regional integration efforts will prove to be successful. The need to improve and build up transport infrastructure has been heightened in recent years by economic and political factors that have reduced investment and triggered a deterioration in existing transport networks in virtually all areas and at all levels. At the same time, the gap in terms of quality and availability of transport infrastructure between Latin America and other developing regions (especially Asia) has been widening.

In-depth ECLAC studies on this subject provide a number of indicators that show just how pressing a need there is to implement consistent policies in order to turn this situation around (ECLAC, 2011). For example, the density or spatial coverage of the region's network of paved roads, measured as the total number of linear meters of paved roadways per square kilometer of land area, is, at 44 m/km2, far lower than in developed countries (944 m/km2, on average, in Western Europe and 390 m/km2 in the United States), as is shown in figure 49, which provides an overview of roadway density in selected countries of the region. The situation with regard to other modes of transport is much the same.

Thus, for a variety of economic, physical and historical reasons, the Latin American region's transport infrastructure clearly falls far short of demand. Most of this infrastructure is in the form of roads, many of which are still not paved and/or are in poor condition, with access to more efficient modes of transport, such as trains and waterborne vessels, being quite limited. In fact, with some notable exceptions (such as the use of boats in the Amazon Basin, the mining industry's use of cargo trains in some cases, and urban trains in some large cities), automobiles, buses and trucks are the main vehicles used to transport people and goods in Latin America.

**FIGURE 22**
**PROPORTION AND DENSITY OF PAVED ROADS IN SELECTED COUNTRIES AND REGIONS**




Source: ECLAC, 2011.

In addition to the direct implications of the region's flawed transport infrastructure and reliance on roadways (such as high logistical costs, barriers to in-country and inter-country integration, and the poor quality of mass transit services in terms of comfort, frequency and average speed), this situation has quite serious implications for energy demand and, hence, a severe impact on the environment. The transport sector accounts for around one third of the region's total energy consumption, almost all of which is petroleum-based, and has high energy loss rates. There is thus a great deal of scope for measures that will help to move the region towards more rational and efficient energy use.

This study seeks to describe the current situation and future outlook with regard to the energy use associated with the transportation of passengers and cargo in Latin America. It then draws on that information as a basis for analyzing government programs and initiatives, including regulatory measures, to promote energy efficiency in mobility. This introductory chapter on the subject will look at transport-sector indicators, at how the sector's energy intensity has changed over time and at major trends in the energy/transport dyad in Latin America. It is important at the outset of this analysis to recognize the fact that the available databases and other sorts of information on the transport sector –and particularly on energy-related aspects of the sector— suffer from a number of shortcomings, with most of the data being available only in an aggregated form or being piecemeal or unsystematic in terms of its coverage.

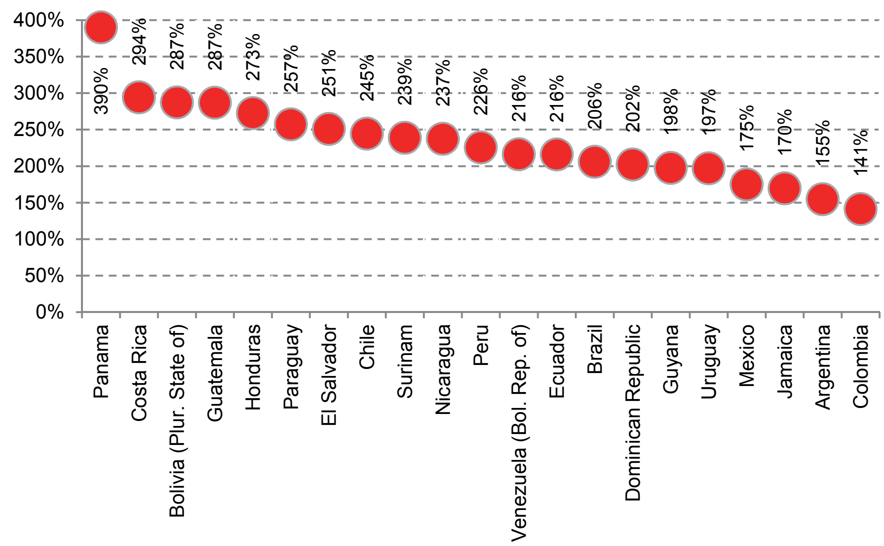
## 1. Energy consumption in the Latin American transport sector

In recent years, energy consumption in the Latin American transport sector has totaled over 2 billion tons of oil equivalent (toe), which represents about one third of the region's energy matrix (OLADE, 2013). Using the data provided by the countries in their national energy audits as reported by the Latin American Energy Organization (OLADE) in its Energy-Economic Information System (SIEE), it is possible to derive some quite interesting results despite the fact that the information is aggregated for all modes of transport (roadways, railways, waterborne vessels and aircraft) (OLADE, 2013).

The burgeoning demand for energy for use in the transportation of people and goods in Latin America is depicted in figure 50, which illustrates the relationship between the transport sector's energy demand and the total supply of energy in various countries for 1990, 2000 and 2010. This sector represented 27%, 31% and 35%, respectively, of total supply (simple unweighted averages) and was the largest single energy consumer in many cases. Its relative weight in the energy matrix is a function, on the one hand, of the configuration of the transport sector's own energy demand, level of activity, modes of transport used, the size of the vehicle fleet, etc., and, on the other hand, the relative weight of other sectors, especially the electricity-generating and industrial sectors, which are equally large energy consumers in some countries.

At one end of the spectrum, there are countries whose transport sectors consume comparatively less than others, such as Cuba, where the transport sector accounted for just 6% of the total in 2010, and some Central American countries, such as Guatemala, Nicaragua and Honduras, where somewhere between 24% and 26% of their total energy supply in 2010 went to transport. At the other extreme, the transport sectors of Ecuador, Panama and Costa Rica used 53%, 47% and 45%, respectively, of the energy supply in 2010.

**FIGURE 23**
**TRENDS IN THE TRANSPORT SECTOR'S FINAL ENERGY CONSUMPTION, 1990 - 2010**

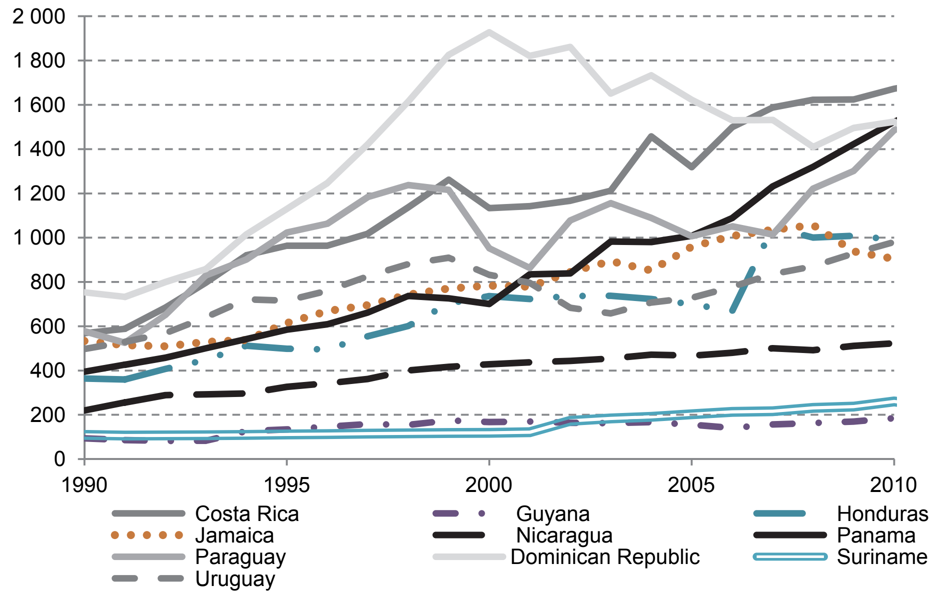



Source: prepared by the authors on the basis of a 2013 OLADE simulation of energy efficiency measures in industrial and transport sectors in Latin America and the Caribbean to the year 2030.

A somewhat more detailed picture of the trend in the transport sector's levels of energy consumption in Latin America is provided in the following figures, which give absolute values (in ktoe) for the sector's demand between 1990 and 2010 and relative values for demand in 1990. Since the absolute values vary a great deal across countries, they are grouped into two categories in these figures, using a cut-off level of 2,000 ktoe/year (in 2010). Owing to apparent inconsistencies in the data, these figures do not include values for Cuba (all years) or Ecuador (in 1995).

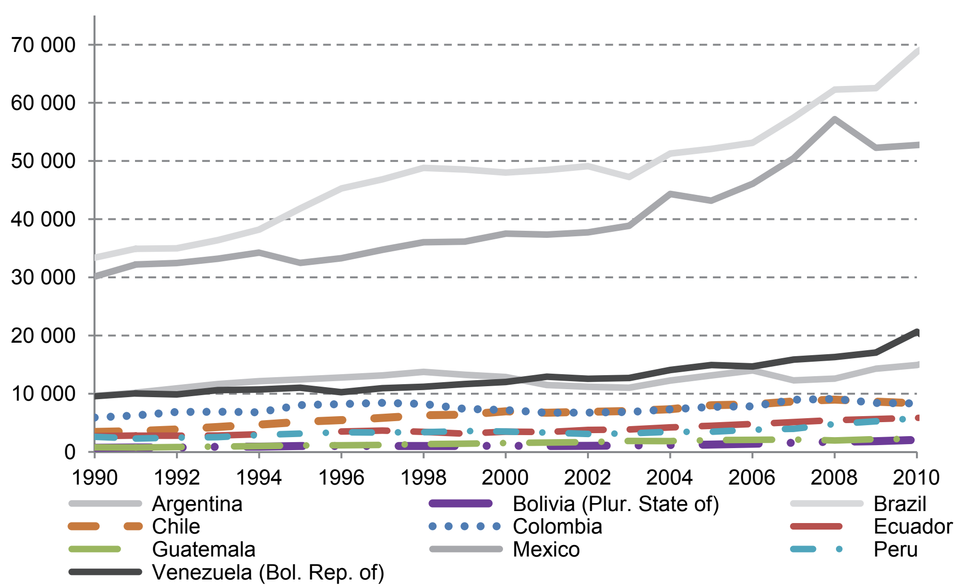
These figures indicate that, from the standpoint of the absolute values involved and the trends in energy consumption in the transport sector, the Latin American countries can be divided into three groups: (a) low-consumption countries (figures 51 and 53), which display varying patterns but in which, with the exception of the Dominican Republic, the transport sector has increased its level of energy consumption significantly; (b) intermediate-consumption countries (consumption levels between 2,000 and 20,000 ktoe in 2010) (figures 52 and 54), in which consumption levels also increased, but less sharply (Chile, Colombia, Ecuador, Guatemala, Peru and the Bolivarian Republic of Venezuela); and (c) high-consumption countries, in which the sector's energy use rose steeply (Brazil and Mexico). In sum, it can be inferred from the information presented in these figures that the transport sectors of Latin American countries account for a large proportion of total energy use and that, in some countries, this sector's energy demand is rising steeply while, in others, the increase in demand has been more moderate. This is illustrated by the average annual growth rates between 1990 and 2010 shown in table 23.

**FIGURE 24**
**ENERGY CONSUMPTION IN THE TRANSPORT SECTOR, COUNTRIES WITH LESS CONSUMPTION**
*(Countries with consumption levels below 2,000 ktoe/year)*



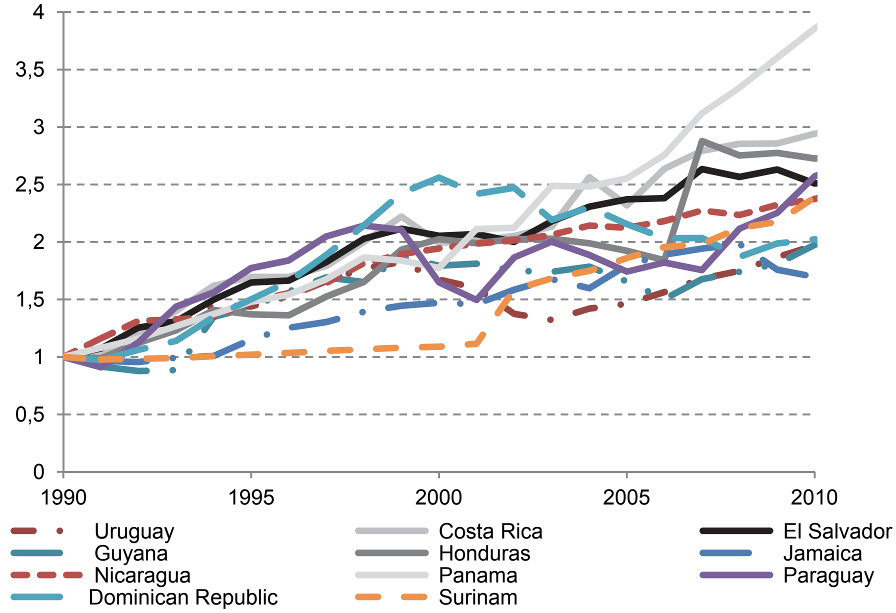

Source: prepared by the authors on the basis of OLADE data, 2013.

**FIGURE 25**
**ENERGY CONSUMPTION IN THE TRANSPORT SECTOR COUNTRIES WITH MAYOR CONSUMPTION**
*(Countries with consumption levels above 2,000 ktoe/year)*



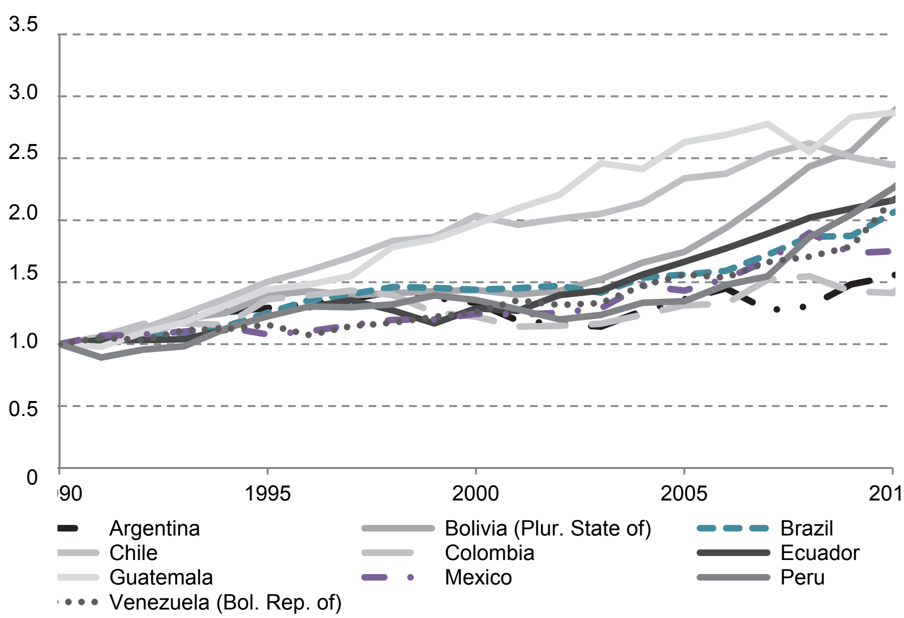

Source: prepared by the authors on the basis of OLADE data, 2013.

**FIGURE 26**
**ENERGY CONSUMPTION IN THE TRANSPORT SECTOR AS COMPARED TO CONSUMPTION LEVELS IN 1990 COUNTRIES WITH MINOR CONSUMPTION**
*(Countries with consumption levels below 2,000 ktoe/year)*




Source: Prepared by the authors on the basis of OLADE data, 2013.

**FIGURE 27**
**ENERGY CONSUMPTION IN THE TRANSPORT SECTOR AS COMPARED TO CONSUMPTION LEVELS IN 1990**
*(Countries with consumption levels above 2,000 ktoe/year)*




Source: prepared by the authors on the basis of OLADE data, 2013.

**TABLE 23**
**AVERAGE ANNUAL GROWTH RATES IN THE TRANSPORT SECTOR'S ENERGY DEMAND BETWEEN 1990 AND 2010**

| Country | Growht rate | Country | Growht rate |
|---|---|---|---|
| Panama | 7.0% | Venezuela (Bolivarian Republic of) | 3.9% |
| Costa Rica | 5.5% | Ecuador | 3.9% |
| Bolivia (Plurinational State of) | 5.4% | Brazil | 3.7% |
| Guatemala | 5.4% | Dominican Republic | 3.6% |
| Honduras | 5.1% | Guyana | 3.5% |
| Paraguay | 4.8% | Uruguay | 3.4% |
| El Salvador | 4.7% | Mexico | 2.8% |
| Chile | 4.6% | Jamaica | 2.7% |
| Suriname | 4.4% | Argentina | 2.2% |
| Nicaragua | 4.4% | Colombia | 1.7% |
| Peru | 4.2% | | |

Source: prepared by the authors on the basis of OLADE data, 2013.

## 2. The energy intensity of the transport sector in Latin America

The amount of energy used for transport, as discussed in the preceding paragraphs, is not an indicator of energy efficiency as such, which is measured as the relationship between the useful functions performed (moving people and cargo) and the consumption of energy vectors, such as fuels and electricity. The extent to which energy use is rational is actually determined by its level of energy efficiency strictu sensu, which is measured by the yield and operation of engines and vehicles combined with the system of roads, highways and storage and, at a higher level, with the need to transport, which may be re-evaluated with a view to reducing energy losses. In order to arrive at these kinds of determinations, information is needed on transport activities, the status of transport equipment fleets and trends in that regard, the condition of logistics infrastructure and other factors.

Given the transport sector's inherent complexity, physical indicators are needed in order to gauge its degree of energy efficiency. The indicators of choice measure its direct effects in relation to energy consumption and provide a clearer picture of trends in the physical productivity of the energy that has been used. One frequently used indicator that is recommended by the International Energy Agency (IEA, 2007) is energy consumption per ton of cargo/kilometer or passenger/kilometer that is transported. In addition, energy consumption is measured in tons/kilometers for the transport of freight in the ODYSSEE (Energy Efficiency Indicators in Europe) database, which was started up years ago by the countries of the European Union and region and also uses consumption indicators for transport by air, energy consumption measured in road car equivalents and the specific average consumption of automobiles (cars) (ADEME, 2008). The accuracy of these indicators obviously depends on the availability of consolidated national statistics on transport and energy.

One example of the trend in the transport sector's specific energy consumption in a Latin American country is depicted in the following figure, which is based on data for freight and passenger road transport in Brazil, where diesel fuel is virtually the only fuel used for transporting cargo but is not permitted in light vehicles. Since Brazil's energy balance (MME, 2012) disaggregates the consumption of diesel by mode of transport, with estimates of the percentage used for transporting passengers and statistics for transport activities (EPE, 2012), the specific consumption of freight transport by railway and by roadway can be estimated for the period 2003-2010, as shown in figure 54. The statistics show that transport by train consumes about 12 times less fuel than transport of the same amount of cargo by road.

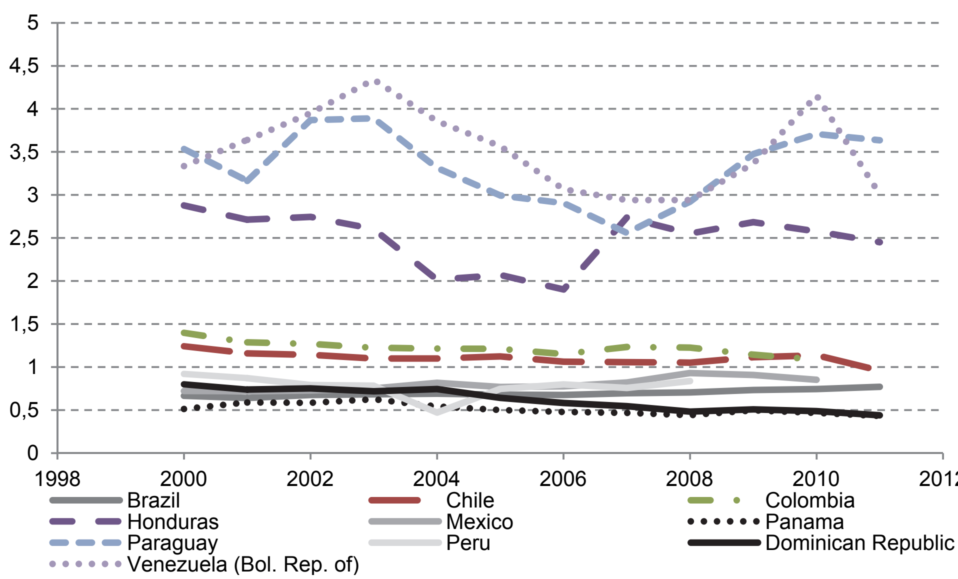
Although transport data are being compiled in some countries, physical indicators of cargo and passenger transport activities are unfortunately not yet available in any systematic or consolidated form for the Latin American countries. In order to work around this shortfall of data, which has been noted in earlier studies on energy efficiency indicators for the region (ECLAC, 2010), the sector's total energy consumption per unit of GDP will be used, given the fact that transport demand is closely correlated with economic activity. Thus, the indicator that we can construct, given the available data, is the quotient of the transport sector's energy consumption divided by the economic value added by this activity, or the sector's GDP.

It should be noted, however, that economically determined energy intensity poses some difficulties in terms of its interpretation and is of limited use in gauging the efficiency of energy consumption owing to the types of structural changes that occur within the sector in the course of inter-modal substitutions to meet transport demand and the very different specific consumption levels of different types of vehicles. An alternative indicator could be energy consumption divided by the vehicle fleet, with possibly a greater degree of disaggregation, but the problem here is that the indicator would not incorporate the average annual distance covered by those vehicles, which may vary a great deal and has a direct impact on energy consumption levels.

In order to determine the transport sector's energy intensity in the Latin American countries, information on the sector's energy consumption was taken from the SIEE database of OLADE. Data on the value added by the transport sector were initially obtained from the statistical databases of the Latin American Network Information Centre, which includes figures for a selection of Latin American countries. However, the procedures used to compile those data are such that the values for transport sectors/activities are often amalgamated with the figures for storage and communications in general, which makes it very difficult to determine exactly what part of those values corresponds to activities that are directly related to passenger and freight transport.

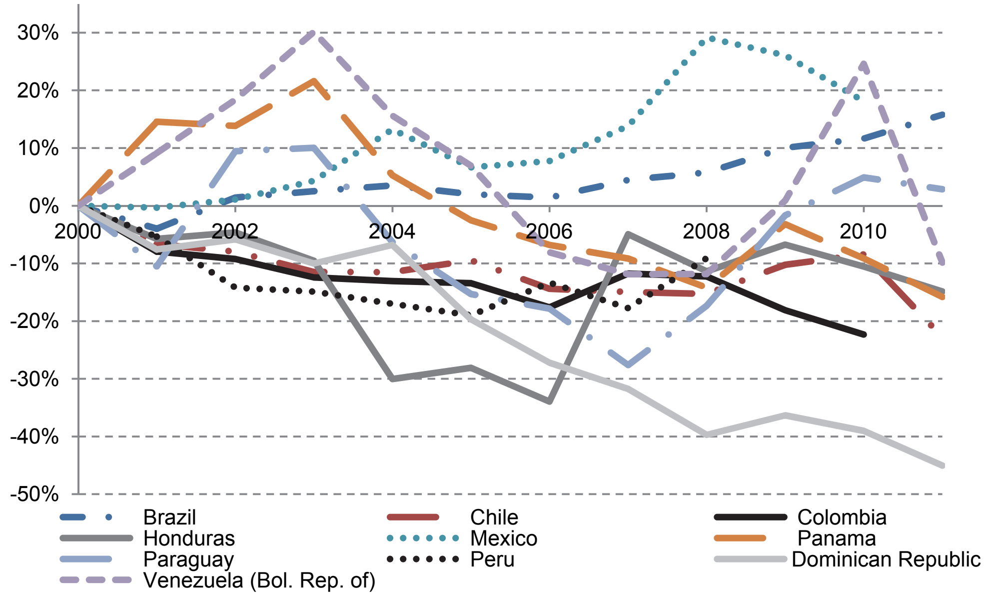
In view of this situation, the choice was made to use the sectoral data on value added provided in the Statistical Yearbook for Latin America and the Caribbean (ECLAC, 2012) as a single, standardized source. The values for the transport sector's energy intensity shown in figure 55 (absolute values, in koe/US$) and figure 56 (relative values for the year 2000) therefore refer to the 10 countries for which all the data could be obtained.

**FIGURE 28**
**ENERGY INTENSITY OF THE TRANSPORT SECTOR IN SELECTED COUNTRIES OF LATIN AMERICA AND THE CARIBBEAN**




Source: prepared by the authors on the basis of data from ECLAC, 2012, and OLADE, 2013.

**FIGURE 29**
**ENERGY INTENSITY OF THE TRANSPORT SECTOR IN SELECTED COUNTRIES OF LATIN AMERICA AND THE CARIBBEAN (RELATIVE VALUES FOR 2000)[a]**




Source: prepared by the authors on the basis of data from ECLAC, 2012, and OLADE, 2013.
[a] The 2004 value for Peru was corrected to rectify an obvious error in the data.

As the figure shows, most of the countries covered by this study have an energy intensity ranging from 0.5 to 1.3 koe/US$, with the exceptions being Honduras, Paraguay and the Bolivarian Republic of Venezuela, which have much higher values (between 2.5 and 4.1 koe/US$). Apart from methodological reasons, this could be signaling that those countries actually consume more energy, but it must always be borne in mind that the indicator of energy intensity as such reflects the overall economic productivity of energy use rather than energy efficiency in a technical sense. An analysis of the trend in this variable for individual countries, as shown in figure 26, is more straightforward. For the period under study (2000-2010), 7 of the 10 countries covered in this analysis exhibit a reduction in the energy intensity of their transport sectors, while the other 3 witnessed an increase: Brazil (+ 5%), the Dominican Republic (+ 12%) and the Bolivarian Republic of Venezuela (+ 18%). As noted above, however, this variation may be associated with changes in relative prices and other purely economic factors.

This brief overview of the economic measurement of energy intensity in the transport sector of the Latin American countries indicates that the sector's value added, as recorded in national accounts, includes only commercial transport activities and thus does not cover private transport, which accounts for a large part of transport activity in some countries. The transport sector's energy consumption is thus measured on the basis of divisions 60 - 62 of the International Standard Industrial Classification of All Economic Activities (ISIC) in accordance with the statistical procedures used in the region for the preparation of energy audits and balances (OLADE, 2011). The final figure for the transport sector's energy consumption therefore corresponds to the total amount of fuel needed to move passenger and freight vehicles encompassing the different modes of transports (road vehicles, railroads, airplanes, river craft and sea-going vessels). It should be noted that the figures for the transport sector's energy consumption cover the vehicles that take on and use fuel within the country's borders. They do not cover ships or aircraft that take on fuel for international voyages; that type of consumption is recorded under the heading of "bunkers".

Another methodological difficulty is posed by the portion of energy consumption represented by international passenger and cargo transport, which is usually categorized under the heading of "bunkers". This type of fuel consumption is a considerable factor for some countries and is recorded in various ways. There is a clear-cut disconnect between the significant levels of energy consumption involved and the supply of data on the transport sector, as the economic, physical and energy indicators in the available transport databases need to be systematized and standardized and to be disaggregated by modes of transport, uses (passengers, freight) and energy vector (diesel, gasoline, etc.). There are not many statistics on the make-up and age of the vehicle fleet, the decommissioning of vehicles, etc. that could help provide a clearer picture of how energy is used to move people and goods.

## 3. An assessment of the energy outlook for the Latin American transport sector

The absolute and relative intensities of energy use by the transport sector in the Latin American countries are determined by the exogenous factors of levels of economic activity, income levels and population growth and by the sector-specific factors of the distribution of modes of transport and their efficiency in a broad sense, which includes the technologies embedded in the equipment that is used, the level of use (load factors), the condition of the railway system and others. Although there are fairly few studies on the influence exerted by these factors, some trends in the Latin American countries can be discerned.

The rapid expansion of the vehicle fleet, particularly vehicles used for personal transportation, is a significant consideration. The increase in the number of automobiles per capita at a time when the roadway network has not kept pace with that expansion has turned mobility into a challenge and a high-priority issue in terms of comfort, transit times and air pollution for the governments of many cities, especially in Latin America. With traffic jams during rush hour nearly inevitable, the average commute time for workers totals several hours a day. Governments have sought to cope with this situation by taking steps to manage the private vehicle fleet. The measures they have used to encourage people to use public transit have included the introduction of urban toll roads and bans on driving in some areas and during some time periods, the designation of exclusive lanes for buses (bus rapid transport systems) in various Latin American cities as an adaptive replication of Curitiba's ground-breaking initiative, as well as the much more costly option of introducing and expanding subway systems. Other innovative approaches for mitigating mass transit problems in Latin American cities have been the construction of bike paths as an incentive for people to bike to work and of park-and-ride stations as a way of reducing private-vehicle traffic in the downtown areas of large cities.

Another evident trend in Latin America is that the use of diesel fuel by automobiles has been on the rise, chiefly because the price of diesel is usually lower than gasoline and because the use of sport utility vehicles is increasing as well and most of these vehicles use diesel-fuelled engines. In many cases, diesel fuel is cheaper because it is subject to lower taxes owing to the fact that it is usually used by vehicles that transport freight, mass transit passenger vehicles and agricultural equipment. The implications of this trend include an increasing imbalance between supply and demand for the various products of Latin American refineries, with an oversupply of gasoline and a deficit of diesel, and an increase in air pollution in cities, since diesel engines usually emit more soot and, depending on their configuration, sulphur oxides. For example, in Mexico, diesel engines are estimated to account for 26% of $CO_2$ emissions, to be the major source of particulate emissions (51% of PM10 and 60% of PM2.5) and the source of 50% of NOx emissions (SERMANAT, 2013).

A third environmentally significant trend that is evident in some countries is the expansion of the use of biofuels. While this trend is less widespread, it may eventually become a factor in other Latin American countries as well. Ethanol, most of which is produced from sugarcane, is regularly blended with gasoline in Argentina, Brazil (which also commonly uses pure hydrated ethanol as well), Colombia, Costa Rica and Paraguay, while biodiesel, which is produced from palm or soya oil, is used in Argentina, Brazil and Colombia. The particularly favorable climatic and soil conditions in the region for the production of biofuel crops suggest that the share of these economically competitive and environmentally desirable crops can be expected to swell, with the impacts of this trend in terms of local and global air quality being an open question.

# B. Programs and initiatives in Latin America to promote energy efficiency in mobility

A search for government programs focusing on promoting energy efficiency in transport in Latin America turns up some interesting –but very limited-- results. The nature, scope and expected outputs of the programs and initiatives that have been identified will be described in the following sections. The programs are grouped into categories on the basis of their main features in relation to driver behavior, vehicle use and vehicle technology. In some cases, these programs and initiatives have multiple objectives that are inherently complementary. The most efficient technologies are not always used in the most suitable way and vice versa.

## 1. Vehicle inspection and driver training programs

These types of programs are usually designed for drivers of commercial vehicles, such as buses and trucks. They assess the operational status of the vehicle engines (primarily diesel engines, for which they measure the air/fuel mix and pollutant emissions under different freight scenarios) and teach drivers how to drive more safely and in a more energy-efficient way by identifying energy and resource economies.

A number of Latin American countries have vehicle inspection programs that are specifically designed to reduce emissions and that have had immediate effects in terms of energy efficiency.

### a) Driver training and instruction programs (Brazil)

The Social Transport Service (SEST) and the associated National Transport Instruction Service (SENAT) are non-profit organizations that have been created and are run by transport companies in Brazil. They cover 124,600 enterprises and 824,000 independent transport workers, with 146 offices located throughout Brazil. SENAT regularly holds in-class and distance courses for transport company professionals to further their career development by providing them with on-the-job advanced training that will also promote occupational safety and traffic management.

Starting in 2007, courses in safe and energy-efficient driving techniques have been offered in the SENAT offices located in Espirito Santo, the Federal District, Minas Gerais, Paraná, Santa Catarina and São Paulo. The programme covers the main components and parts of transport vehicles and the definition of energy-efficient driving, along with its objectives, techniques, benefits and the procedures to be used. This 32-hour course can be provided to around 1,500 drivers per year. SENAT records show that over 24,000 passenger-vehicle drivers (54%) and freight vehicle drivers (46%) have been trained so far (SENAT, 2013).

The expectation is that a driver who has completed this course will be able to drive a vehicle properly and more safely while saving on fuel, reducing emissions and prolonging the working life of the vehicle. One spot-check indicates that fuel savings amounted to around 14% (SENAT, 2013).

A simpler-format 8-hour course focusing on environmental issues is also offered by SENAT (entitled “Environmentally Friendly Truckers”) and has been given to a total of 5,300 drivers. Talks for truckers and other drivers on energy-efficient driving have been attended by a total of 21,210 participants (SENAT, 2013). SENAT sees the most important challenge in this effort as being the promotion and consolidation of a behavioural change motivated by economic and environmental benefits.

The National Transport Confederation has been working with SEST/SENAT since 2007 to run an anti- pollution programme for drivers that focuses on vehicle inspections as a means of reducing the overall environmental impact of transport activity. Under this programme, a database has been created that provides information on 900,000 vehicle emissions evaluations that have been conducted for nearly 20,000 drivers, and a regular report on roadway transport environmental data is being issued. This report indicates that the average age of the vehicles in Brazil’s commercial transport fleet is 13 years and that 64% of the fleet is concentrated in four states: São Paulo, Rio Grande do Sul, Paraná and Minas Gerais.

Brazilian truckers cover an average of 125,000 km per year, with that rate declining as they age. Data relevant to measurements of energy efficiency include data on maintenance schedules, the use of devices to reduce aerodynamic drag, the percentage of empty-running vehicles (with an indication that the use of containers makes it possible to reduce the number of empty runs for roadway transport) and the impact of road quality on fuel consumption (CNT, 2013).

### b) Fuel conservation programs for transport companies (Brazil)

Established in 1991, the National Programme for the Efficient Use of Petroleum Products, Natural Gas and Biofuels (CONPET) is the Brazilian government's federal fuel efficiency programme and is executed by PETROBRAS, Brazil's government-run oil company. In recent years, CONPET developed two fuel-economy freight and passenger transport programmes (the Projeto EconomizAR and the Projeto TransportAR). They were suspended in 2011, but it is nonetheless interesting to look at how they were run and what outcomes they achieved.

The Projeto TransportAR sought to encourage fuel transport businesses and drivers to maintain their vehicles and to test the opacity of fuel emissions in order to reduce the level of black smoke that is released and conserve diesel fuel. The target population for this programme was transport operators that used the distribution terminals of the 11 PETROBRAS refineries. These refineries are located in nearly all the regions of the country but are concentrated in the central southern region. According to CONPET, between 2003 and 2008, it carried out 7,189 evaluations of the trucks of 400 companies; in 32% of those evaluations, the vehicles failed to meet the specified parameters, and the tune-ups that were done as a result are estimated to have resulted in a savings of 17 million litres of diesel fuel per year (CONPET, 2012).

The Projeto EconomizAR was set up in 1996 to provide technical support at no cost to freight and passenger transport companies and independent drivers in order to help them conserve diesel fuel and contribute to an improvement in air quality. This was a nationwide programme that was executed under an agreement between PETROBRAS (on behalf of CONPET), the Ministry of Mines and Energy, the Ministry of Transport and the National Transport Confederation (CNT). Its main outputs in 1996-2005 were: 1,750 participating companies, 48 mobile evaluation units (generally parked for several weeks at a time in high-traffic service stations located at strategic points along major highways), with 120,000 evaluations of 98,000 vehicles (buses and trucks).

In order to leverage the effectiveness of the vehicle evaluations, these stations also had an adjoining room where drivers could read pamphlets and watch videos that provided them with technical information about how to conserve fuel while they waited for their vehicles to be tested. The total annual energy savings is estimated at 252 millions of liters of diesel fuel, which equates with a reduction of 700,000 tons of $CO_2$ emissions per year (CONPET, 2012).

Unfortunately, these programmes were discontinued and CONPET is now reviewing its initiatives in this area. The objectives of this programme are still being pursued through the vehicle labelling programme, however, which will be discussed in a later section.

### c) Evaluation of driver training impacts (Brazil)

In early 2013, the municipal sanitation company of Rio de Janeiro, with support from the Federal University of Rio de Janeiro and SENAT, developed the COMLURB Eco-driving Project in order to gauge the energy-use impact of a training programme for drivers of garbage trucks and the trucks used to transport materials to waste treatment and recycling centres. A statistically representative sample of 21 drivers and 11 trucks was used. The designated drivers were in all cases using the same trucks on the same routes (D'Agosto, 2013).

Pre- and post-programme measurements of fuel consumption were taken for two different phases: the basic training phase (five hours of classes on theory and three having a more practical focus) and a phase in which discussions were held that focused on the importance of the profession, reasons for conserving fuel on a day-to-day basis, and participants' suggestions about ways to maintain vehicles and about working conditions. Company managers and decision-makers participated in this second phase.

This study produced some very interesting results. Compactor trucks' average fuel consumption actually rose by 7.7% (climbing from 1.42 km/litre of diesel to 1.31 km/litre) while the dispersion of fuel use rates narrowed dramatically, with this trend being associated with a reduction in the fuel consumption of what had been the less efficient vehicles before the programme was up and running. A 13% reduction in fuel consumption was registered for garbage trucks, whose fuel use dropped from 1.73 km/litre to 1.96 km/litre (D'Agosto, 2013).

According to the authors of the study, the expectation is that the continued implementation of these training programmes will lead to fuel savings for all types of trucks. Whether this is borne out or not, the results clearly point up the importance of careful planning and the potential and limitations of driver training programmes.

#### d) Clean Transport Programme (Mexico)

Since 2007, the Ministry of the Environment and Natural Resources of Mexico (SEMARNAT), in cooperation with the Ministry of Science and Technology, has been running the Clean Transport Programme, which focuses on promoting energy efficiency, competitiveness and more environmentally friendly practices in the transport sector. The target groups have been private and public freight and passenger transport companies specializing in urban and/or international routes and users of freight services that could increase the demand for environmentally sound freight services. Fuel savings are therefore just one of the many benefits to be derived from initiatives to promote energy efficiency.

The next table lists the various measures that are being promoted and the associated potential energy savings. These measures have to do with driver behavior, maintenance and different technologies (SEMARNAT, 2013).

**TABLE 24**
**THE CLEAN TRANSPORT PROGRAMME: MEASURES AND EXPECTED ENERGY IMPACTS**

| Measures | Potential fuel savings |
|---|---|
| Use and driving strategies | |
| Training of operators in technical-economic driving | 10 - 30% |
| Regulation of maximum speed | 5 - 10% |
| Reduce unnecessary motor use | minimum 5% |
| Selection and specification of vehicles | variable to 30% |
| Maintenance | 7 - 15% |
| Fuel control | minimum 5% |
| Technological measures | |
| Aerodynamic improvements | 5- 10% |
| Single wide-base tires | 3% |
| Automatic inflation systems for tires | 1% |
| More advanced lubricants | 1,5% |
| Emission control devices | variable |

Source: prepared by the authors on the basis of data from SEMARNAT, 2013.

This programme provides businesses four different types of support:

- It provides technical assistance, including operator training and entrepreneurial consultancies;

- It liaises with suppliers in order to open up access to efficient technologies;
- It reduces the cost of imported equipment thanks to an agreement reached between the Ministry of Economic Affairs and the Ministry of the Environment and Natural Resources under which clean-technology capital goods can be imported tariff-free;
- It evaluates the activities and reports on their results on the basis of a yearly survey and offers an informative web page.

The Clean Transport Programme has used the Fleet Model as a guide for its implementation and operation. This model was developed by the Environmental Protection Agency of the United States as part of the Smart Way Transport Partnership (EPA, 2013) and involves the following stages: (1) interested businesses send a membership request letter, (2) these businesses fill out a questionnaire, (3) SEMARNAT uses the information provided on the questionnaire to assess the businesses' status on the basis of an environmental performance model similar to the Fleet Model, (4) applicant firms develop a three-year action plan, and (5) the participating firms produce a progress and output report each year (SEMARNAT, 2013).

At the end of 2011, there were 118 businesses participating in the programme, with those businesses accounting for a total of 16,561 trucks on the road. The annual $CO_2$ emissions of that fleet in 2011, as estimated using the baseline conditions, is calculated at 2,259,400 tons; an estimation based on the improved scenario of transport conditions lowers the estimate to 1,663,200 tons, for a reduction of 596,200 tons of $CO_2$. This is equivalent to a 26.4% reduction in those emissions, which can be equated with a similar savings in fuel consumption (SEMARNAT, 2013).

The directors of the Clean Transport Programme believe that inculcating technically and economically sound driving techniques is one of the strategies that generates the best cost/benefit ratio. Drivers learn to use progressive shifting techniques, optimize engine speed, brake and accelerate smoothly, drive defensively and keep their speed in check. A three-stage methodology is used in this programme: at first, there is a "free-driving" circuit, where the drivers drive as they usually do and their fuel consumption is measured; during the second stage, the drivers are given a presentation on the theory of technically and economically sound driving techniques; in the third stage, they then cover the same circuit, with fuel consumption being measured, but this time they apply the driving techniques that they have been taught. The Clean Transport Programme has given 21 courses of this kind to 300 people from 90 different companies and has achieved fuel economies of between 6% and 50% (SEMARNAT, 20133).

The next steps that are planned in order to expand and consolidate this programme are to adapt the Model Fleet for use in estimating transport-related energy savings, to make this evaluation model available online, to build the programme's communication resources, to create a green transport label (in order to identify the companies that pollute the least), to further develop the urban component of the programme and partner with state governments, and to create a nationwide network of trainers.

#### e) Programmes to promote efficient vehicle technologies

Whereas driver training programmes focus on changing attitudes and behaviours, efficient technology programmes can produce results without involving drivers to any great extent. These programmes for the development and introduction of more efficient technologies tend to be more costly, however, and it may therefore be necessary to have promotional and marketing arrangements that may entail the levying of special taxes.

#### f) Vehicle labelling programmes and performance standards (Brazil, Chile and Mexico)

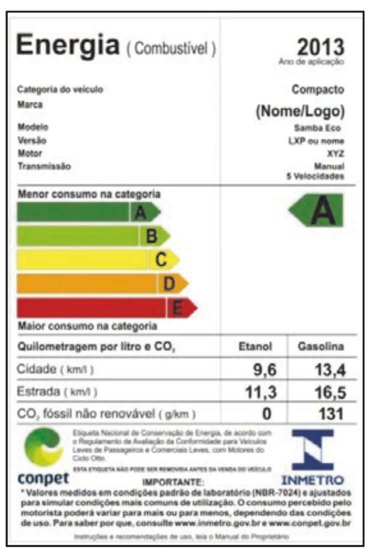
In view of the positive results of the large number of energy-efficiency labelling programmes that have been introduced for home appliances, some years ago the United States and the European countries introduced labelling programmes for light motor vehicles and, more recently, for heavy transport equipment. Latin America does not yet have a great deal of experience in this area, but some countries are launching initiatives of this type. These programmes are primarily using a consolidated system for the evaluation and certification of efficiency levels for the different categories of vehicles, and they provide a clear delineation of the options for improved performance and their implications. These energy efficiency programmes are closely linked with environmental programmes focusing on reducing emissions.

#### g) The Brazilian Vehicle Labelling Programme

Brazil's energy-efficiency labelling programme was launched in 1984 and has gained acceptance among consumers and the market in general, but for quite a long time its scope was limited to electrical appliances such as refrigerators and electric motors. It was not until 2007 that labels were introduced that provide information on the energy efficiency of fuel-consuming appliances such as stoves and gas-powered water heaters under a cooperation agreement between the National Meteorological and Industrial Standardization and Quality Institute (INMETRO) and CONPET, a programme of the Ministry of Mines and Energy. Following a number of studies beginning in 2004 (CONPET, 2005) and protracted negotiations concerning the standardization of vehicle fuel-efficiency tests and classifications, the Brazilian Vehicle Labelling Programme for light motor vehicles was finally launched in 2008. At first the programme was voluntary, but mandatory adherence has been being phased in since 2012, and, under the existing regulations, the programme will be in place for the whole of the motor vehicle industry by 2017. The government agencies that will be involved in this venture are INMETRO, CONPET, the National Petroleum, Natural Gas and Biofuels Agency (ANP), the Brazilian Environmental and Renewable Natural Resources Institute (IBAMA), the Environmental Company of the State of São Paulo (CETESB) and the PETROBRAS Research Centre (CENPES), together with all members of the Brazilian motor vehicle industry, both directly and through its associations, the National Association of Motor Vehicle Producers (ANFAVEA) and the Brazilian Association of Motor Vehicle Importers (ABEIVA).

In the labelling system used in this programme, as shown in figure 60, vehicles are classified by their level of energy efficiency, with the categories going from category A (the most efficient) to E (the least efficient). Fuel consumption levels for both urban driving and highway driving are determined and, depending on the model; include the fuels usually available in Brazilian service stations: petrol (with 22% ethanol), pure hydrated ethanol and/or compressed natural gas (CNG) (the latter being restricted to vehicles that have been designed to use it).

**IMAGE 4**
**VEHICLE ENERGY EFFICIENCY LABEL USED IN BRAZIL**




Source: INMETRO, 2012.

Consumption levels are reported in absolute terms and in comparative terms relative to other vehicles in the same category. The categories may be: subcompact, compact, medium-sized and large, sports vehicles, off-road, sports utility, minivan, commercial freight and commercial passenger vehicles. This labelling scheme has been in development for several years and new categories have been being added, such as fossil-fuel $CO_2$ emissions (ethanol fuel emissions are not included).

Consumption level ratings and other data for the test vehicles are available on the INMETRO and CONPET websites. These parameters are measured and set on the basis of the ABNT NBR 7024 technical standards, which are similar to those used in the United States and include rolling road tests for urban areas (Federal Test Procedure, FTP 75) and highways (Highway Driving Cycle). These driving cycles, as shown in the next figure, are linked to different speeds and operational conditions. The load on the dynamometer used for the rolling road tests is determined on the basis of the resistance of the rolling stock to displacement. The calibration of the dynamometer has to dovetail with the on-road resistance coefficients in accordance with the ABNT NBR 10312 technical standard so that the measurements will accurately reflect the full force required for locomotion, taking into account such factors as aerodynamic drag, for example. Because of these types of considerations, a consistent set of standards is required in order to implement a performance labelling programme.

Optional components, such as air conditioning, that influence energy consumption and that have a sales forecast of over 33% of the sales of the units of a given model must be included in the model's evaluation. In order to monitor the fuel consumption levels published by manufacturers, each year INMETRO selects one unit of any vehicle produced by each participating manufacturer at random and runs the tests used to measure consumption. Values up to 10% higher than the declared consumption level are acceptable.

The fourth version of the fuel-efficiency label, issued in 2012, is used by eight manufacturers: Fiat, Ford, Honda, Kia, Peugeot, Renault, Toyota and Volkswagen. They account for a total of 157 versions of 105 models, which represent 55% of the automotive industry's sales in Brazil. Under the laws now in force, all vehicles and models will have to bear fuel efficiency labels within the next five years.

**IMAGE 5**
**THE CONPET SEAL AWARDED TO THE MOST FUEL-EFFICIENT VEHICLES IN EACH CATEGORY IN BRAZIL**


Source: CONPET, 2012.

In addition to the label, a CONPET seal is affixed to the most highly rated models (see figure 51). The seal shows the ratings that appear on the label and directs consumers' attention to the best vehicles in each category (CONPET, 2012). For light vehicles, INMETRO and CONPET are in the process of developing a tire labelling programme that will evaluate the tires' contribution to energy efficiency (i.e., lower rolling resistance) and the safety rating of the vehicles that use them. Labelling for the tires used by heavy vehicle (such as trucks) is also being developed.

### h) The Chilean Vehicle Labelling Programme

In 2010, the Ministry of Energy, the Ministry of Transport and Telecommunications, and the Ministry of the Environment partnered with the National Automotive Association of Chile (ANAC) – which represents the automotive models present in the Chilean market-- to launch a labelling programme for light vehicles (less than 2,700 kg) which have been certified since January 2008. The label (see figure 52) began to be used on a voluntary basis in September 2012 and was to become mandatory as of February 2013.

**IMAGE 6**
**VEHICLE FUEL-EFFICIENCY LABEL USED IN CHILE**


Source: ME, 2013.

The label used in Chile provides information on vehicle fuel consumption (km/litre) in city driving, highway driving and a mixture of the two and on $CO_2$ emissions (expressed in g/km). This information is provided by the Vehicle Certification Centre (3CV) of the Ministry of Transport, which runs laboratory tests under controlled driving conditions in order to obtain these measurements. By law, this label must be affixed to the windshield of vehicles on display in sales lots and must be visible to the public at all times (ME, 2012).

The label states that the efficiency rating is a standard rating only, since actual fuel consumption will depend on each person's driving habits and on the frequency of vehicle tune-ups and other maintenance. Environmental and geographical factors also influence vehicle performance. The programme's web page offers a QR-enabled vehicle comparison function that can be used to compare the fuel efficiency ratings of different models (ME, 2013).

Since the programme was launched so recently, no results or indicators are yet available, but it is noteworthy that it has been mandatory from the very start and therefore has a greater potential for bringing about change.

In Mexico, the National Sustainable Energy Programme for 2009-2012 is based on recognition of the fact that there is a large gap between the predominant technologies in use and the most efficient technologies currently available in this high-priority sector. The two-pronged programme focuses on improving vehicle performance and improving driving practices and is thought to have the potential to reduce transport-vehicle fuel consumption by between 18% and 26% from the current benchmark levels (Government of Mexico, 2009).

In keeping with this approach, the Mexican government prepared a preliminary draft version of a vehicle performance and emissions standard with the help of government and civil society organizations, including the Ministry of Economic Affairs, the Ministry of Energy, the Ministry of the Environment and

Natural Resources, the Ministry of Commerce and Industry, the National Ecology Institute, the Mexican Automotive Industry Association (AMIA) and CTS-EMBARQ Mexico (a Mexican NGO that works in the areas of mobility, mass transit, urban development, climate change and air quality). This draft was circulated in May 2012 and submitted to the three national consultative committees on standardization that deal with the environment and natural resources, the conservation and sustainable use of energy resources, and user safety and commercial information and practices, respectively. This wide-ranging consultative process produced a draft fuel efficiency and $CO_2$ emissions standard for new light-duty vehicles (Government of Mexico, 2013) which was submitted for consultation with the public at large in February 2013. In June 2013, the comments received and the responses formulated by the corresponding agencies were circulated, and the draft standard is therefore in the final stages of discussion and approval.

Based on an evaluation and certification standard similar to that of the Corporate Average Fuel Economy (CAFE) regulations, which have been used in the United States since 1975, the Mexican regulations set out values and parameters for the calculation of targeted levels of $CO_2$ emissions for each manufacturer or importer that sells or will sell new light-duty vehicle models for 2014, 2015 and 2016. The methodology used for these calculations is aligned with the United States regulations, as follows:

- It sets sales-weighted averages weighted using a shadow value (vehicle size);
- It defines separate benchmarks for two categories: passenger vehicles and light trucks;
- It uses CAFE formulas for calculating projections of $CO_2$ emissions and the equivalent fuel efficiency levels;
- It includes the following flexible parameters: systems for earning credits (for example, credits for using improved air conditioning equipment), for building up credits for 2014 - 2016, and for swapping credits between different vehicle and assembly categories;
- It includes alternative benchmarks for niche companies, small-scale producers and exporters.

According to this standard, the average consumption benchmark for the fleet of new vehicles is 14.6 km/litre for 2016. Since average fuel consumption in 2011 for the fleet of new light vehicles was 13.1 km/litre, achieving this target figure would entail reducing specified emissions by nearly 11% over a span of five years. These regulations are expected to result in a reduction in consumption of 35 million litres of fuel per year, which equates with a reduction in annual $CO_2$ emissions of 13.2 million tons; the resulting reduction in air pollution is expected to yield significant public health benefits (ICCT, 2013). The fit between this standard and the United States standard is depicted in which gives fuel consumption values for various countries based on the standardized CAFE test cycle.

Increases in vehicle efficiency come at a cost, however. In the case of Mexico's programme, it is estimated that the average price of a vehicle could increase by as much as 4.7% in 2014 as a result of the entry into force of Fuel Efficiency Regulation No. 163, according to the Ministry of the Environment and Natural Resources, while the Federal Regulatory Commission puts the increase in the price of motor vehicles as a consequence of the implementation of this regulation at 6.30% for subcompacts, 3.80% for compacts, 2.58% for luxury models, 2.66% for sports vehicles, 3.6% for small multi-purpose trucks and 5.23% for light trucks (Reforma, 2013). These price increases will very probably be offset by the associated fuel savings, however.

An overview of the major features of existing fuel-efficiency programmes in Latin America is shown in table 25.

**TABLE 25**
**VEHICLE EFFICIENCY ASSESSMENT PROGRAMMES IN LATIN AMERICA**

| Country | Start | Mode | Character | Motivation |
|---|---|---|---|---|
| Brazil | 2008 | Label | Progressive | Energy and environment |
| Chile | 2010 | Label | From start | Energy and environment |
| Mexico | 2012 | Targets for enterprises | Not defined | Energy and environment |

Source: Author´s elaboration.

### i) Taxation of efficient technologies

One way of encouraging people to adopt efficient technologies is by introducing differentiated taxation schemes. This is being done in a number of countries, where higher taxes are levied on higher-powered (and therefore generally less efficient) vehicles. In addition to such schemes, fuel efficiency can also be promoted by setting up a tax structure that provides lower rates or rebates for users who meet established performance targets. This has been done under the Inovar-Auto Programme in Brazil, for example, since May 2013.

The automotive industry is a major sector of the Brazilian economy and includes a diversified range of manufacturers (end-product firms) and makes and an extensive production chain for parts and services. In 2000, there were 15 different manufacturers; today, there are 49 North American, European and Asian manufacturers that produce over 2.6 million vehicles annually. Lower tax rates on less powerful vehicles (ones with engines of less than 1,000 cc) drove up sales of these types of models from less than 4% of the market to more than 70% between 1990 and 2001. However, the reduction of this tax stimulus after 2001 and the automotive industry's promotion of models with larger engines had shrunk these less powerful vehicles' market share to around 40% by 2012 (Façanha, 2013).

In response to this situation, an effort has been made to promote the introduction of more efficient automotive technologies that will be more competitive while spurring a more environmentally sound form of energy use. In September 2012, the Brazilian government promulgated Act No. 12.715, which provided for the establishment of the Inovar-Auto Programme. This initiative focuses on providing incentives for technological innovation and the densification of the automotive production chain. Implementing regulations were later introduced by Decree 7.819 and Decree 8.015. The objective of the programme is to implement technological innovations in the automotive industry that will improve vehicle fuel efficiency over the period 2013-2017. As an incentive for innovation, tax reductions of up to 30% for the main tax on Brazilian-made and imported vehicles (the manufactures tax, known by its Portuguese-language acronym of IPI) are offered, as shown in table 4. As may be seen from the table, the 2012 tax rates were not lowered by any appreciable amount, but, if certain conditions are met, the rate will then be held to that level.

**TABLE 26**
**IPI TAX RATES ON MOTOR VEHICLES IN BRAZIL**

| Capacity | IPI before 2012 | IPI after 2012 |
|---|---|---|
| Less than 1 000 cc | 7% | 37% |
| Between 1 000 and 2 000 cc, ethanol or flex-fuel | 11% | 41% |
| Between 1 000 and 2 000 cc, gasoline | 13% | 43% |
| More than 2 000 cc | 25% | 55% |

Source: Prepared by the authors based on Façanha, 2012.

In order for companies to access the benefits provided under the Inovar-Auto Programme, they have to meet a series of productivity and efficiency targets and obtain accreditation from the Ministry of Development, Industry and External Trade and the Ministry of Science, Technology and Innovation. The efficiency targets are progressive, ranging from fuel-consumption reductions of between 12% and 19% (currently around 2.05 MJ/km). Consumption is measured using the same methodology as the one used for Brazil's vehicle labelling initiative, as described earlier, which uses average values for consumption weighted by the tonnage of vehicles sold in Brazil by accredited firms based on an approach similar to the one used in the CAFE regulations.

The Inovar-Auto target figures are in line with those used in Europe for 2015 (130 g of $CO_2$/km) following their adaptation to Brazil in order to take account of differences in driving cycles, fuel and highway specifications (ICCT, 2013). The reductions in emissions that the Inovar-Auto Programme is expected to produce for different scenarios in terms of the penetration of more efficient technologies are shown in the next figure, which provides indications of the projected contributions to greater fuel efficiency of the Inovar-Auto Programme and other similar initiatives. It is to be hoped that the combination of different tools, such as the labelling programme and differentiated tax rates, will prove to be a decisive factor in boosting the efficiency of the vehicle fleet and reducing emissions.

#### j) Evaluation of the use of fairings and spoilers on trucks (Chile)

Reducing aerodynamic drag by placing aerodynamic fixtures on trucks increases the efficiency of freight transport vehicles. A study conducted in Chile by the Latin American Centre for Innovation in Logistics (CLIL) of Andrés Bello University indicates that the use of fairings and spoilers can result in a fuel savings of as much as 15% for highway cargo vehicles. Four different combinations of devices were tested that included cab-overs, lateral fairings for truck-trailers and spoilers. Fuel savings were estimated at between 12%, for the most elementary device package, and 16%, for the most complete one. This reduction could result in an annual savings of about 9,944 litres of fuel per truck; the corresponding investment would be amortized within 8 to 11 months (Contreras, 2013).

Substantive outputs of this study include the establishment of a strict standardized testing procedure in Chile for measuring the potential fuel savings afforded by aerodynamic devices, tires, cabin and trailer-truck designs and types, lubricants, etc., and the development of the National Standardization Institute (INN) NCh3331 standard for testing road vehicle fuel consumption.

### 2. Overview of freight vehicle fuel-efficiency programmes

The following table outlines the main features of the programmes reviewed in this study.

**TABLE 27**
**OVERVIEW OF SELECTED FUEL-EFFICIENCY PROGRAMMES IN LATIN AMERICA**

| Programme | Responsible institution | Estimated impact |
|---|---|---|
| Inspection and driver training programmes | | |
| Training and information of drivers programme | SEST/SENAT (Brazil) | Aprox. 14% energy saving per trained driver |
| Fuel savings programme for transport businesses | CONPET (Brazil) | Anual saving of 252 millones liters of diesel (2012) |
| Impact evaluation of driver trainings | COMLURB (Brazil) | Savings up to 13% |
| Clean transport project | SEMARNAT (Mexico) | Savings of 26,4% of fuel consumption |
| Promotion of efficient vehicle technologies programmes | | |
| Labelling and efficiency norms programmes | Institutions in Brazil, Chile and Mexico | For Mexico saving of 35 million liters of fuel per year, no evaluations are available for Brazil and Chile |
| Taxes based on adoption of efficient technologies | MDIC and MCTI (Brazil) | Between 19 and 34% fuel savings |
| Evaluation of spoilers on trucks | CLIL (Chile) | Potential savings between 12 and 16% of fuel consumption |

Source: Author´s elaboration.

## C. Outlook and conditioning factors for fuel-efficiency programmes in Latin America

Initiatives for the promotion of fuel efficiency in the Latin American transport sector are still limited, and there is substantial scope for their expansion, especially in view of the fact that this sector's energy consumption levels account for a large percentage of total energy demand. In addition to their expansion, more synergies can be sought between fuel-efficiency programmes and other associated initiatives, such as those focusing on emissions reductions (with local and global assessments of the benefits), the development of the industry and productivity gains, a secure energy supply, urban development, mass transit and road infrastructure.

Although in many cases it is known that such synergies exist, especially in relation to environmental factors, there is clearly much more that can be done to take advantage of the links between various energy-related issues and other aspects of the promotion of energy efficiency. For example, the roadway development plans in major cities of Latin America that provide for dedicated bus lanes (bus rapid transit (BRT) systems) contribute to an improvement in transit systems in those cities, a reduction in emissions and the consequent improvement in air quality, and they are also associated with a decline in the use of private vehicles and, hence, a reduction in inefficient forms of fuel consumption.

In conjunction with this brief review of some of the fuel-efficiency programmes that are being implemented or developed in Latin American countries, emphasis should be placed on the need for these programmes to take users into account at all times, since rational energy use is, and will always be, the combined result of technology and the way that it is used. Innovations such as electric vehicles should be taken into consideration and have received a great deal of attention in many countries, but it is important for them to be analysed from an overarching perspective in order to gain an accurate pictures of their advantages and implications.

Clearly, the transport sector will not achieve greater fuel efficiency without the decisive support of the government as a source of strategies and an agent of change. In line with this reality, the issues discussed in the preceding section in connection with fuel-efficiency programmes in some Latin American countries focus on the inculcation of suitable behaviour patterns and more efficient technologies. The implementation of programmes of this sort can and should be considered by all the countries of the region, but they should also make sure that essential conditions and suitable institutional structures are in place, since they will be needed in order to propose, develop and implement these kinds of initiatives. The overall situation at this point is, however, suboptimal. Major changes and clear-cut government decisions are needed in order to achieve an efficient level of energy use that will serve the needs of society at large.

An in-depth ECLAC study on energy efficiency in the countries of the region has identified three major challenges (ECLAC, 2009):

- In many countries, political shifts have triggered widespread uncertainty about the regulatory environment and this, in turn, makes it more difficult to determine whether long-term investments (such as many of those required for the implementation of projects designed to boost fuel efficiency) will be feasible or not;
- The fact that many countries of the region are energy exporters and/or control the energy services market acts as a disincentive, in many cases, for the investments in energy efficiency needed to reduce consumption, since the taxes on energy consumption are an important source of revenues whose political cost is very low;
- Because of the fairly clean energy mixes used in a number of the countries of the region (which include hydroelectricity and biofuels), the environmental impact of energy use is a less serious consideration.

These factors notwithstanding, initiatives for promoting energy efficiency are in place in a number of countries. The analysis of these different projects has served as a basis for a series of in-depth conclusions concerning the obstacles that need to be overcome (ECLAC, 2009):

- The status of energy-efficiency projects, programmes and initiatives varies markedly from one country to the next. Institutional conditions play a crucial role;
- It is neither possible nor desirable to simply copy the regulations developed by other countries. Initiatives have to be tailored to the conditions in each country;

- In a number of countries, the lack of continuity in the implementation of energy efficiency measures has been a critical factor and has led to the loss of the services of experienced technical teams. Putting together and maintaining teams of well-trained local experts who are qualified to manage national energy-efficiency programmes takes time and continued effort;
- In most of the countries, there are no local lenders that specialize in energy-efficiency programmes;
- It is difficult to monitor the outputs of an energy-efficiency programme, and the introduction of performance benchmarks for this purpose is of key importance in each and every country of the region;
- The mere existence of laws or regulations under which efficient energy use is mandatory is no guarantee that a national energy-efficiency programme will be a success;
- In many cases, national energy-efficiency programmes are still overly reliant on international assistance. The volatility of energy prices is beginning to spur the appearance of local energy-efficiency investments and initiatives, however;
- Even though numerous studies have been conducted on barriers to the transmission of information to energy consumers, those barriers are still quite formidable.

With regard to the institutional framework, although a number of countries do have agencies or ministerial divisions that work to promote energy efficiency, they are almost exclusively concerned with the end uses of electricity and devote scant attention to the transport sector. The way in which this sector is organized, with a wide range of modes of transport and types of equipment, different types of users and different end uses, makes the promotion of energy efficiency in the transport sector all the more challenging. Some of the specific types of problems that have to be addressed include: (a) fuel price structures, which are seriously distorted in some countries, with little correlation between consumer prices and actual production/import costs, make it difficult to gauge the savings that would be obtained from reducing energy losses; (b) the limitations that hinder the promotion of more efficient public transit systems create a situation in which the use of inefficient private vehicles becomes the option of choice; (c) the countries lack laboratories that are equipped to evaluate motor vehicles; and (d) there is a significant proportion of used imported vehicles in the vehicle fleet of some Latin American countries.

The shortage of laboratories that are equipped to measure energy efficiency can be mitigated to some extent by using direct vehicle emissions measurements, since there is clearly a close correlation between fuel performance and environmental considerations in the transport sector. For example, studies on the use of adjustments in fuel specifications, vehicle inspection programmes and the introduction of more efficient vehicles as ways of reducing vehicle emissions in Colombia have furnished valuable inputs for the development of more precisely targeted energy-efficiency initiatives (Clean Air Institute, 2010).

Since the transport sectors in neighbouring Latin American countries have, in many cases, similar consumption structures and face similar problems, there is a great deal of scope for cooperation in the development of regulatory schemes, the implementation and evaluation of energy-efficiency programmes, and exchanges and training of programme managers. The monitoring and assessment of the outputs of initiatives aimed at boosting the efficiency of transport systems is a field in which cooperative efforts can be especially effective in developing and testing methodologies, designing indicators and drawing comparisons (ECLAC, 2010). It would therefore be useful to determine how long-lasting the effects of training and economic counselling programmes are and how their outputs can be consolidated in the short term. Another line of enquiry has to do with the driving cycles as they actually exist in Latin America, where urban and highway driving patterns differ substantially from those of the cycles that are currently used in research. These latter cycles provide a standardized framework for comparisons, but they may also yield unrealistic impact estimates.

The widespread and growing availability of efficient, innovative technologies –ranging from hybrid light- and heavy-duty vehicles to more sophisticated, energy-saving lubricants and deflectors that reduce trucks' aerodynamic drag— underscores the importance of ongoing efforts to encourage users to adopt these devices. At the same time, efforts need to be directed towards the promotion of good driving practices, maintenance programmes and logistical optimization studies so that existing technologies can be used correctly. Be this as it may, the greatest energy savings of all is no doubt afforded by an avoidance of the need to move people and cargo through the use of intelligent ICT alternatives, the reorganization of production activities and distribution systems, changes in use patterns, etc.

Energy efficiency, defined as the extent of the useful effects produced by the consumption of a given unit of energy, is independent of the capacity of the vehicles that are used, which may be much greater than the capacity required for normal conditions of use. For example, a vehicle equipped with an excessively powerful engine consumes much more than other vehicles do to achieve the intended purpose of transporting people and goods. The widespread use in urban areas of high-powered, heavy sport utilities vehicles (SUVs) by people who are driving alone or those carrying just a few passengers in urban areas squanders so much energy that it would be extremely difficult to counterbalance that waste through the use of efficient technologies.

The predominant development model in Latin America, which involves a heavy concentration of people and economic activities in large metropolitan areas and a rising number of people who drive their own cars while dealing with increasingly bad traffic conditions, calls for an exploration of what might be more sustainable alternatives whereby the transport system could serve as a factor of production and well-being rather than an ongoing source of environmental impacts, challenges for planners and high costs for society.

## D. The potential impact of increased energy efficiency in mobility

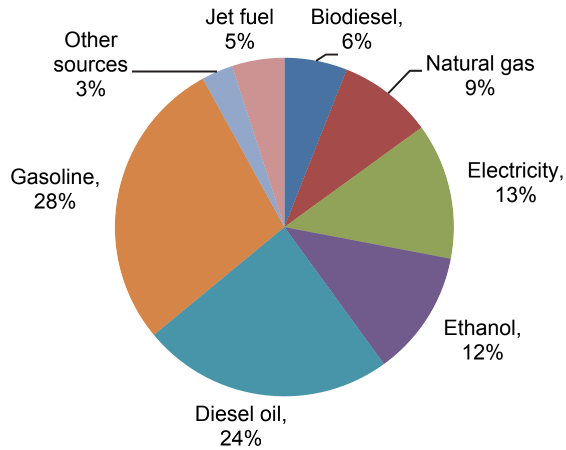
In rounding out this review of the present situation and outlook for energy-efficiency programmes in the transport sector of Latin America, it may be useful to try to gauge the contribution that such programmes could make to energy conservation if more effective measures for achieving energy efficiency in mobility are adopted. These kinds of estimates can feed into the Sustainable Energy for All (SE4ALL) initiative, which is focused on doubling global energy efficiency by 2030 (United Nations, 2013).

With this in mind, an assessment of the region's potential for promoting energy efficiency in the transport sector was conducted by the Latin American Energy Organization (OLADE), which simulated the adoption of energy efficiency measures in the transport sector as of the year 2030. This was done with the help of the Simulation and Analysis of the Energy Matrix (SAME) model, which was used to compare a projected scenario based on existing conditions (the baseline scenario) with a simulated scenario in which changes had been brought about by concrete modifications in development policies and possible technological advances (OLADE, 2013).

The baseline scenario was set at 2011, the most recent year for which the OLADE Economic Energy Information System has complete, validated datasets. In that year, the total final consumption of the transport sector in Latin America was 211 million toe, or 35% of total final energy consumption in the region. The figures used for projecting the region's energy consumption were based on an average annual growth rate of 3.3% starting from 2011, which corresponds to an 85% increase in energy flows for 2011-2030. This fits in with the estimates prepared by the International Energy Agency, which projects that energy demand in the Latin American region could double by 2030 (IEA, 2012).

A summary table of the results is provided in the next figure which shows that the introduction of efficient technologies and an increased use of innovative energy vectors such as biofuels and electricity in the transport sector could alter the energy matrix and lower energy consumption by 102 Mtoe per year; in that simulated scenario, energy demand would be 26% less than it would be in the projected scenario.

**FIGURE 30**
**STRUCTURE AND FINAL DEMAND FOR ENERGY IN THE TRANSPORT SECTOR IN LATIN AMERICA AND THE CARIBBEAN IN 2030**




Source: prepared by the authors on the basis of OLADE, 2013.

Total annual emissions of $CO_2$ for the transport sector in 2030 could be reduced by 32%, from 582.6 Mt $CO_2$e to 394.4 Mt $CO_2$e.

The extent and feasibility of a scenario of greater energy efficiency can be gauged by referring back to the consumption and energy-intensity values cited in the introductory section of this study and then assuming that the lowest of those levels are achieved. Caution is called for when using this type of assessment, however, because what may appear to be significant variations across countries or within a country across a given time period may instead be the result of changes in the economic system that are not directly linked to efficiency as such.

The most reliable results on the promotion of energy efficiency in the transport sector indicate that the most effective efficiency-boosting methods are associated with well-designed technological changes in equipment, logistics systems, transport route infrastructure, and more sustainable use and maintenance approaches.

# VII. Energy efficiency in international mobility options between Buenos Aires, Argentina and Montevideo, Uruguay

## A. Introduction

Today, almost 80% of the population in Latin America lives in urban centres and is projected to reach 90% in the coming decades. Almost 60 cities in LAC have more than a million inhabitants, including four "megacities" (with more than 10 million inhabitants) and 23 cities with more than 2 million inhabitants, all of them with an above average population growth in comparison to their respective countries (OMU, 2010).

This chapter focuses on the analysis of energy consumption and mobility patterns of passenger and goods between the two capitals of Argentina and Uruguay - Buenos Aires and Montevideo.

## B. Socioeconomic context and general data on mobility

Argentina and Uruguay share 495 km of border. The capitals Buenos Aires and Montevideo are located on the western and northern shores of the Rio de la Plata.

In terms of their socioeconomic characteristics, the city of Buenos Aires and Montevideo are significant in terms of dimensions, Buenos Aires is the largest and Montevideo the smallest metropolitan area among the 15 metropolitan areas analyzed by the Observatory for Urban Mobility in Latin America (OMU, 2010).

**TABLE 28**
**SOCIOECONOMIC CHARACTERISTICS, 2007**

| Metropolitan area | Total metropolitan area | | | Urbanized area | | |
|---|---|---|---|---|---|---|
| | Area [km2] | Population [inhabitants] | Population density [inhabit./km2] | Area [km2] | Population [inhabitants] | Population density [inhabit./km2] |
| Buenos Aires | 16 770 | 13 267 181 | 791 | 3 883 | 13 156 404 | 3 388 |
| Montevideo | 529 | 1 325 968 | 2 507 | 196 | 1 273 934 | 6 509 |

Source: Author, adapted from OMU, 2010.
Note: Latest data available in OMU - omu.caf.com/ (accessed January 2014).

In both cases the priority given to public transport and pedestrians is relatively low, considering that Buenos Aires and Montevideo have 44,994 km and 3,011 km of roads respectively, only few kilometres of road give priority to public transport and pedestrians.

**TABLE 29**
**PRIORITY LANES, 2007**

| Metropolitan area | Lanes with priority for public transport [km] | Lanes with priority for pedestrian [km] |
|---|---|---|
| Buenos Aires | 16 | 5.4 |
| Montevideo | 0 | 1.0 |

Source: Author, adapted from OMU, 2010.
Note: Latest data available in OMU - omu.caf.com/ (accessed January 2014).

Aside from priority lanes, public transport offered in both cities is mainly relying on buses, although Buenos Aires complements its options with the rail, metro and tram. The average age of the bus fleet in Buenos Aires is ten years of less, but rail wagons and locomotives are around 40 years old. The average age of the bus fleet in Montevideo is also above 18 years.

**TABLE 30**
**PUBLIC TRANSPORT OFFER, 2007**

| Metropolitan area | Public transport on wheels | | | | | Public transport on rail | | |
|---|---|---|---|---|---|---|---|---|
| | Vans | Microbus | Minibus | Standard bus | Articulated bus | Railway | Metro | Tram |
| Buenos Aires | 401 | 0 | 496 | 15 585 | 0 | 1 207 | 447 | 12 |
| Montevideo | 0 | 43 | 0 | 1 435 | 2 | 2 | 0 | 0 |

Source: Author, adapted from OMU, 2010.
Note: Latest data available in OMU - omu.caf.com/ (accessed January 2014).

**TABLE 31**
**PUBLIC TRANSPORT FLEET AVERAGE AGE, 2007**

| Metropolitan area | Vehicles on wheels | | | | | Rail | | |
|---|---|---|---|---|---|---|---|---|
| | Vans | Microbus | Minibus | Standard bus | Articulated bus | Railway | Metro | Tram |
| Buenos Aires | 3.6 | 0 | 7.2 | 10.3 | 0 | 40.0 | 43.0 | 16.0 |
| Montevideo | 0 | 18.0 | 20.0 | n.a. | n.a. | n.a. | 0 | 0 |

Source: Author, adapted from OMU, 2014.

Buenos Aires presents a higher motorization rate in cars in comparison to Montevideo however; in the latter motorcycle ownership per capita is higher. The city has one of the highest motorization rates within the 15 metropolitan areas analysed by the Observatory for Urban Mobility in Latin America, and Montevideo one of the lowest. (OMU, 2010).

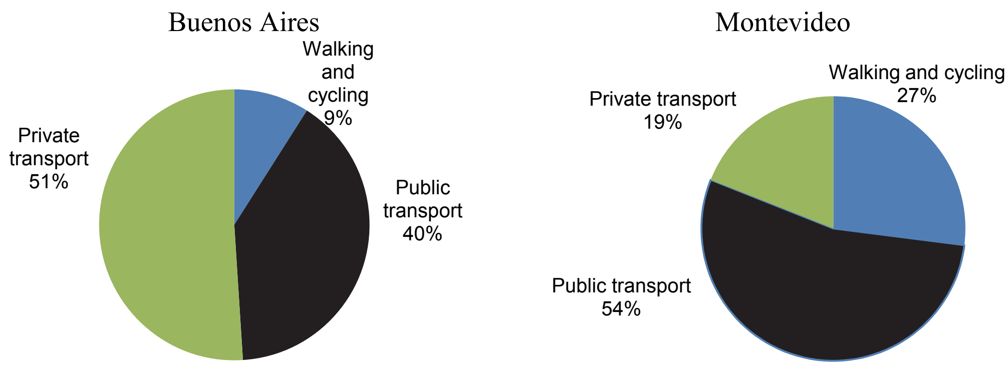
**TABLE 32**
**MOTORIZATION RATE FOR PRIVATE TRANSPORT, 2007**

| Metropolitan area | Cars | Motorcycles | Cars/1000 inhabit. | Moto/1 000 inhabit. |
|---|---|---|---|---|
| Buenos Aires | 4 285 312 | 470 000 | 320 | 40 |
| Montevideo | 210 004 | 75 500 | 160 | 60 |

Source: Author, adapted from OMU, 2010.
Note: Latest data available in OMU - omu.caf.com/ (accessed January 2014).

The modal distribution for daily trips in the two cities (see next figure) reveals that there is a preference for individual motorized transport[57] in Buenos Aires and for public transport in Montevideo. With 3.1 pkm the urban public transport (bus) in Montevideo shows a higher productivity than other Latin American cities (BID, 2011). In comparison the costs of using individual transport in Montevideo are around 438 USD per person per year, while the cost of using public transport amounts to USD 106 per person per year, a significantly lower amount. Since 2003 the demand for public transport has been growing, as the price for public transport was significantly reduced at that point in time.

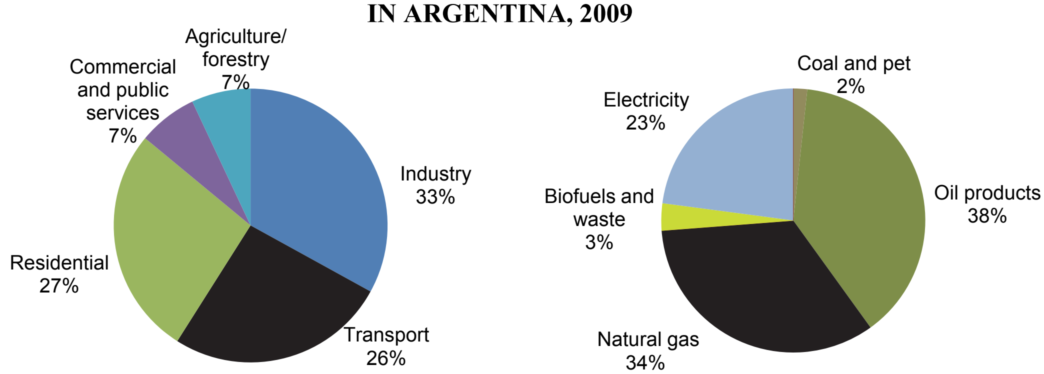
**FIGURE 31**
**MODAL DISTRIBUTION IN BUENOS AIRES AND MONTEVIDEO FOR DAILY TRIPS, 2007**




Source: Author, adapted from OMU, 2010.
Note: Latest data available in OMU - omu.caf.com/ (accessed January 2014).

In order to understand the share of and differences in energy consumption of the available modes the following figures depict the total final energy consumption by sector and source of energy in both countries. In general the industry sector consumes the greatest share of energy, followed immediately by the transport sector (next figures).

**FIGURE 32**
**TOTAL FINAL ENERGY CONSUMPTION BY SECTOR (LEFT) AND SOURCE (RIGHT) IN ARGENTINA, 2009**

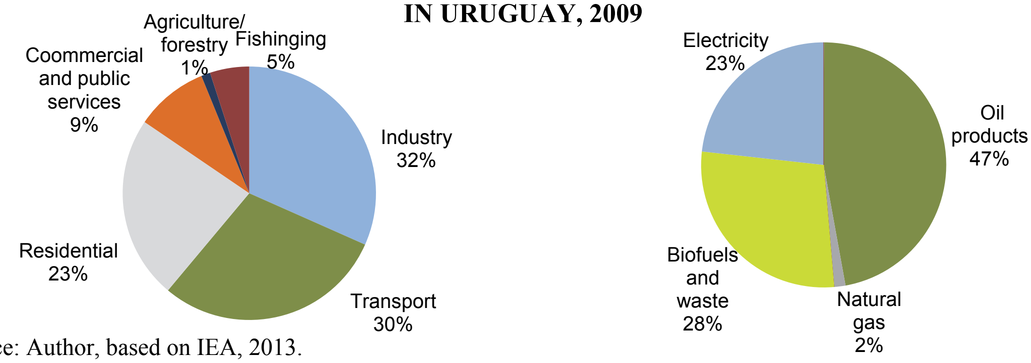



Source: Author, based on IEA, 2013.

57 Includes automobiles, motorcycle, taxis and bicycles.

In Argentina, the most relevant sources of energy are oil products and natural gas, followed by electricity and a minor participation of biofuels, coal and petroleum. The transport sector relies to around 80% on oil products and 19% on natural gas. Electricity and biofuels are the remaining 1% used as sources of energy (IEA, 2013). The import matrix of energy commodities includes natural gas (39%), oil products (24%), coal and pet (22%) and electricity (14%) (IEA, 2012).

**FIGURE 33**
**TOTAL FINAL ENERGY CONSUMPTION BY SECTOR (LEFT) AND SOURCE (RIGHT) IN URUGUAY, 2009**

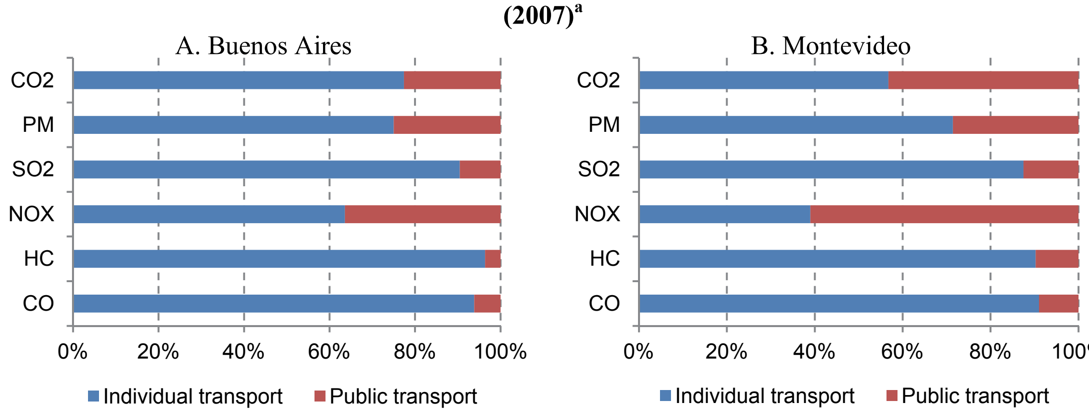



Source: Author, based on IEA, 2013.

In Uruguay oil products are the main source of energy in the country, followed by similar shares of biofuels and electricity. The transport sector is 100% based on the use of oil products. The main shares of energy commodities imports are crude oil (60%), oil products (34%), and electricity and natural gas (with 4% and 2%, respectively) (IEA, 2012).

In both cities, emissions from the transport sector stem predominantly from individual motorized transport. $NO_X$ is an exception as it is primarily emitted from public transport in Montevideo and Buenos Aires.

**FIGURE 34**
**COMPARATIVE EMISSIONS FROM PUBLIC AND INDIVIDUAL TRANSPORT PER DAY (2007)[a]**




Source: Author, adapted from OMU, 2010.
[a] Latest data available in OMU - omu.caf.com/ (accessed January 2014).

The G20 has highlighted the numerous negative climate impacts of fossil-fuel subsidies and, linking subsidies to climate change, a recent report by the International Monetary Fund (IMF) has stated, “fossil-fuel subsidies (to consumers) are almost always bad policy, as even apart from the increase in emissions they cause, there are generally better ways to help the poor” (Whitley, 2013).

Argentina, as part of the G20 countries, has committed to rationalize and phase-out inefficient fossil fuel subsidies over the medium term, as fuel subsides “encourage wasteful consumption, distort markets, impede investment in clean energy sources and undermine efforts to deal with climate change."[58] In 2012 energy subsidies were cut for commercial users (banks, insurance companies, casinos, airport operators etc.) and for residents of several wealthy neighborhoods in the city of Buenos Aires. On 14 February 2012, Argentina abolished the fossil fuel subsidies for urban and suburban public transport. At the same time, Argentina continues its plans of expanding the natural gas pipeline network to reduce its dependence on less effective gas energy sources, such as butane gas cylinders. In Uruguay a decision was made regarding the subsidies of airline fuel, as part of an aeronautic national policy. Currently, the country has a fuel subsidy for passenger transport companies.

The previous analysis reveals the transport sector, as one of the main energy consumers in Argentina and Uruguay. The following sections present a detailed analysis and comparison of energy consumption and mobility patterns of passengers and goods between Buenos Aires and Montevideo for individual modes. Data is derived from official sources whenever available or, when based on own calculations, using national or reference documentation.

## C. Mobility options and comparative analysis

This section analyses the available mobility options between Buenos Aires and Montevideo. Passengers have the following mobility options to travel between Buenos Aires and Montevideo:

- Road transport comprises of private (passenger car vehicles and motorcycles) and public transport. In the case of private transport, users can reach Buenos Aires and Montevideo with their private car/motorcycle, choosing one of the three border passages between the two countries and through the national paved roads. There are also 4 public transport companies that provide daily service on the route between the two cities by bus, with modern vehicles that offer comfort for their passengers;
- Maritime transport from Buenos Aires (Terminal Dársena Norte) and Montevideo (Terminal Montevideo) is offered by Buquebus with daily connections between the two ports. The majority of these boats also have the capacity to transport private cars;
- Air transport between the cities is made through two airports in Buenos Aires: Ezeiza Ministro Pistarini International Airport (located about 34 km outside Buenos Aires) and Aeroparque Jorge Newberry Airport (located in downtown of Buenos Aires). These airports have both connections to Carrasco International Airport in Montevideo (around 19 km outside Montevideo) on a daily basis.
- Rail transport, is not an option at the moment as the service has been inactive for 30 years. In August 2011, a first stage of the rail system was inaugurated; the connection of the city of Pilar 35 km away from Buenos Aires, to Paso de los Toros in Uruguay, with a total of 813 km, crossing the border at Salto Grande. The train was designed with a capacity of 140 passengers and a journey time of eight hours. The concession of the service was given to the company "Trenes de Buenos Aires". However, since last year the service is no longer in operation with no indication for recommencement.

Freight transport includes the following possibilities:

- Road transport is possible via the three border passages between the two countries, which have integrated control also for cargo transport;
- Rail transport is also possible, although it can only be realized through the border of Concordia (Argentina) and Salto (Uruguay), which have a railway bridge. In Argentina, rail cargo transport service to Uruguay is offered by the private company América Latina Logística Mesopotámica. In Uruguay, the Administración de Ferrocarriles del Estado (AFE)

[58] G20 Leaders Statement: The Pittsburgh Summit, G20 Information Centre (Toronto) 24-25 September 2009.

is the autonomous entity responsible for rail transport and the maintenance of the Uruguayan rail network. Nevertheless, data from the National Statistic Institute of Argentina show that since 2011 no cargo movements by rail have been registered between Argentina and Uruguay.

- Maritime transport for cargo between the port of Buenos Aires and the port of Montevideo, can be made crossing the Plate River, a distance of 128 nautical miles;
- Air freight transport can be made between the Ezeiza Ministro Pistarini International Airport and Aeroparque Jorge Newberry Airport to the Carrasco International Airport in Montevideo, however, no specific registry for cargo movements between these airports has been found.

Further, combined transport for both, passenger and freight, is available through the ferry services:

- Passengers can travel between Buenos Aires and Montevideo, using Buquebus ferries and the buses that make the connection from the Tres Cruces terminal in Montevideo, to the Port of Colonia (182 km). The companies Colonia Express and SEACAT also connect Buenos Aires and Montevideo through Colonia. This connection can also be made by ferry from the port of Buenos Aires to Colonia and thereafter by bus to the Tres Cruces terminal in Montevideo;
- Freight movements can also be made by the Ro-Ro ferries of Lineas Platenses that transports trucks and other vehicles and connects directly the port of Buenos Aires to the terminal Rio de la Plata (terminal 1, 2 and 3), an exclusive sector for these services. Using this ferry, the trucks begin their journey in Buenos Aires, arriving around 5 hours later in Juan Lacaze port, being able to afterwards continue their trip to Montevideo, avoiding the road traffic over the Paraná and Uruguay rivers.

As previously mentioned, the mobility options between Buenos Aires and Montevideo, both for passengers and cargo are diverse and present different operational aspects that are relevant when analysing each mode's performance and energy consumption. One aspect is the travel distance as it directly influences the duration of the journey and its cost.

**TABLE 33**
**DISTANCE BETWEEN BUENOS AIRES AND MONTEVIDEO, USING DIFFERENT MODES OF TRANSPORT**

| Transport Mode | Via Border/Port/Airport | Distance [km] Buenos Aires <-> Montevideo |
|---|---|---|
| Road | | |
| | Puerto Unzué - Fray Bentos | 538 |
| - private transport | Colón - Paysandú | 703 |
| | Concordia - Salto | 962 |
| - public transport | Puerto Unzué - Fray Bentos | 600 |
| Rail | | |
| - freight | Concordia - Salto | 1 120 |
| Air | | |
| - private and freight | Ezeiza - Carrasco | 282 [a] |
| - private | Aeroparque - Carrasco | 238 [b] |
| Maritime | | |
| - private and freight transport | Dársena Norte - Montevideo | 237 |
| Combined | | |
| - private transport | Dársena Norte - Montevideo | 232 [c] |
| - freight transport | Rio de la Plata - Juan Lacaze | 303 [d] |

Source: Author´s elaboration.
Note: Distance considered from the city centre of Buenos Aires to the city centre of Montevideo.
[a] Includes also the distance to and from the airport.
[b] Includes also the distance to and from the airport.
[c] Includes also the distance from the Tres Cruces terminal to the Porto of Colonia.
[d] Includes also the distance from Juan Lacaze to Montevideo.

To be able to estimate the energy consumption of different mobility options it was necessary to revert to statistical methods. In the case of road transport, the consumption was estimated according to the EMEP/EEA[59] methodology (former EMEP/CORINAIR), which allowed also the estimation of the greenhouse gas emissions.

Thus, in general, the energy consumption associated to the modes of transport will be estimated using the following expression:

$$Energy_{consumed} = \sum \left( Consumption\ factor \times Activity \right)$$

The GHG emissions will be then calculated through the use of the following equation:

$$Emission_{GHG} = \sum \left( Emission\ \ factor_{fuel,GHG} \times Energy_{consumed\ ,fuel} \right)$$

## 1. Road Transport

### a) Private transport

Passenger and cargo mobility between Buenos Aires and Montevideo can be realised using three border crossings between Argentina and Uruguay each with different length and travel times (see table).

**TABLE 34**
**DISTANCES TO BORDER CROSSINGS BETWEEN BUENOS AIRES AND MONTEVIDEO**

| O/D | Border | Distance [km] | Border | Distance [km] | O/D | Duration | Fuel Cost [a] [$/l] |
|---|---|---|---|---|---|---|---|
| Buenos Aires | Puerto Unzué | 229 | Fray Bentos | 309 | Montevideo | 6 hours | Diesel oil: 1.54 USD<br>Gasolina Super 95: 1.61 USD |
| | Colón | 324 | Paysandú | 379 | | 7h45 | Gas oil: 1.14 USD |
| | Concordia | 464 | Salto | 498 | | 10h45 | GNC: 0.54 USD<br>Gasolina Super 95: 1.39 USD |

Source: Author, based on data from the Government of Uruguay and Argentina Website, 2013 and ANCAP, 2013.
[a] Values converted to USD at the current rate of 5th September 2013.

Considering different types of fuels, and the three different border crossing options, the estimates for energy consumption were based on the use of a regular vehicle using different types of fuels (DNETN, 2008 and MDSMA, 1997) presented in the following table.

**TABLE 35**
**ENERGY CONSUMPTION BETWEEN BUENOS AIRES AND MONTEVIDEO**

| Border | | Petrol car [MJ] | GNC car[MJ] | Diesel car [MJ] | Motorcycle [MJ] |
|---|---|---|---|---|---|
| Puerto Unzué | Fray Bentos | 1 619 | 1 543 | 1 372 | 341 |
| Colón | Paysandú | 2 116 | 2 016 | 1 792 | 445 |
| Concordia | Salto | 2 895 | 2 759 | 2 453 | 610 |

Source: Author´s elaboration.

In a more detailed analysis, and assuming different occupancy rates per vehicle, the energy consumption per passenger and kilometre decreases as occupancy levels increase (see table).

59 Evaluation methodology recommended by the entities that coordinate the climate change and air pollution theme at international level, IPCC - Intergovernmental Panel for Climate Change

**TABLE 36**
**ENERGY EFFICIENCY INDICATORS**

| Occupancy | Puerto Unzué - Fray Bentos [MJ/pass/km] | | | Colón - Paysandú [MJ/pass/km] | | | Concordia - Salto [MJ/pass/km] | | |
|---|---|---|---|---|---|---|---|---|---|
| Car | Gas. | GNC | Die. | Gas. | GNC | Die. | Gas. | GNC | Die. |
| 1 | 3.0 | 2.9 | 2.5 | 3.9 | 3.7 | 3.3 | 5.4 | 5.1 | 4.6 |
| 2 | 1.5 | 1.4 | 1.3 | 2.0 | 1.9 | 1.7 | 2.7 | 2.6 | 2.3 |
| 4 | 0.8 | 0.7 | 0.6 | 1.0 | 0.9 | 0.8 | 1.3 | 1.3 | 1.1 |
| Motorcycle | | | | | | | | | |
| 1 | 0.63 | n.a. | n.a. | 0.83 | n.a. | n.a. | 1.13 | n.a. | n.a. |
| 2 | 0.32 | n.a. | n.a. | 0.41 | n.a. | n.a. | 0.57 | n.a. | n.a. |

Source: Author´s elaboration.

The greenhouse gas emissions from the operation of these vehicles can be directly derived from the application of a specific emission factor to the estimated energy consumption. In this sense, it's possible to estimate the greenhouse gases intensity for this mode of transport (table). The gasoline vehicle has higher GHG emissions per kilometer, and cars using compressed natural gas are the "cleanest" among all the fossil fuel vehicles considered. This is also reflected in the carbon intensity per passenger and kilometer. These indicators also increase when distance increases, therefore users choosing the border crossing Concordia/Salto will emit more carbon dioxide as a consequence of the higher energy consumption.

**TABLE 37**
**GHG EFFICIENCY INDICATORS**

| Border | | Gasoline | GNC | Diesel | Motorcycle |
|---|---|---|---|---|---|
| | | | [kg $CO_2$ eq./vehic.km] | | |
| | | 0.22 | 0.17 | 0.19 | 0.05 |
| | | | [g $CO_2$ eq./pass/km][a] | | |
| Puerto Unzué | Fray Bentos | 109 | 85 | 93 | 23 |
| Colón | Paysandú | 142 | 111 | 122 | 30 |
| Concordia | Salto | 195 | 152 | 167 | 41 |

Source: Author´s elaboration.
[a] Considering an average of 2 passenger.

### b) Public transport

Public road transport services are provided by several bus companies which connect the Retiro terminal in Buenos Aires and the Tres Cruces terminal in Montevideo (through the bridge General San Martín, a distance of approximately 600 km) on a daily basis (table).

**TABLE 38**
**PUBLIC TRANSPORT COMPANIES**

| Company | | Trips (BA/MVD) | Duration | Price[a] |
|---|---|---|---|---|
| Cauvi | | Daily | 7h40 | n.a. |
| CITA | A commercial agreement was made between these 3 companies called Bus de la carrera | Daily | 7 hours | 43 - 61 USD |
| COT | | Daily | 8 hours | 65 - 78 USD |
| El Cóndor - La Estrella | | Daily | 8 hours | 78 USD |
| Pullman General Belgrano | | Daily | 8 hours | 65 - 78 USD |

Source: Author, based on direct interviews with companies and their websites.
Note: Prices and schedules subject to change; data collected during July 2013.
[a] Values converted to USD at the current rate of 5th September 2013.

The service provided between Buenos Aires and Montevideo uses very modern vehicles (e.g. Mercedes Benz with a Comil body, from 2012) which include comfort and (e.g. reclining seats that resemble a bed) and other amenities (air conditioning, TV, bar, toilet, etc.). Journeys are normally made overnight given the considerable travel times.

Based on the data provided and assuming similar operational characteristics (age of vehicles, number of vehicles, fuel consumption, and distance travelled), the following average data were obtained for bus travel:

**TABLE 39**
**EFFICIENCY INDICATORS**

| Indicators | 2013 |
|---|---|
| Number of vehicles | 2 |
| Trips/per day | 2 |
| Capacity (seats) | 42 |
| km/year.bus | 219 000 |
| Passenger/month | 1 284 |
| Seat.km | 18 396 000 |
| Passenger.km | 9 243 600 |
| Fuel consumption (gas oil) | 112 ton |
| MJ/pass | 308 |
| MJ/pass/km per year | 0.5 |
| | 1.6 kg $CO_2$ eq./km |
| Green house gases | 19 g $CO_2$ eq./seat.km |
| | 38 g $CO_2$ eq./pass/km |

Source: Author´s elaboration.

The analysis shows that the buses are highly efficient, when compared to private car as the energy consumption per passenger per kilometer equals 0.5 MJ compared to the energy used in individual transport. This is also reflected in the carbon intensity per passenger and kilometre results, where the GHG emissions per passenger and kilometer are 38 g $CO_2$ eq., a number that is lower if the buses are used at maximum capacity.

### c) Freight transport

Cargo movements by truck use all three border crossings between Argentina and Uruguay. However, no specific data for truck movements between Buenos Aires and Montevideo is available.

**TABLE 40**
**TRUCK MOVEMENTS BETWEEN ARGENTINA AND URUGUAY**

| Country | Traffic between | Border crossing | Entries | Exits | Total |
|---|---|---|---|---|---|
| Uruguay | Uruguay - Argentina | Fray Bentos - Puerto Unzué | 4 548 | 13 970 | 18 518 |
| | | Paysandú - Colón | 7 249 | 11 885 | 19 134 |
| | | Salto - Concordia | 12 455 | 18 754 | 31 209 |
| Argentina | Argentina - Uruguay | Puerto Unzué - Fray Bentos | 13 970 | 4 548 | 18 518 |
| | | Colón - Paysandú | 11 885 | 7 249 | 19 134 |
| | | Concordia - Salto | 18 754 | 12 455 | 31 209 |

Source: DTN, 2012.
Note: The number corresponds to vehicles loaded. Exits includes exportations, exits in transit and other customs operations. Entries include imports, entries in transit and other customs operations.

Considering a reference value for the average fuel consumption per truck and cargo carried (DNETN, 2008 and MDSMA, 1997, the following energy and environmental data were obtained for the different border options.

**TABLE 41**
**ENERGY EFFICIENCY AND GHG INTENSITY**

| Border crossing | Fuel consumption [MJ] | Tonne/km | Energy efficiency [MJ/ton.km] | GHG intensity [g $CO_2$ eq./ton.km] |
|---|---|---|---|---|
| Fray Bentos - Puerto Unzué | 77 630 | 35 846 | 2.2 | 158 |
| Paysandú - Colón | 101 439 | 24 203 | 4.2 | 306 |
| Salto - Concordia | 138 811 | 24 724 | 5.6 | 410 |

Source: Author’s elaboration.

## 2. Rail Transport

Rail transport of passengers is no longer in operation. Using standard assumptions energy consumption was calculated for passenger and cargo movements. On average, a passenger that uses the diesel rail has an energy efficiency of 1.4 MJ/pass/km and a GHG gas intensity of 48 g$CO_2$eq./pass/km. Cargo movements account on average 0.5 MJ/ton.km and a GHG intensity of 43 g$CO_2$eq./ton.km (IEA, 2010).

## 3. Maritime Transport

### a) Passenger transport

Buquebus[60] operates a large fleet of ferries that among other routes directly connects Buenos Aires (terminal of Dársena Norte) and Montevideo (terminal of Montevideo). This ferry also has the capacity to transport automobiles, and in 2011 almost half a million passenger and almost 60,000 vehicles were transported on this route (Table 36).

**TABLE 42**
**PASSENGER MOVEMENTS BETWEEN BUENOS AIRES AND MONTEVIDEO**
*(Number passengers)*

| | 2010 | 2011 |
|---|---|---|
| Passengers BA-MVD | 227 330 | 245 254 |
| Passengers MVD-BA | 227 755 | 249 363 |
| Total | 455 085 | 494 617 |
| Number vehicles | 58 780 | 59 752 |

Source: Author, based on DTN, 2012.

The ferry Juan Patricio with a capacity of 450 pax and 55 vehicles makes two round trips a day (Table 43).

**TABLE 43**
**OPERATIONAL DATA FOR JUAN PATRICIO**

| | Passenger capacity | Vehicle capacity | Daily frequency | Trip duration | Distance [km] | Average ticket price[ab] |
|---|---|---|---|---|---|---|
| BA <-> MVD | 450 | 55 | 4 | 3h15 | 237 | 80 - 150 USD[c]<br>115 - 133 USD[d] |

Source: Author, based on Buquebus Official Website, 2013.
[a] Values converted to USD at the current rate of 10th September 2013.
[b] Prices and schedules subject to confirmation; data collected during September 2013.
[c] Passenger ticket, one way.
[d] Vehicle ticket, with weight between 1201kg and 2001kg, one way.

60 http://www.buquebus.com.

Based on the previous data and considering reference fuel consumption for the ferry according to its technical characteristics (MTU, 2013), the following efficiency and GHG intensity indicators were possible to be obtained for the movements between the port of Montevideo and Dársena Norte in 2011.

**TABLE 44**
**ENERGY EFFICIENCY AND GHG INTENSITY**

| | Fuel consumption [MJ] | pass/km | Energy efficiency [MJ/pass/km] | GHG intensity [g $CO_2$ eq./pass/km] |
|---|---|---|---|---|
| Buenos Aires - Montevideo | 225 405 431 | 117 224 229 | 1.9 | 14.4 |

Source: Author's elaboration.

This high speed ferry, achieves a maximum speed of 50 knots and still energy consumption per passenger is quite favourable in comparison to other modes.

### b) Freight transport

The specific cargo movements between Buenos Aires and Montevideo could not be obtained. The following efficiency and GHG intensity indicators were calculated for the ferry movements between the port of Montevideo and Dársena Norte.

**TABLE 45**
**ENERGY EFFICIENCY AND GHG INTENSITY**

| | Fuel consumption [MJ] | tonne.km | Energy efficiency [MJ/ton.km] | GHG intensity [g $CO_2$ eq./ton.km] |
|---|---|---|---|---|
| BA - MVD | 74 037 | 1 185 000 | 0.06 | 4.8 |

Source: Author's elaboration.

Compared to the previous modes analysed so far, maritime transport can be considered the most efficient, since less energy is spent for each tonne of cargo transported in a kilometre. Thus, there is also a lower environmental impact with values of GHG intensity quite inferior, when compared to the road or rail transport.

## 4. Air Transport

### a) Passenger transport

There are two airports in Buenos Aires that have direct flights to Carrasco International Airport in Montevideo. Five airlines operate daily and weekly flights between the two destinations (Table 46). In 2011 around 56,000 passengers travelled by air between BA and MVD (Table 47).

**TABLE 46**
**AIRLINES COMPANIES**

| Airport origin/destination | | Frequency (weekly) | Air company | Airplane | Capacity (pass.) | Average Price[ab] |
|---|---|---|---|---|---|---|
| Ezeiza | | 4 | Aerolíneas Argentinas; Austral | Embraer Jet E90 | 114 | 68-263 USD |
| Aeroparque | | 20 | | | | |
| Ezeiza | | 8 | Air France | B777-200 | 309[c] | 138-144 USD |
| Ezeiza | Carrasco | 4 | Aeromás | Embraer 110 | 21 | n.a. |
| Ezeiza | | 2 | Buquebus | ATR 75-500 | 68 | 148 USD |
| Aeroparque | | 4 | | | | |
| Aeroparque | | 4 | Air Class | Fairchild Metro III | 19 | 100 USD |

Source: Aeropuertos Argentina 2000, 2013 and Aeropuerto Internacional de Carrasco, 2013.
[a] Values converted to USD at the current rate of 5th September 2013.
[b] Average prices presented are for one way trip.
[c] This flight does the route Paris – Montevideo – Buenos Aires and back. Consequently not all seats will be available for only the trajectory Montevideo – Buenos Aires and vice versa.

**TABLE 47**
**PASSENGER TRANSPORTED BETWEEN BUENOS AIRES AND MONTEVIDEO**

| | 2011 | 2010 |
|---|---|---|
| Entry | 254 118 | 280 272 |
| Exit | 258 096 | 280 229 |

Source: DNT, 2012.

Considering reference values for the fuel consumption for each type of airplane, it was possible to calculate the total energy consumption, between Buenos Aires and Montevideo. Based on the number of transported passengers, the energy efficiency and carbon intensity indicators were estimated as follows.

**TABLE 48**
**ENERGY EFFICIENCY AND GHG INTENSITY**

| Airport origin/destiny | | Fuel consumption [MJ] | Energy efficiency [MJ/pass/km] | kg $CO_2$/passenger | GHG intensity [g $CO_2$ eq./pass/km] |
|---|---|---|---|---|---|
| Buenos Aires | Carrasco | 534 x 106 | 2.33 | 75.3 | 168 |

Source: Author's elaboration.

For each passenger, a total of 2.33 MJ of energy are necessary, which implies that each passenger emits on average 75.3 kg $CO_2$ per trip. Overall this mode of transport is one of the most polluting and least energy efficient.

Table 48shows that the number of passengers transported reduced between 2010 and 2011, in case this trend continues, either a reduction in supply or other operations concepts might be necessary, if energy efficiency was to be improved.

### b) Freight transport

According to the National Observatory of Transport Data (Observatorio Nacional de Datos de Transporte, ONDAT) from the National Technological University of Buenos Aires, the cargo movements by airplane between Argentina and Uruguay registered in 2010 and 2011 are the following:

**TABLE 49**
**TONNES OF CARGO IMPORTED AND EXPORTED BETWEEN ARGENTINA AND URUGUAY**

| | 2011 | 2010 |
|---|---|---|
| Exports | 2 195 | 574 |
| Imports | 126 | 133 |

Source: ONDAT, 2013.

Nevertheless, no information could be obtained on the aircraft used. It can be assumed that the specific cargo movements between Buenos Aires and Montevideo are included in the weekly passenger flights, since the volumes of cargo are not significant.

## 5. Combined transport

### a) Passenger transport

The combined transport movements between Buenos Aires and Montevideo include the maritime connections between the port of Buenos Aires and the port of Colonia and the subsequent connection between Colonia and Montevideo by bus, to the Tres Cruces terminal. Buquebus, Colonia Express and SEACAT are the three companies that offer such a service. It was only possible to obtain passenger movements between BA and Colonia, but not for the connecting bus services. During certain periods of the year SEACAT also transports vehicles on the ferry.

**TABLE 50**
**PASSENGER MOVEMENTS BETWEEN BUENOS AIRES AND COLONIA**
*(Number passengers)*

| | 2010 | 2011 |
|---|---|---|
| Entry | 1 060 431 | 1 031 330 |
| Exit | 1 062 655 | 1 025 393 |
| Total | 2 123 086 | 2 056 723 |

Source: DNT, 2012.

**TABLE 51**
**VEHICLE MOVEMENTS BETWEEN BUENOS AIRES AND COLONIA**

| | 2010 | 2011 |
|---|---|---|
| Number vehicles | 136 137 | 136 137 |

Source: DNT, 2012.

In general, the three companies offer a good variety in frequency, with an average of three ferries per day and direction. The journey times are comparable, with the exception of the Eladia Isabel from Buquebus that due to its characteristics and average speed requires a longer travel time.

**TABLE 52**
**FERRY COMPANIES OPERATING BETWEEN BUENOS AIRES AND COLONIA**

| | Passenger capacity | Vehicle capacity | Daily frequency | Trip duration | Distance [km] | Average ticket price[ab] |
|---|---|---|---|---|---|---|
| Buquebus | | | | | | |
| Atlantic III | 610 | 110 | 6 | 1h15 | 50 | 55 - 96 USD[c]<br>77 - 92 USD[d] |
| Eladia Isabel | 1 200 | 130 | 4 | 3h15 | | 41 - 73 USD[e]<br>60 - 73 USD[f] |
| Colonia Express | | | | | | |
| Colonia Express | 610 | n.a. | 6 | 1h | 50 | 17 - 40 USD[g] |
| SEACAT | | | | | | |
| Flecha de Buenos Aires | 205 | n.a. | 6 | 1h45 | 50 | 43 - 58 USD[h] |

Source: Companies' websites.
Note: see http://www.seacatcolonia.com.ar y http://coloniaexpress.com.
[a] Values converted to USD at the current rate of 10th September 2013.
[b] Prices and schedules subject to confirmation; data collected during September 2013.
[c] Passenger ticket, one way.
[d] Vehicle ticket, with weight below 1.201 kg, one way.
[e] Passenger ticket, one way.
[f] Vehicle ticket, with weight below 1.201 kg, one way.
[g] Average ticket price, for one way trip.
[h] Average ticket price, for one way trip.

Based on the previous data and considering reference fuel consumption for the ferry according to its technical characteristics (MTU, 2013), the following individual efficiency and GHG intensity indicators were obtained for the movements between the port of Buenos Aires and Colonia.

**TABLE 53**
**ENERGY EFFICIENCY AND GHG INTENSITY**

| | Fuel consumption [MJ] | pass/km | Energy efficiency [MJ/pass/km] | GHG intensity [g $CO_2$ eq./pass/km] |
|---|---|---|---|---|
| Buquebus | | | | |
| Atlantic III | 4 886 | 30 500 | 0.2 | 12 |
| Eladia Isabel | 30 403 | 60 000 | 0.5 | 38 |
| Colonia Express | | | | |
| Colonia Express | 17 655 | 30 500 | 0.6 | 43 |
| SEACAT | | | | |
| Flecha de Buenos Aires | 23 394 | 10 250 | 2.3 | 171 |

Source: Author's elaboration.

From the port of Colonia to Montevideo, all the companies provide a bus service and it was assumed that all companies use a similar type of bus (in the absence of more detailed data). The following estimates were obtained for the energy efficiency and GHG intensity.

**TABLE 54**
**OPERATIONAL DATA AND ENERGY EFFICIENCY AND GHG INTENSITY FOR THE BUS TRANSPORT**

| | Bus capacity [seats] | Trip duration | Distance [km] | Fuel consumption [MJ] | Energy efficiency [MJ/pass/km] | GHG intensity [g $CO_2$ eq./pass/km] |
|---|---|---|---|---|---|---|
| Bus COL -MVD | 42 | 2h30 | 182 | 1 973 | 0.3 | 19 |

Source: Author's elaboration.

Overall, considering the distance travelled by each mode during the course of the combined movement, it was necessary to analyse its relative weight, in order to obtain global energy efficiency and GHG intensity indicators. The combined ferry - road transport between the city of Buenos and Montevideo has an energy efficiency of 0.4 MJ/pass/km and a GHG intensity of 29 g $CO_2$ eq./pass/km.

## b) Freight transport

The Ro-Ro ferries of Lineas Platenses transport trucks and other vehicles, and directly connect the Port of Buenos Aires Terminal Rio de la Plata (terminal 1, 2 and 3) and Juan Lacaze in Uruguay in a distance of 167 km. These trucks are able to afterwards continue their trip to Montevideo (136 km), and other destinations through road transport.

**TABLE 55**
**TRUCK MOVEMENTS BETWEEN BUENOS AIRES AND JUAN LACAZE**
*(Number trucks)*

| | 2010 |
|---|---|
| To Uruguay | 4 085 |
| From Uruguay | 6 047 |
| Total | 10 132 |

Source: DNT, 2012.

Considering reference fuel consumption for the deployed ferry (MTU, 2013) according to its technical characteristics, the following individual efficiency and GHG intensity indicators were obtained for the movements between the port of Buenos Aires and Juan Lacaze.

**TABLE 56**
**ENERGY EFFICIENCY AND GHG INTENSITY**

| | Fuel consumption [MJ] | tonne.km | Energy efficiency [MJ/ton.km] | GHG intensity [g $CO_2$ eq./ton.km] |
|---|---|---|---|---|
| Buenos Aires - Juan Lacaze | 6 740 | 8 350 000 | 0.003 | 0.06 |

Source: Author's elaboration.

From Juan Lacaze to Montevideo trucks use the available road network. Considering the distance travelled for each mode the emissions for each leg of the journey were considered to reach global energy efficiency and GHG intensity indicators. The combined ferry - road transport between the city of Buenos and Montevideo has an energy efficiency of 0.7 MJ/pass/km and a GHG intensity of 47 g $CO_2$eq./pass/km.

## 6. Comparison of energy consumption and efficiency of mobility options

The analysis reveals that the combined transport option ferry – road (public transport) is the most energy efficient one. The estimated indicators for this option present the lowest values when compared to other modes of transport. On the other hand, the ferries used for this transport have a capacity to carry up to a maximum of 1,200 passengers and also the possibility to transport the passengers' private vehicles, which prevents movements by car that are the least energy efficient ones (in the relation BA-MVD given the high diversion factor for road transport). Although the second part of this combined journey is made by road transport, higher efficiencies are possible to be obtained if bus services are used, where the maximization capacity utilization would contribute to the achievement of favourable energy efficiency values. However, the overall journey time is considerably longer than the direct ferry option between BA and MVD.

Today, rail transport is not an option for the Buenos Aires and Montevideo journey due to its inoperability at this point, but the theoretic values depict the potential of rail transport in terms of energy efficiency and reduced GHG intensity. Furthermore, the train would operate on a dedicated track and thus not contribute to road congestion, which is a factor that in an overall strategy should be considered. The least energy efficient modes are air and individual road transport. Although energy efficiency of individual transport increases with the maximum occupancy of the vehicle, it's still a very limited option with overall impacts that can be minimized by opting for one of the other modes.

Freight transport has its maximum potential to decrease energy consumption using maritime transport between the two cities. In this case, the least energy is necessary to move one tonne of goods per kilometre, which also implies a lower environmental global impact. Good values were obtained in the case of the combined ferry – road option, which according to the estimated values for energy efficiency can be considered the third most efficient option (if rail was included). Nevertheless, the fact that there is a pronounced use of the road transport, which is considered one of the least efficient options; this should also be considered in a more comprehensive analysis that also includes technological change.

# D. What solutions are available to improve energy efficiency?

The need for energy efficiency indicators and knowledge on the quantitative impact of energy efficiency policies has been increasing over the years, alongside with the need to develop measures and instruments that can contribute to the reduction of the impacts caused by the transport sector. Existing and planned solutions that are intended to contribute to the improvement of energy efficiency relevant for the case study countries are presented in the following sections.

**TABLE 57**
**ENERGY EFFICIENCY AND GHG INTENSITY INDICATORS BETWEEN ARGENTINA AND URUGUAY**

| | Energy Consumption [MJ] | Energy efficiency [MJ/pass/km] | Energy efficiency [MJ/ton.km] | GHG intensity [g $CO_2$ eq./pass/km] | GHG intensity [g $CO_2$ eq./ton.km] |
|---|---|---|---|---|---|
| Passenger | | | | | |
| Road | | | | | |
| Passenger vehicle[a] | Gasoline: 2 210<br>Diesel: 1 872<br>GNC: 2 106 | Gasoline: 4.1<br>Diesel: 3.9<br>GNC: 3.5 | n.a. | Gasoline: 149<br>Diesel: 116<br>GNC: 127 | n.a. |
| Motorcycle | 1 396 | 0.8 | n.a. | 31 | n.a. |
| Public transport (bus) | 6 507 | 0.5 | n.a. | 38 | n.a. |
| Rail[b] | n.a. | 1.4 | n.a. | 48 | n.a. |
| Maritime | 22 x 107 | 1.9 | n.a. | 14 | n.a. |
| Air | 76 x 106 | 2.3 | n.a. | 168 | n.a. |
| Combined | --- | 0.4 | n.a. | 29 | n.a. |
| Freight | | | | | |
| Road | 105 960 | n.a. | 4.0 | n.a. | 291 |
| Rail[c] | n.a. | n.a. | 0.5 | n.a. | 43 |
| Maritime | 74 037 | n.a. | 0.06 | n.a. | 4.8 |
| Air[d] | n.a. | n.a. | n.a. | n.a. | 800 |
| Combined | --- | n.a. | 0.7 | n.a. | 47 |

Source: Author's elaboration.
[a] Average values assuming occupancy of one passenger.
[b] Considering average values.
[c] Considering average values.
[d] Considering average values.

## 1. Regulatory framework

The analysis of the Argentine efforts in terms of energy efficiency regulations revealed that the National Program for the Rational Use of Electric Energy[61] (December 2007), defined measures and quantified objectives that can contribute to the rational and efficient use of energy. The programme also recognized the relation of energy efficiency and sustainable development, including its contribution to the reduction of greenhouse gases (Decree 140/2007). Measures were defined for different time horizons (EE, 2013). In the short term, the development of massive marketing campaigns in education, information and awareness for children of school age, the replacement of incandescent bulbs with low consumption ones in all the households and the development of a certification system of energy consumption of household appliances are given priority. In the medium and long-term, specific measures for the industry, services, and residential sector, as well as public buildings were established. The transport sector is included with a mix of actions that assure energy savings, namely:

- Expanding and improving the management of public transport and a more adequate implementation according to the demographic distribution and existing mobility pattern in the region;

[61] PRONUREE - Programa Nacional de Uso Racional y Eficiente de la Energía.

- Development of a National Program for rational driving, directed to the driver of transport companies for passenger and cargo vehicles;
- Development of an automotive labelling program;
- Development of a maintenance program for vehicles used in public service and an awareness campaign on the energy efficiency and environmental impacts.

In terms of policies that intend to contribute to the reduction of $CO_2$ emissions,[62] Argentina has no formal policies or clear reduction objectives; although the Transport Secretary shows interest in developing climate change issues (CEPAL, 2010).

Between August 2004 and 2011, Uruguay implemented an Energy Efficiency Project[63] that intended to contribute to the reduction of greenhouse gas emissions, at national level. The Global Environmental Facility (GEF), and the Ministry of Industry, Energy and Mining financed this project. The overall aim was to improve energy use of end users in all economic sectors, promoting the efficient use of all types of energy. Through the project several actions were developed such as raising public awareness about the benefits of energy efficiency and to encourage market entry of a growing supply of energy-efficient equipments. One of the project's objectives was to promote the creation of an appropriate legal and institutional framework for the development of energy efficiency in Uruguay.

The Energy Policy defined for Uruguay 2005-2030 (DNETN, 2009), contains four strategic lines of action, one of them addresses energy demand in the transport sector, and recognizes the sector as the main energy consumer in the country. As such, it is important to integrate energy efficiency in the transport policies.

By 2015 the objective is to reduce the fuel consumption in the transport sector compared to the baseline scenario by 15%, by promoting new modes of transport, technology and sources of fuel. By 2030, the country is expected to save at least ten billion dollars compared to 2010 by replacing energy sources and promoting energy efficiency, compared to the baseline scenario. One of the lines of action includes having energy efficiency integrated within the future views for freight and passenger transport, namely through the promotion of rail and waterborne transport, the promotion of public passenger transport, driving other forms of urban mobility, encouraging fleet renewal of trucks and buses, tax and a regulatory review, promote electric and hybrid vehicles, among others (DNETN, 2009).

More recently, a norm for the energy efficiency of vehicles (PU UNIT1130:2013, see MIEM, 2013) has passed public consultation as it establishes the requirements to label new light vehicles with internal combustion engines, diesel cycle and electric hybrid not charged through the electric network. The objective of this label is to include a reference value for the fuel consumption expressed in km/l.

Montevideo also has a municipal initiative, the Mobility Plan that, following the Law n.º 18.587 in specific strategic lines, includes the implementation of energy efficiency measures in public transport. Further, the plan aims to progressively request transport operators to renew their road vehicle fleet to comply with more recent standards such as Euro III and Euro IV. In 2006, the municipality also established a Commission for Energy that works on and coordinates several activities and is responsible for the elaboration of the Energy Program for Montevideo (IM, 2010), which includes the Mobility Plan. Future projects and actions for energy efficiency in transport include studying the feasibility of electric vehicles for individuals and companies and to investigate new technology changes.

In terms of fuel economy standards, several improvements have been made over the years to implement standards that are meant to reduce fuel demand through vehicle efficiency improvements and fuel quality. The table below presents the actual state in these aspects for Argentina and Uruguay. It is important to retain that although these standards contribute to an overall efficiency in technology, they need to be coordinated along with other regulations to reach the desired results.

[62] This concept is much wider than the simple reduction of emissions, since most emissions come from the energy used to transport people and goods and in this sense there should also be policies that promote modes that are more energy efficient.

[63] Proyecto de Eficiencia Energética - http://www.eficienciaenergetica.gub.uy/.

**TABLE 58**
**FUEL QUALITY AND VEHICLE EMISSION STANDARDS (DECEMBER 2012)**

| | Lead in fuel | | Sulphur maximum allowable by law | | | | |
|---|---|---|---|---|---|---|---|
| | Current status | Comments | Diesel | Petrol | Target date set for 50ppm and below diesel nationwide | Comments | Vehicle emissions standards, Light duty passenger |
| Argentina | Unleaded | since 1999 | 1500 | 300 | 2016 (30ppm) | Diesel: 3 Qualities of Diesel (Gas Oil) are available on the market:<br>Gas Oil G2: ≤ 1500 ppm<br>Gas Oil G2: ≤ 500 ppm<br>Gas Oil G3: ≤ 10 ppm (from June 2011 nationwide)<br>Law 26.093 requires 5% biodiesel to be blended with diesel fuel (from 1st Jan 2010).<br>Looking at increasing this to 7- 10%.<br>From 1st July 2012, Gas Oil G2: 500ppm should be available in all provincial capitals, Buenos Aires, cities of Rosario, Mar del Plata y Bahía Blanca. The resolution exempts the capitals of the Patagonia: Ushuaia, Rio Gallegos and Rawson.<br>Gasoline: 300ppm available nationwide from 2012 and 50ppm in cities.<br>9 refineries | Importation only of new vehicles allowed – no second hand cars, although a few exceptions.<br>Emission standards:<br>As of 2012, new light-duty vehicles must comply with Euro IV standards for gasoline and diesel passenger vehicles, likewise for new diesel trucks and buses. I/M programs are implemented in 7 major cities in the country, with emission inspections beginning January 2008.<br>Before 1990: Euro 0<br>1990: Euro I / 1997: Euro II /2006: Euro III (New Models) /2007: Euro III (All Models) /2009: Euro IV (New Models)/ 2012 -2014: Euro IV (All Models)<br>All models active in 31/11/11<br>2012: Euro III New Vehicles: In discussion with National Government<br>2013: Euro V (New Models)<br>2015: Euro V (All Models)<br>Some vehicles imported from Brazil. About 56% of passenger vehicles in Buenos Aires are diesel, 35% are petrol, and the rest are CNG.<br>Currently preparing the network for the availability of Automotive Liquid Urea required for Heavy Duty Engines equipped with SCR technology ($NO_X$ Reduction). |
| Uruguay | Unleaded | since 2003 (ARPEL) | 7000 | 700 | 2013 | Diesel: 50ppm diesel, planned for late 2012 nationally - after refinery upgrades completed. (90% less sulfur than current standards)<br>70% of the fuel used in Uruguay is diesel.<br>Gasoline: 30ppm petrol planned for late 2012 nationwide<br>Plans to establish a biodiesel plant and an ethanol plant in the country.<br>1 refinery – La Teja | Importation of used vehicles is banned, new vehicles must meet Euro III standard.<br>Indication of vehicle inspection system<br>Average age of vehicle fleet 17 years. |

Source: UNEP, 2012.

## 2. Technical solutions

The ferries that make the connection between the port of Montevideo and Buenos Aires are from the company Buquebus. Since 2013 the company operates a new dual-fuel ferryboat, operating with Liquefied Natural Gas (LNG) and fuel oil. The ship is powered by a GE LM2500 engine that is adapted to operate on LNG as a primary fuel, and can also burn marine distillate for standby and ancillary use. The vessel has a maximum capacity of 1,024 persons (passengers and crew), 150 car spaces and a maximum speed of 51.8 knots. In the absence of operational data, an estimation regarding the performance of the energy efficiency was made, based on data from the manufacturer (GE, 2013). In this sense, using this ferry an energy consumption of approximately 0.1 MJ/pass.km could be achieved, denoting the greater efficiencies that are possible with this new technology.

**BOX 27**
**LIQUEFIED NATURAL GAS AS SHIP FUEL**

Natural gas is also a fossil fuel and consists mainly of methane (CH4) with minor concentrations of ethane and propane. It's considered to be the cleanest of the fossil fuels because it has a high ratio of hydrogen to carbon, so a smaller contribution than other fossil fuels to GHG emissions. Natural gas is in gaseous form at ambient temperatures, and is a liquid when it is cooled to -162ºC and held at atmospheric pressure. In liquid form, the same energy content of gas takes up 1/600th the amount of space, with obvious advantages. In terms of emissions benefits, the process of liquefying natural gas removes sulfur from the gas (MIT, 2008). Hence, SO2 emissions are not present when the fuel is burned. A comparison of the emissions of natural gas to typical marine fuels results in reductions of four pollutants: $SO_2$, $NO_X$, $CO_2$, and PM. As mentioned previously, $SO_2$ emissions are completely eliminated, $NO_X$ emissions are reduced by up to 90%, $CO_2$ by 20%, and PM is also reduced.

Source: MIT, 2008.

## 3. Public information

In Argentina, the national energy efficiency plan contemplates the capacity building and awareness raising in the population, mostly targeting and proposing actions for children with a set of activities and measures, although no focus was given to the transport sector. A guide on energy efficiency was elaborated in 2003, with a small number of advices for transport.

In Uruguay, in terms of communication activities and public information, a highlight is given to the transport sector with a section on useful advices on a website[64] dedicated to the theme, providing information to users on different areas that go from efficient driving, aspects to consider when buying vehicles and maintenance actions. The website also includes a calculator on $CO_2$ emissions for transport. Several manuals have also been developed with advices to become more energy efficient, with one specifically focused on fuel savings for transport companies: Buenas Prácticas para el ahorro de combustible (EE, 2011).

Under the mobility plan for Buenos Aires, a mobile phone application (BA Móvil) was developed that finds one's location and provides accurate and constantly updated real time information in order to be informed about traffic, streets obstructions, availability of parking spaces and information on the schedule, frequency and service conditions of the subway. Montevideo has a similar application (A qué hora pasa, beta version), for its local network of buses.

## 4. Financial and non-financial incentives

The lack of support to identify and prepare energy efficiency projects is considered to be a significant restriction to invert the path followed by Argentina in terms of energy efficiency. In this sense, the development of an Argentine Fund for Energy Efficiency[65] is one of the priorities with support from GEF. These funds will partially finance the cost of developing a diagnosis and energy audits and to

64 http://www.eficienciaenergetica.gub.uy/
65 FAEE - Fondo Argentino de Eficiencia Energética

prepare the necessary studies for energy efficiency projects, however the activity does not focus on projects in the transport sector. From 2011 to 2013 several calls for tenders were launched from the Energy Secretary of Argentina for the development of consultancy services, however, none was related to transport related measures.

In Uruguay, the mechanism of a Diesel Trust Fund consists in collecting (by inclusion in the final price) 0.14USD/litre of diesel oil bought by domestic consumers. The collected money, about 40 million USD annually, is transferred to the public passenger transport system. The objective is to reduce the passenger fares in public transport in order to encourage their use (WEC, 2010).

Based on Law Nº18.587, other regulatory actions were developed that include the promotion of electric and hybrid vehicles. Law Decree Nº 099-2012 (27/03/2013) modifies the vehicle categories and reduces taxes applied to electric and hybrid vehicles, considering their energy efficiency. Accordingly, just on 28/08/2012 the internal taxes applied to conventional cars, motorcycles, and all the other classes of vehicles were increased.

## 5. Energy efficiency measures: Identifying the success criteria

The improvement of energy efficiency refers to a reduction in the energy used for a given service (heating, lighting, transportation, etc.) or level of activity. The reduction in energy consumption is usually associated with technological changes. But it can also result from better organisation and management or behavioural changes, which for themselves do not imply technical factors. For instance, in the transport sector energy efficiency can be improved through the diffusion of more efficient vehicles, from the shift of passengers and freight from cars and trucks to other modes of transport, from a better organisation of transport logistics (increased load factors and reduction of empty running for trucks) and from eco-driving of vehicles (WEC, 2010). Improving energy efficiency reflects the results of actions that aim at reducing the amount of energy used for a given level of services: purchase of efficient equipment, retrofitting investments to reduce the consumption of existing buildings and facilities, or shift to soft modes instead of private transport.

### a) Monetary: Cost of the solution

Establishing adequate pricing is one of the main conditions when promoting energy efficiency. It is essential to establish consumer energy prices that reflect the cost of energy supply, at least the present cost but better future costs: the long-term marginal cost for electricity or the long-term price of oil products on international markets for fossil fuels.

In this sense, it becomes important to adjust energy prices to energy supply costs in order to give correct signals to consumers, to give them incentives to change their behaviour or to acquire energy efficient equipment and technology. Nevertheless, there is always the necessity to consider the impact of energy price corrections on the consumer price index. This causes price adjustments to be slow or non-existent in many developing countries, which complicates the shift of paradigm towards new ways of mobility.

As previously stated, subsidies for fossil fuels in transport companies are a reality in Uruguay, and are being abolished in the case of Argentina due to commitments under the G20 participation. In the case of Uruguay, this subsidy had a significant implication in the modal share of Montevideo, where public transport has seen an increase in the past years being the most important mode of transport used in the city. On the other hand, the diesel and gasoline prices in Uruguay are higher than in Argentina, which influences the use of individual transport since the final cost is considerable when compared to the public transport.

In most cases the subsidies mask the true cost of a particular good or service, which creates market distortions, leading to inefficient allocations within the energy sector where investments in new forms of energy are less emphasised due the difficulties in the competition with fossil fuels. The decisions on subsidies initially had good intentions such as encouraging certain productive sectors and improving access to energy for depressed populations. The massive use of these fuels in particular for activities that the subsidy was not designed for, coupled with distorted political dealings, combined with the lack of control have distorted their goals, resulting in benefiting segments of the population with sufficient resources (Ríos, Garrón and Cisneros, 2007).

In general, actual costs are often not taken into account adequately by the user. Users often focus on fuel expenses, not considering maintenance, tolls, environment, etc. The full cost analysis is not common for the typical user.

### b) Feasibility

The regular diesel and internal combustion engines are technologies well known for many years, with high technical feasibility: the technology is widely available and the necessary resources for it are also easily obtained (maintenance, fuel supply, accessories, etc.).

The acceptance of new technologies or fuels is very dependent on the local reality: for example, Argentina is a natural gas producer, making this fuel also an option for the transport sector, namely for the private user. Thus, it could be expected that natural gas is an option for heavy vehicles, namely for road public transport. This is a technology widely recognized and used, whose wider implementation is many times dependent on the strategy and political orientations that should not only take into account the users' needs but also the long term sustainability. The proximity between Argentina and Uruguay, and the existence of movements between their capitals would justify the implementation of a cooperation agreement between several transport bus companies that could include the implementation of a gas fuelling stations (in Uruguay).

In this case study, the Buquebus Company that is responsible for the operation of several ferries between Buenos Aires and Montevideo, has been operating a new LNG ferry since 2013. It would be interesting to analyse the utilization rates of this new ferry and its operational characteristics in order to verify its effect in terms of energy consumption, efficiency and emissions.

Maritime and rail transport, in addition to having energy and environmental advantages, also entail many favourable aspects at the level of urban planning and land use. These modes operate on a dedicated route and thus do not contribute to the congestion of urban and regional roads.

In this particular case, it is also possible to improve energy efficiency within the public transport through the creation of dedicated lanes, which allows greater reliability and speed of public transport vehicles.

### c) Impacts on users

The different modes of transport used for passenger and freight movements between Buenos Aires and Montevideo present diverse time and cost alternatives. Although the monetary cost of the journey can be the most direct factor that affects the user's decision, door-to-door travel time, comfort and convenience of the transport mode may also be crucial factors. In this sense, it can be seen from the case study analysis that in the case of air travel the energy inefficiency from the user's perspective is compensated by the duration and convenience of this mode of transport. On the other hand, waterborne mobility options, achieve higher energy efficiencies, where time and cost have a favourable impact for the final user, guarantying the safety of its users and cargo. In the case of passenger transport, the ferry option is enhanced with the possibility of having the private vehicle carried along in the ferry, which presents additional convenience in onwards travel.

## E. Conclusions

The case study demonstrated that more attention has been given to energy efficiency in national policies and regulations, but there's still the necessity to better coordinate and organize the proposed actions and strategies.

In terms of the transport companies analyzed, almost no relevance is given to energy efficiency, this aspect that should be wider disseminated, encouraging the citizens to opt for a mode of transport that is more efficient and has less impact on the environment. Not only the comfort should be enhanced, but also the achievements in terms of operating characteristics and efforts in providing a service whose impact that goes beyond what's evident for the user.

Scarce and many times incoherent information has been found for the cities, specifically for the mobility patterns between them. It was not always possible to collect analytical and consistent data directly related to the local reality being necessary to estimate based on reference values. Although individual energy efficiencies and GHG intensity for each mode was obtained, it would be important to know which one of the analysed modes is more relevant in the modal matrix. That could help in the future definition of measures and actions to be more targeted.

In terms of transport modes, there is a wide variety of options between Buenos Aires and Montevideo, with the exception of rail transport where significant efficiencies could be obtained when compared for instance to road transport. With respect to public transport, namely for road, air and maritime transport, tickets are easily accessible through the internet, which facilitates the logistics associated, saving time and costs, both for the operator and the final user. It is indeed a strategy that should be followed and continuously improved to promote its wider use among citizens.

Great achievements can be made with regulations on fuel and vehicles quality standards, but that does not solve the energy dependency problem. Although incentives in terms of purchasing new technology vehicles, like hybrid or electric is desirable, it is also important to define measures at the planning level that can contribute to a restrain individual transport, since the overall objective should be the promotion of public transports whose efficiency can be obtained with increased use rates.

It's necessary to inform and capacitate the citizens, so that more conscious decisions implying lower energy impacts are made. These actions should be targeted towards populations of different age groups (with special focus on children, who can easily assimilate new contents and pass them through to future generations). A paradigm shift is necessary towards new ways of mobility that users can identify with.

# VIII. Metropolitan mobility and energy efficiency —Medellin

## A. Geographical and urban context

### 1. Decisive geographical factors

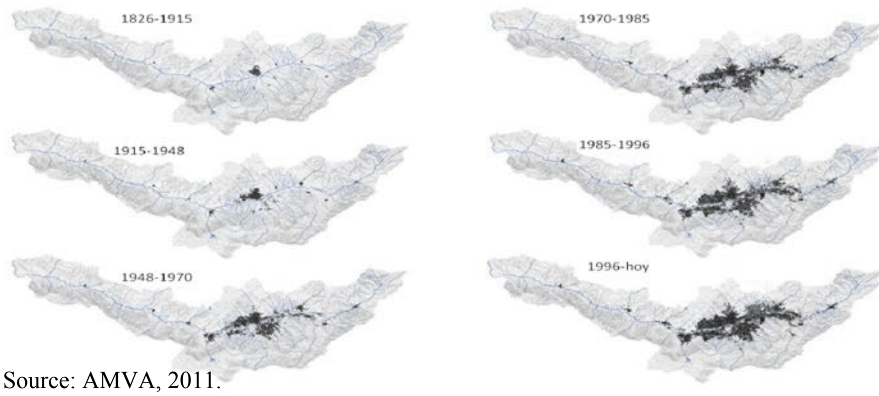
Medellin is the capital of the Department of Antioquia and is the urban centre for the Aburra Valley, which is situated in the central Colombian Andes, which range in elevation from 1,500 to 2,500 metres above sea level.

Because of its geographic location and the valley's topography, Medellin has a temperate climate year round, with temperatures varying from 15°C and 35°C. The records of the Olaya Herrera Airport weather station indicate that in 2012 the city had a total of 214 rainy days, an average wind speed of 7.3 km/hour and total annual precipitation of 1,489 mm (IDEAM, 2012). Given these characteristics, it has been dubbed the *"city of eternal spring"*.

The Municipality of Medellin has a population of 2,800,000, while another 860,000 people live in the nine neighbouring municipalities, for a total population in the metropolitan area of 3,638,000.

The central conurbation stretches over 7 of the 10 municipalities making up the metropolitan area, while the remaining three municipalities are predominantly rural.

**MAP 1**
**URBAN POPULATION TRENDS IN ABURRA VALLEY**




Source: AMVA, 2011.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

## 2. Urban sprawl

Despite various urban planning initiatives in the twentieth century, the city was unable to keep the growth of (formal and informal) urban districts from spilling over onto the surrounding slopes. This poses a problem, since the steep gradients (over 20%) of these slopes and the heavy rainfall in the area make these areas prone to landslides that pose a danger to the inhabitants, as well as making many urban sectors very difficult to access.

As the city grew in the twentieth century, the tendency to differentiate urban functions geographically led to a high degree of social segregation within the area, as well as spurring the ongoing spread of the population to the surrounding slopes, while the economic and institutional activities of longer standing remained in the flatter areas within the city, which have better mobility and services infrastructures.

## 3. The reign of the automobile and the decline and rebirth of mass transit

Against this backdrop, the automobile became the mode of transport of choice for urban planners and for builders of transport infrastructure, while mass transit was relegated to a secondary role. Although, even so, it is still the most commonly used mode of transportation, it suffers from shortcomings in terms of user accessibility, safety and comfort that make it less attractive and less competitive.

Since the 1990s, Medellin and its neighboring municipalities, with the help of federal and departmental funding, have invested heavily in consolidating a mass transit system of a type that represents a pioneering achievement in Colombia and has garnered international recognition. This system is composed of two subway lines, three gondola lifts (also known as aerial cable cars) —Metrocable San Javier-La Aurora J Line, Acevedo-Santo Domingo K Line and Santo Domingo-Arví L Line— and a bus rapid transit (BRT) network known as Metroplús (a reserved bus lane with central platforms and elevated floors) made up of two routes between Parque Aranjuez and Medellin University, which also have subway transfer stations. This is supplemented by the Ayacucho tram, which is an extension of the BRT infrastructure, and the by gradual introduction of large buses as a feeder service for the BRT system in the Belén and Aranjuez basins. In addition, new gondola lifts are being built and other projects are in the design stage or are under consideration.

The mass transit system uses electrically powered units (zero urban emissions) and buses fuelled by natural gas (low emissions of airborne pollutants). With its range of integrated public transport options, advanced technologies, the linkage of all sectors of the city and the creation of a culture around the system, Medellin is an example in Colombia and all of Latin America of a ground-breaking initiative for the construction of an efficient, equitable and environmentally friendly mass transit system.

Thanks to this infrastructure and its smooth operation, the public is highly satisfied with the system and views it as safe. A 2011 user satisfaction survey focusing on mobility and public spaces yielded high user satisfaction ratings for that year for the subway and for the buses. The results indicated that nearly half of the population of Medellin felt that the subway and gondola transportation services had improved in the past year. The same study indicated that 93% of the people of Medellin felt that the subway system was safe and that 63% of the population thought that the mass transit system as a whole was safe.

With the expansion of the system's coverage and the increase in the range of integrated services that it offers, combined with the positive perception of those services, the number of users has been on the rise. In 2000, the integrated mass transit system was used for 8% of all daily commutes; by 2012, that figure had climbed to 10% (AMVA, 2012).

However, even though the system has been well received, the motor vehicle fleet has been expanding swiftly and steadily throughout the past decade, and the city is beginning to experience the kinds of traffic problems seen in large metropolises. As a result, mobility has become an ongoing concern of the population and a major political issue. The report on public perceptions, "Medellin cómo vamos" (How are we doing, Medellin?), indicates that the public views traffic congestion as the most important environmental issue to be addressed by the municipal government (56%), rating this issue more highly that others such as air quality (40%) and noise pollution (31%).

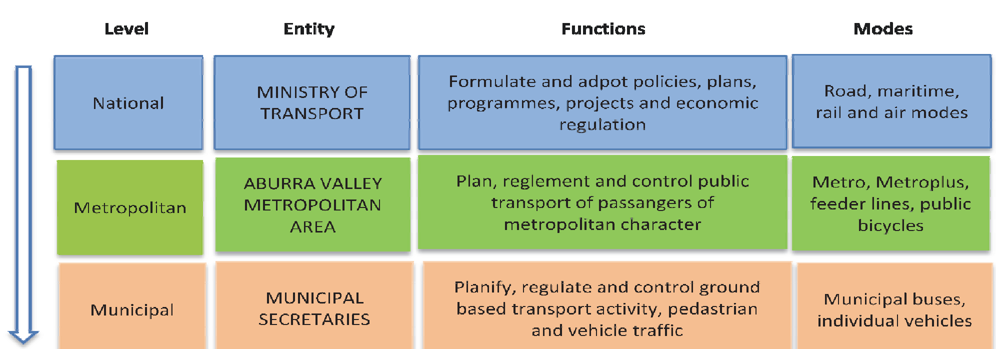
## 4. A complex institutional environment

The Ministry of Transport —the highest authority in the area of mobility at the national level— has delegated the responsibility for serving as the lead agency in this area to the Aburra Valley Metropolitan Area (AMVA), whose scope of authority takes in all the relevant municipalities. AMVA is also the metropolitan environmental agency.

At first sight, this would seem to grant a significant amount of legal power to AMVA, but its authority is actually quite limited, since key services such as municipal public transport and the issuance of taxi licences do not fall within its terms of reference. In addition, while AMVA has authority over mass transit systems (the subway system and Metroplús), the vertical implementation of this provision has not been completed or enforced, which means that, at each step along the way, AMVA has to consult with the Ministry for clarification as to the scope of its functions as the transport authority. Clearly, then, its functions in this respect have not yet been clearly delineated.

Meanwhile, the departments responsible for transportation in each municipality focus on their individual districts.

**DIAGRAM 17**
**HIERARCHY OF TRANSPORT AUTHORITIES**




Source: prepared by the authors, 2011.

Given this institutional structure, which is composed of various levels and decision-makers, organizing mobility at the metropolitan level is a complex undertaking. As a result, mobility in the Aburra Valley is governed by municipality-specific policies that are subject to the influence of local interest groups.

## 5. The energy situation in Aburra Valley

Colombia has a wide range of energy sources that provide a sufficient supply to meet domestic demand. The country's energy consumption in 2008 amounted to 242,575 Tcal (tera calories). The residential sector accounted for 21.2% of total energy demand, while the industrial sector accounted for 26.3%. Given the structure of the transport services being provided in Colombia, this sector is the largest single source of final energy demand, with a total of 38.3% (Mining and Energy Planning Unit (UPME), 2009).

Diesel fuel is the most widely used secondary form of energy in the country, accounting for 33.3% of the total in 2008, followed by electricity (23.8%) and gasoline (21.9%). Petroleum products (diesel, gasoline, LPG and kerosene) account for 61.3% of total secondary energy consumption.

The increasing use of diesel fuels throughout the country is primarily the result of the large-scale introduction of diesel-fuelled engines for use in mass transit systems, cargo transport, river-going vessels and private automobiles. The lower cost of diesel fuel and the greater efficiency of diesel engines have spurred the progressive increase in this technology's market share in the Colombian transport sector. Over the long run, the demand for gasoline is expected to fall off sharply as more efficient technologies come into use, along with alternative energy sources such as natural gas and biofuels, and as mass transit and freight consolidation systems are expanded.

The trends in energy intensity depicted in the following figure reflect the ratio between energy efficiency and productivity. At the country level, this indicator has been steadily declining due, in part, to greater urbanization and modernization, which lead to a progressive decline in the use of firewood and its substitution with more efficient energy sources. The result is a decrease in net energy consumption. The trend in energy intensity also reflects the effects of programmes focusing on the management of energy demand, the rapid increase in the use of natural gas and the introduction of environmental standards (UPME, 2009).

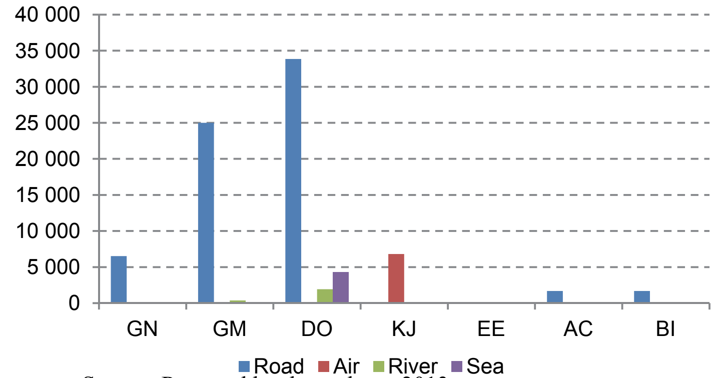
The transport sector's percentage share of energy demand in the country has shrunk somewhat, falling from 39% in 2005 to an estimated 37% in 2009 (UPME, 2010). The following figure shows the levels of energy consumption, by type of fuel, of the transport sector as of 2009.

One of the strategies for the partial substitution of petroleum products in the overland transport sector revolves around biofuels. According to UPME (2010), a minimum of 10% ethanol will be the standard to be maintained in the medium term. In the case of biofuel, the required levels increase by an average annual rate of 2.8% over the projected time horizon, with a mix of 5%. In 2009, the demand for biodiesel came to nearly 5,400 barrels per day; by 2025, demand is projected to stand at 8,400 barrels per day, for an increase of 55.1%.

The UPME baseline scenario projects an average annual increase of 3.5% in the demand for natural gas up to 2018, with the total rising from 716 tcf/d (thousands of cubic feet per day) in 2008 to 1,014 tcf/d by 2018. The underlying factors include population growth, the industrial sector's share of economic activity and the substitution of liquid fuels in the transport sector. The fastest-growing components in the baseline demand scenario are refining and transport, with average annual growth rates of 8.3% and 7.8%, respectively, from now until 2018.

Electricity is the most reliable form of energy for the transport sector in terms of the country's energy self-sufficiency over the long term. The country's generation system covers all of its domestic demand, and enough is left over to export electrical power to Ecuador and the Bolivarian Republic of Venezuela. According to XM (2013), 80% of the country's electricity demand is covered by hydroelectric generators and 20% by combined-cycle thermal plants running on coal and natural gas. The effective net installed capacity of the National Interconnected System (SIN) as of the end of 2012 was 14,361 MW.

**FIGURE 35**
**ENERGY DEMAND IN THE TRANSPORT SECTOR IN COLOMBIA, 2009**
*(in Tera calories)*




Source: Prepared by the authors, 2013.
Note: GN = Natural gas, GM = Gasoline motor, DO = Diesel oil, KJ = Kerosine, EE = Electricity, AC = Alcohol, BI = Biodiesel

Hydroelectric generators represent 68.8% of Colombia's installed electric power generation capacity (9,878 MW) at the present time, while thermal plants represent 30.8% (4,426 MW). In the short term, the system of reliability charges has locked in the country's supply of electricity up to 2019. New energy generation projects will add 3,000 MW of hydropower and 450 MW of thermal power. The following figure gives installed and projected generating capacity and contrasts that with the demand for electrical power under three potential demand-growth scenarios. As can be seen from the figure, the suspension of the Porce IV project would not threaten the country's energy self-sufficiency in the medium term.

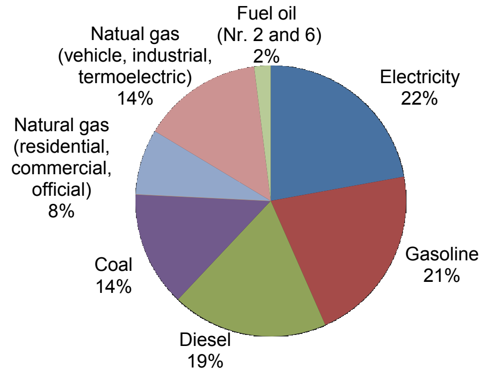
Under these scenarios, the greatest threat to the reliability of the country's electricity supply is the possibility that water levels in the country's rivers might drop due to extreme, long-lasting changes in the climate. Available contingency strategies include the regulation of the river basins that feed into dams and reservoirs, the construction of new dams for flow-regulation purposes, the possibility of increasing hydropower capacity and the installed capacity of thermal plants, and the possibility of developing the country's large coal reserves. According to UPME, power generation projects that have reached advanced design stages and are registered with the Ministry of Mines and Energy would bring on board another 4,750 MW of hydropower, 4,660 MW of thermal power (natural gas, coal, fuel oil) and 20 MW of wind power.

Electricity charges have held fairly steady and have thus risen less than the prices of liquid fossil fuels. This has been made possible by the use of competitive bidding systems, the development of bilateral contracts and a futures market, marketing firms' efforts to boost efficiency, the sector's energy self-sufficiency and regulation of the market by national oversight agencies.

The Department of Antioquia is regarded as a leader in the production and supply of electrical power. Some 40% of the country's electricity is produced by that department, which has built hydropower generators that enable it to tap into its wealth of hydropower sources and make use of its mountainous terrain, thanks to the effective operation of Empresas Públicas de Medellin (EPM). EPM is a municipal supplier of electricity, water and natural gas which, for a number of years now, has been working on an ambitious expansion project that has enabled it to export electricity to other regions of Colombia and to other countries. Yet, despite its enormous generating potential, the Aburra Valley still is a heavy user of fossil fuels. In the first half of the twentieth century, the city of Medellin actually did have an electricity-powered mass transit system consisting of nearly 45 kilometers of tram and trolley routes (IBRD, 2010). This infrastructure was torn down in the last 1940s, however, as a result of misguided development and urban transport policies. It was not until 80 years later that consideration was given to reintroducing electricity-powered transport systems, and today Medellin is the only city in the country that has such systems.

The Medellin subway used 68.3 GWh of electricity in 2011, 80% (54.6 GWh) of which went to traction systems and the other 20% to lighting and power. Average monthly energy consumption amounted to 5.7 GWh (Metro Medellin, 2012).

**FIGURE 36**
**COMPOSITION OF ENERGY CONSUMPTION IN ABURRA VALLEY IN 2010**

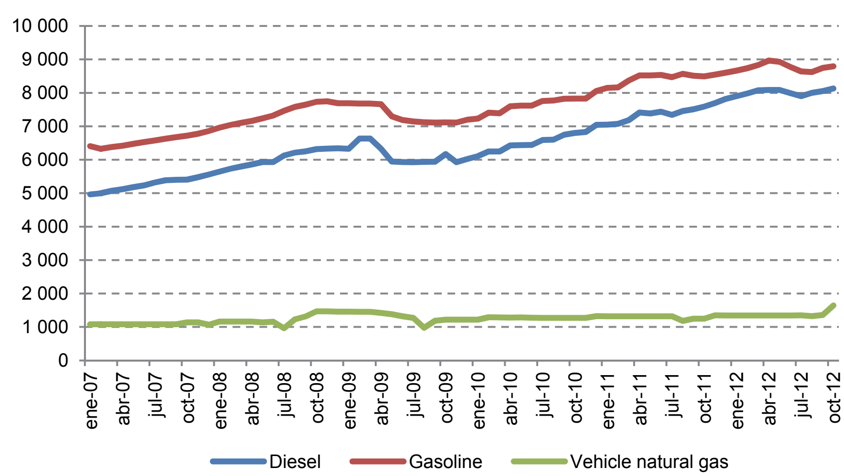



Source: prepared by the authors on the basis of data from AMVA, Ecopetrol and EPM, 2010.

The government's policy of keeping fossil fuel prices on a par with international benchmarks and the existence of additional fuel taxes have transferred the transportation system's incremental operational costs to users. According to UPME records (2013), over the five-year period from January 2007 to January 2013, the price of regular gasoline in Medellin increased approximately 1.7 times over, and the price of diesel rose by a factor of 1.3. As of January 2013, the price of a gallon of diesel fuel was 8,169 Colombian pesos (US$ 4.30) and the reference price for a gallon of regular gasoline was 8,444 Colombian pesos (US$ 4.44). By contrast, the price of a cubic metre of vehicle-grade natural gas has remained fairly stable at (as of December 2012) about US$ 0.7 /m3.

Fuel prices have become the factor that has the greatest impact on the economic viability of transport activities. Consequently, in order to remain financially viable, transport systems have had to raise ticket prices, which has an adverse impact on low-income sectors of the population. Fuel prices also have a direct impact on the prices of other products, such as foodstuffs and other inputs, as well as the cost of private modes of transport, all of which has an effect on household budgets.

**FIGURE 37**
**AVERAGE FUEL PRICES IN MEDELLIN, 2007-2012**
*(Colombian pesos/gallon – Colombian pesos/m3 VNG)*




Source: prepared by the authors on the basis of UPME, 2013.

## B. Comparative evaluation of different passenger and freight mobility options

The factors described above indicate that urban mobility is one of the city's main challenges and will be a determinant of its future urban, social and economic development. Urban mobility has, up to now, been thought of only in terms of passenger transportation, but it should also be approached from the standpoint of the movement of cargo, since freight transport accounts for a significant percentage of vehicular traffic at the present time.

### 1. Available options for passenger mobility

The backbone of the metropolitan transport system is provided by a road network and a public transportation scheme.

The road network in the Aburra Valley took shape independently in each municipality as it expanded around the main centres of activity and then gradually began to be extended as new areas became settled. The Medellin metropolitan area has a layered road system composed of principal arteries and secondary roads, as well as feeder routes that provide full accessibility in some areas but limited accessibility in others.

The system's functionality is enhanced by the Rio corridor, which is the only longitudinal route that connects all the municipalities of the metropolitan area. The continuity of this route is limited or cut off entirely in some of the mountainous and sloping areas, however, due to the presence of deep ravines that act as natural barriers between different neighbourhoods or districts.

Besides the width of the valley, the gradient of slopes in most sectors is a limiting factor in terms of the provision of safe, smoothly operating passenger transport systems.

The urban/metropolitan mass transit system is composed of two parallel operating structures:

**The traditional bus system**, which consists of urban and metropolitan bus routes, provides coverage for almost all the urban areas of the municipalities located in the Aburra Valley, including areas in which the terrain makes access difficult. This service is used for about 34% of daily commutes (AMVA, 2012). Local governments outsource the operation of this transportation service to private firms. The firms that have the permits for these routes pool the services of various vehicle owners in order to provide the necessary coverage. The Medellin Transport Department reports that 4,288 buses and mini-buses had operating permits in the city in 2013.

While this arrangement may seem to be a positive development because it "democratizes" the ownership system, it has given rise to a series of dysfunctionalities. This segment of the transport sector has grown not only in response to increased demand, but also because private firms are looking for business opportunities, and the public transport system has come to be viewed as a source of employment, while transit authorities have failed to keep the number of vehicles in operation and their route assignments in check. This has led to the emergence of supply surplus and a proliferation of transport units that have led to a deterioration in the quality of service in terms of traffic congestion, the economic viability of the transport firms involved, accident rates and pollution.

**The integrated transport system (SIT-VA)** has evolved from the subway system (in operation since 1995) and serves as the backbone system that links other transport systems along the Aburra River corridor. Since 2004, it has been expanded by gondola lifts and integrated bus routes. Recently (2012), new BRT corridors have entered into operation that supplement the integrated system and provide new integrated routes.

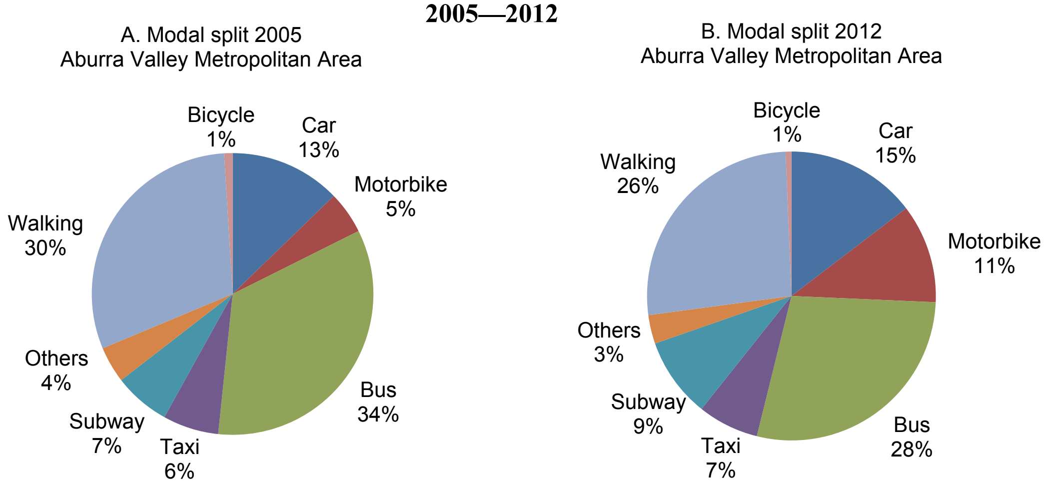
This system's operations are headed up by the Metro de Medellin company. It offers the most sophisticated structure to accommodate the physical and fare-based integration of the different modes of transport, which generates economic and social benefits for the most vulnerable sectors of the population.

According to Metro de Medellin (2012), the subway system (including aerial cable cars) carries 550,000 passengers per day and a total of 183 million passengers per year. In 2012, its trains covered 7,041,755 km, for a monthly average for the entire fleet of 586,812 km. The three gondola lines operated for a total of 17,408 hours, and the 20 articulated buses in the system covered a total of 1,499,903 km, for a monthly average for the entire fleet of 124,991 km. The Metroplús fleet has 47 buses that use technology similar to the technology used in the articulated buses, which run on natural gas.

### a) Modal distribution

The modal distribution figures compiled over the last decade point to a sharp increase in the use of private vehicles (from 18% to 26% for automobiles and motorcycles) and a decrease in the use of the traditional bus system and non-motorized means of transport. The user share of the subway system rose (from 7% to 9%), but is not commensurate with the high level of investment made in consolidating an integrated mass transit system.

**FIGURE 38**
**MODAL DISTRIBUTION OF PASSENGER TRANSPORT IN THE ABURRA VALLEY, 2005—2012**

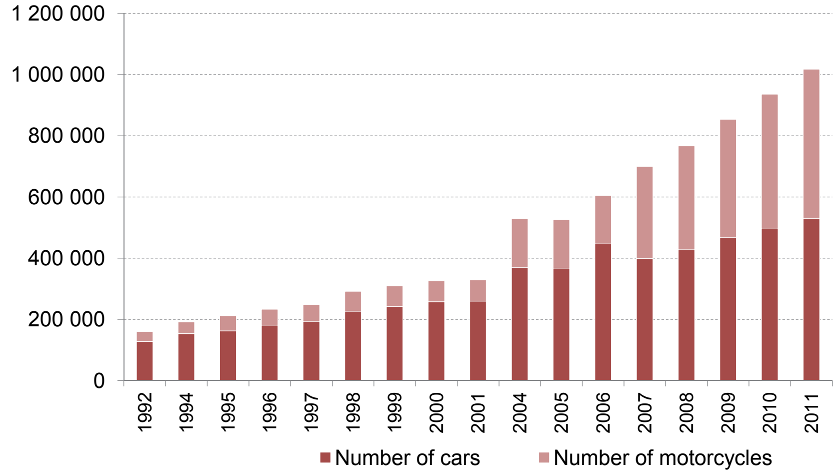



Source: prepared by the authors on the basis of AMVA, 2005 and 2012.

In the last decade, the automobile market has been booming, given the continued economic growth experienced by the country, steeply dropping prices for new and used cars (owing to reductions in tariffs, the conclusion of free trade agreements and the revaluation of the Colombian peso) and the easy credits offered by local banks.

The city's motorcycle market is also booming: salespersons, with calculator in hand, show prospective buyers that it will cost them less to make the monthly payments on a motorcycle than it would to buy bus tickets for their daily commute. In addition, there is a higher social status attached to owning a vehicle for private use.

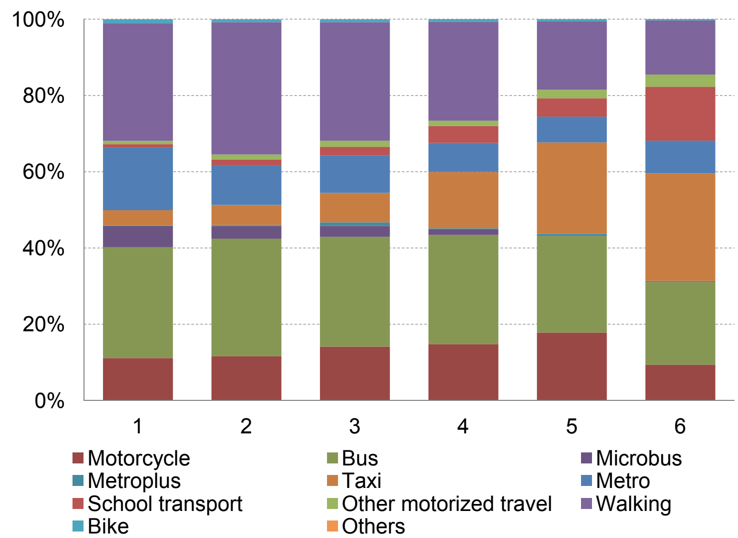
**FIGURE 39**
**GROWTH OF THE MOTOR VEHICLE FLEET IN THE ABURRA VALLEY, 1989 - 2011**




Source: Prepared by the authors on the basis of data from the transportation departments of Medellin, Envigado, Itagüí and Bello, 2012.

The number of automobiles has risen particularly sharply in high-income sectors of the city. In those areas, private vehicles are the main mode of transport (up to 70%), whereas, in low-income neighborhoods, mass transit (up to 65%) and walking are the most common means of moving from place to place.

**FIGURE 40**
**MODES OF TRANSPORT USED, BY SOCIOECONOMIC STRATUM**




Source: prepared by the authors on the basis of AMVA, 2005 and 2012.

According to the records of the Ministry of Transport (2012), the country's vehicle fleet in 2011 was estimated at 7,220,219 units. Of that figure, 3,448,620 were motorcycles, 2,173,189 were automobiles, 213,182 were buses (large and small), 977,042 were pickup trucks/jeeps or four-wheel drives, 13,064 were three-wheeler vans and 237,288 were cargo vehicles. In all, 777,242 vehicles in the fleet were used for public transport and 120,845 were official vehicles. The country's vehicle fleet has been expanding steadily throughout the last decade. In 2009-2011, nearly 616,000 vehicles (automobiles, pickup trucks and jeeps) and 1.12 million motorcycles were brought into the country. Somewhat more than 50% of Colombia's total vehicle fleet is located in Bogota and the Aburra Valley.

The Aburra Valley Metropolitan Area is one of the regions that has the most motorcycles (see table). As of October 2012, there were 3,645,000 motorcycles in the country, and 79.6% of them had engines of less than 125 cc. This type of vehicle is widely used because it is more affordable, is easier to drive and is perceived as being safer than larger ones.

**TABLE 59**
**MOTORCYCLES IN COLOMBIA'S MAJOR METROPOLITAN AREAS**

| City | Number of motorcycles | Number of motorcycles / 1 000 inhabitants |
|---|---|---|
| Aburra Valley Metropolitan Area | 434 608 | 124 |
| Envigado | 256 519 | |
| Medellin | 23 847 | |
| Sabaneta 77.293 | 77 293 | |
| Itagüí | 76 949 | |
| Bogota | 332 976 | 42 |
| Metropolitan Area of Cali | 449 588 | 125 |
| Cali | 139 944 | |
| Guacari | 74 825 | |
| Florida | 45 373 | |
| Cartago | 42 547 | |
| Pradera | 41 091 | |
| Buga | 57 087 | |
| Tulúa | 48 721 | |
| Metropolitan Area of Bucaramanga | 230 079 | 210 |
| Bucaramanga | 23 364 | |
| Giron | 123 433 | |
| Floridablanca | 83 282 | |

Source: Prepared by the authors on the basis of RUNT, 2012.

The growth of the vehicle fleet in Medellin ushered in an increase in emissions of pollutants (with a major factor being the former users of mass transit who switched over to motorcycles) and in the number of accidents, with the latter being at least partially to blame on the poor driving skills of many motorcyclists and on conflicts between them and pedestrians, bicyclists and drivers. While it is a fact that the expansion of the motor vehicle fleet is problematic and that no clear-cut policies are in place to discourage its further growth, there is nonetheless an enormous potential for supporting the use of the traditional public transportation system, increasing the use of the integrated mass transit system and rationalizing the use of private vehicles. The phased consolidation of the traditional and integrated systems will provide an avenue for rectifying the former's shortcomings and will thus serve as a key component in the overall effort to improve transportation services.

Targeted public policies to promote non-motorized modes of transport are lacking. Consequently, bicycles are used for no more than a small fraction of daily commutes, and fewer and fewer people are walking to work, as is evidenced by the figures on the modal distribution of transport for 2005 and 2012.

Bicycles are an urban mode of transport that offers major environmental, energy, economic, social and public health benefits, both for the users and for the city at large. Despite all of these benefits, however, bicycles are used very little. Some of the reasons for this are the following:

- The use of bicycles in steeply sloping areas requires a great deal of physical effort. People are reluctant or unable to bicycle up long, steep gradients. Bicycling down those same slopes is also dangerous for novices. According to Dekoster et al. (2000), slopes of several dozens of metres in length with a gradient of over 6% are a strong deterrent to the use of bicycles.
- Weather conditions are seen as a limiting factor for bicycle use, but some types of weather, such as cold or heat, have no more than a marginal effect on the decision to use a bicycle or

not. Rain is a deterrent because of the risks and discomfort involved. What is more, in areas subject to poor urban drainage systems and faulty roadway infrastructure, the deterrent effects of rainfall may last for minutes or hours after the rain has stopped. For cities in tropical zones, high levels of humidity and direct solar radiation are additional deterrents to bicycle use.

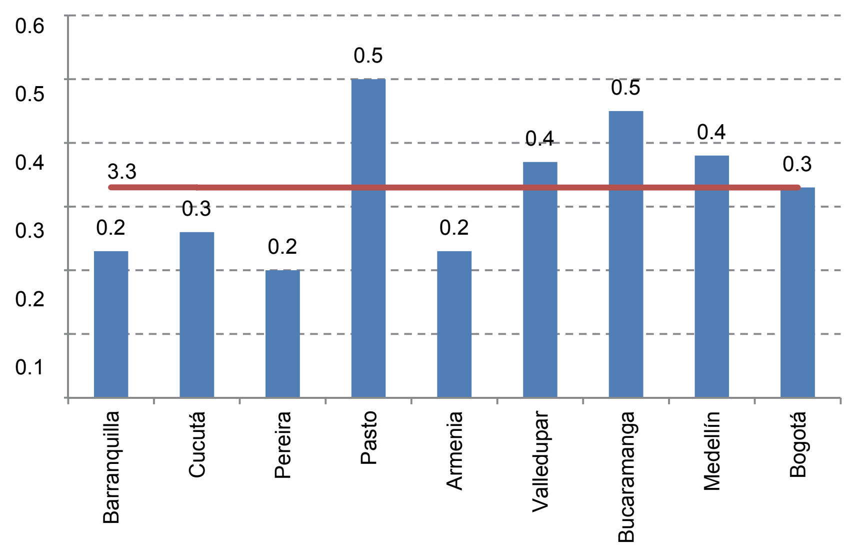
- Bicycle use is also discouraged by poor-quality urban roadway infrastructure (e.g., cut-offs of bicycle lanes, inaccessibility, uneven road surfaces, potholes, missing manholes).
- People are also reluctant to use bicycles in dangerous areas –or what are perceived as being dangerous areas—within the city. Cyclists' vulnerability to robbery or theft en route or in parking areas make many people rule out the use of a bicycle as a regular means of transportation.
- Other factors that discourage the use of bicycles include shortcomings in urban facilities for them, such as drinking fountains, bicycle parking garages, meeting spots, signage for cyclists and the absence of public rest stops near the routes that cyclists take. The lack of suitable infrastructure and signage to help ensure the safety of cyclists also results in more accidents and contributes to the perception of vulnerability.
- Yet another factor is the absence of bicycle-specific infrastructure. Bike lanes provide important benefits for the user, but, as demonstrated by the Netherlands' experience, bike lanes alone are not enough to boost the number of cyclists or improve the conditions for them (Welleman, 1992). When cyclists have to use busy roadways and are therefore exposed to the associated risks, they tend to rule out the use of bicycles as a regular mode of transport.
- While bicycles are embraced as a form of recreation, their use as a daily mode of transport is sometimes associated with poverty or straitened economic circumstances. By contrast, automobiles are seen as symbols of the aspirations and desires of a large segment of the population. This perception is continually being reinforced by television programmes, films and commercials in which the highest-status, most beautiful or richest characters have luxury automobiles or motorcycles.
- The mandatory use of helmets and reflective vests, rigorous quality standards and regulations concerning types of accessories are seen as bothersome deterrents by cyclists or potential cyclists. In public bicycle systems, the use of a helmet may be seen as an obstacle, but this may be mitigated by the provision of information on the risks of riding without one.
- A sedentary lifestyle poses a public health problem in modern societies. A portion of the population relies on certain technologies, uses motorized forms of transport and pursues sedentary hobbies, all of which, taken together, makes for very little physical activity. This type of apparently comfortable and accepted lifestyle acts as a disincentive for bicycle use.
- The lack of political will to provide a reliable flow of funding for the development of infrastructure, the adoption of safety precautions and the promotion of bicycle use restricts the role of bicycles in urban transportation schemes. The existence of commitments to other interest groups and fear of advocating a political initiative that might meet with failure also have a negative impact on the promotion of bicycle use.
- The fact that, in some systems, bicycles are not allowed on buses and trains is another impediment. Park-and-ride schemes and arrangements that enable users to take their bicycles with them to their final destination and to combine them with public transport are options that should be revisited.
- The absence of policy incentives for bicycle users and for companies that encourage their use (tax reductions for firms that develop free bicycle rental systems for their employees) is yet another factor.
- Vandalism is one of the biggest problems faced by bicycle rental schemes.

- Conflicts between motor vehicle drivers, motorcyclists and bicyclists are an issue that needs to be addressed in order to reduce the risks for bicycle users and improve safety conditions and perceived safety conditions for cyclists in the city.

Both the public sector and civil society are beginning to develop projects and initiatives to promote the use of bicycles (civil society collectives, the introduction of a public bike system known as EnCicla and plans to build urban bike paths). Large-scale urban renewal works and projects to create more public areas are also under way that will improve the environment for non-motorized urban transport. These initiatives include the reversal of some parts of 10th street and 107th street, improvements in the Metroplús corridor (routes along 45th boulevard and 30th street) and the Paseo Carabobo. Some of these projects also include other facilities, such as libraries (Tomás Crrasquilla, España, Leon de Greiff, Belén and San Javier), botanical gardens, parks and environmental zones (the prohibition of construction in areas adjacent to ravines that are prone to landslides). The photograph shows a BRT station with a reserved bus lane.

According to the Office of the Comptroller-General of Medellin (2013), the amount of public space per capita came to 3.79 m²/person, which represented a 1.04 percentage-point reduction from the situation in 2010. This figure falls short by 74.7% from the minimum standard of 15m²/person established by article 14 of Decree No. 1504 of 1998. Even so, Medellin has higher public space indices than Bogotá, Cali and Barranquilla.

**FIGURE 41**
**PER CAPITA PUBLIC SPACE INDICES FOR COLOMBIAN CITIES**
*($m^2$/inhabitant/year)*

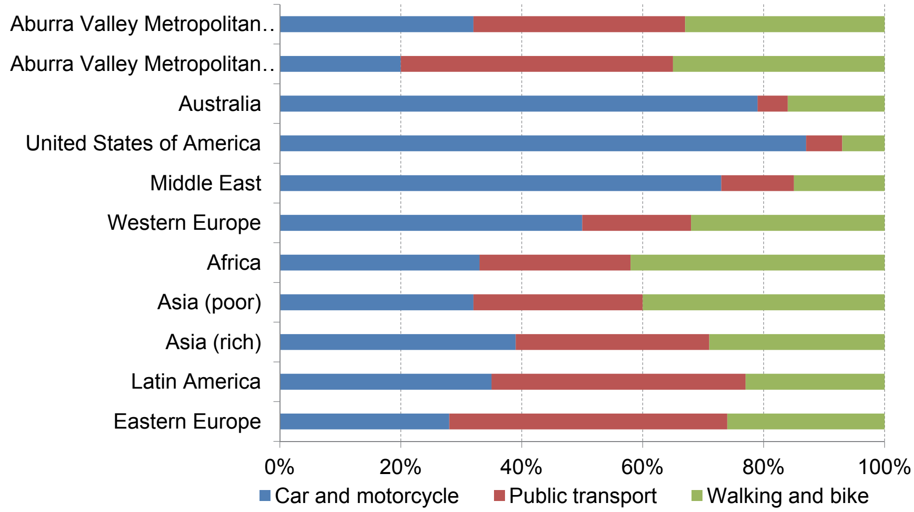



Source: Office of the Comptroller-General of Medellin, 2013; prepared by DNP-DDU, 2010.

The available public space in Medellin represents 8.2% of the total. This percentage reflects the number of square metres of public space actually available in the urban area. The only types of areas included in this indicator are permanent public spaces, such as parks, squares and green areas within the city (Office of the Comptroller-General, 2013).

A comparison with the distribution of modes of transport with other regions in the world shows that the distributional pattern in the metropolitan area of Aburra Valley is similar to those seen in other developing regions. This should be seen as an opportunity to consolidate a sustainable mobility model and to rectify existing flaws, rather than perpetuating the mistakes made by developed countries during the last century.

**FIGURE 42**
**DISTRIBUTION OF MODES OF TRANSPORT IN DIFFERENT WORLD REGIONS**

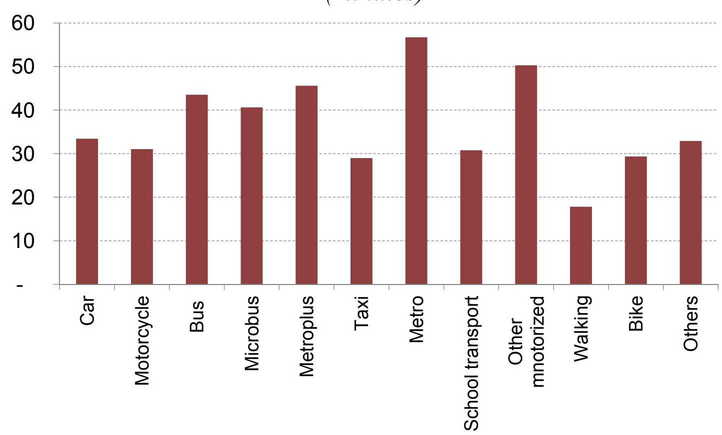



Source: Prepared by the authors on the basis of UITP, 2001, and AMVA, 2005 and 2012.

## b) Commuting times

In Medellin, the average commute takes 31 minutes, but the commute for people living in poor, outlying areas may take as much as an hour, while for others it may be no longer than 20 minutes.

**FIGURE 43**
**AVERAGE LENGTH OF COMMUTES, BY PRINCIPAL MODE OF TRANSPORT[a]**
*(minutes)*

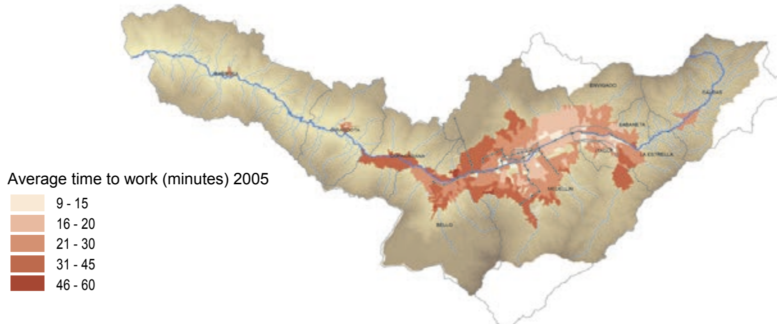



Source: prepared by the authors on the basis of AMVA, 2012.
[a] The catgegory "other" refers to less conventional means of transport such as motorcycle taxis, company-owned vans and inter-city taxis.

The starting and ending points of people's commutes, the mode of transport used and the associated cost, and the presence or absence of any physical disability can all have a strong influence on the length and cost of their commute. In the Aburra Valley Metropolitan Area, fewer people in the lower-income sectors of the population commute than those who are better off, but their commuting times are longer.

The following figure shows average commute times. The figures confirm the observation that lower-income sectors of the population spend more time commuting than their richer counterparts, who generally spend less than 20 minutes getting to work. The data thus illustrate the inequitable situation that exists in terms of mobility and accessibility.

**MAP 2**
**AVERAGE COMMUTE TIMES, BY SECTOR, IN THE ABURRA VALLEY METROPOLITAN AREA**




Source: AMVA and the Municipality of Medellin, Plan BIO2030, on the basis of the results of the Metropolitan Quality of Life Survey, 2009.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

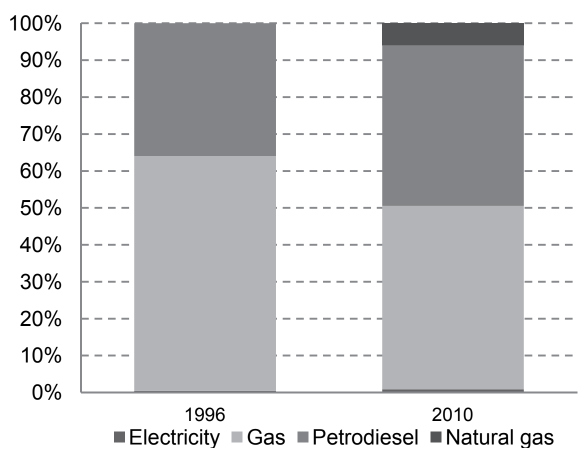
The figure and map do not tell the whole story, however. The sectors with the highest rates of automobile ownership also experience the highest rates of traffic congestion during rush hour, so, for those who live far from where they work, the commute from home to their place of work may take more than an hour. These members of upper-income sectors are the main advocates of an expansion of the road network.

Although the average commute times for each mode of transport appear to be reasonable when compared with the averages for Latin America, people in lower-income sectors, who represent 45% of the commuters who use public transport and 46% of those who walk to work or school, have commutes of over 35 minutes (data compiled by the authors on the basis of AMVA, 2005). There are cases in which these commutes take longer than 40 minutes, which is the maximum length considered to be reasonable for Latin American cities according to the CAF Mobility Observatory.

### c) Energy consumption

When urban activities are geographically concentrated, transportation times are reduced and infrastructure costs are lower, and a smaller, more compact city can therefore be assumed to be more efficient in terms of the energy required for transportation purposes (Newman and Kenworthy, 1999). By contrast, suburban residential patterns necessarily entail the use of private vehicles for commutes, since the introduction of mass transit systems in low-density areas is not economically viable.

**FIGURE 44**
**PERCENTAGE OF TOTAL ENERGY CONSUMPTION FOR TRANSPORT IN THE ABURRA VALLEY IN 1996 AND 2010**




Source: prepared by the authors on the basis of AMVA, 2009 and 2011.

A comparison of the amount of energy consumed in transport in 1996 and now in the Aburra Valley shows that it has declined from 14.63 to 10.01 gigajoules (GJ) per person per year. In a city where population density tends to be greater in the outskirts and where more and more people are living in the suburbs, the only possible explanation for this decrease lies in technological changes and better-quality fuels. Both of these factors make a direct contribution to improved air quality and energy efficiency, but they are not enough in and of themselves to make mobility truly sustainable.

An increased use of the metro system and its linkage with outlying districts via cable cars, the integration of transport routes and some modernization of the motor vehicle fleet would contribute to increased transport energy efficiency in Aburra Valley. Although the statistics do not yet provide a clear indication of this, the introduction of articulated, natural-gas-powered buses using bus-only lanes also contributes to the system's energy efficiency.

The increase in the use of private vehicles and motorcycles, on the other hand, has an adverse impact, but, even so, the transport sector's per capita energy consumption continues to trend downward. Cross-comparisons of data on urban density and commuter energy consumption yield highly and increasingly favourable energy efficiency ratings relative to other world cities.

The vehicle fleet's emissions are influenced by the quality of the fuels used, engine technologies and maintenance, and driving speeds. Although the transport sector's per capita level of energy efficiency increased between 1996 and 2010, as has the percentage share of electrically powered means of transport, the overall shares of gasoline and diesel fuel are larger and will remain so in the long term.

### d) Coverage

The Aburra Valley Metropolitan Area is beginning to gear its investment policies towards collective and mass transport. The proportion of urban land covered by the heavy public transport network has increased during the period under analysis, thanks to the construction and launch of the new Metrocable on the west side of Medellin and the Metroplús system, which provides coverage in a central area and links the east and west sides of the city. The metro system has built two new stations, providing additional coverage in the south of the conurbation. The high-capacity public transport infrastructure has thus raised urban coverage from 4.70% in 2005 to 7.83%. These data permit a degree of optimism when compared with the global figures, since Tokyo's metro system covers 10%, while that of Paris covers 6.5% of the urban territory (CERTU, 2008).

The growing coverage is attributable in part to the new infrastructure built to support mass transit, taking the segregated lanes from 1.05% to 1.78% of the urban area. This is well below the figure for systems like that of Bogota (6.4%) and Curitiba (6.3%) and is slightly higher than that of Rio de Janeiro (0.9%, CAF, 2009). Paradoxically, while the dedicated bicycle infrastructure has increased from 0.44% to 0.81%, the proportion of use has fallen from 0.96% to 0.66%.

Although a greater area is now covered, it is apparently still insufficient in relation to the main user population. The authorities' efforts have evidently been concentrated on consolidating the central areas rather than on prioritizing quality accessibility in outlying sectors.

**TABLE 60**
**KILOMETRES OF INFRASTRUCTURE, BY TRANSPORT MEANS**

| Infrastructure by mode (km) (km) | | |
|---|---|---|
| Mode | km | Ratio in comparison to road network |
| Metro | 31.3 | 1.08% |
| Metrocable (cable car) | 9.32 | 0.32% |
| Metroplus (Bus Rapid Transport) | 12.5 | 0.43% |
| Seperated cycle lane | 24.13 | 0.83% |
| Road network | 2 908 97 | 100% |

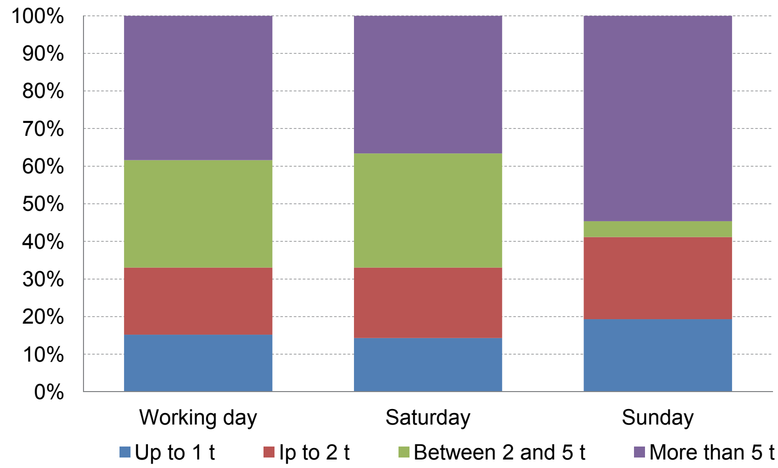
Source: prepared by the authors, on the basis of Metro de Medellin, AMVA, 2012.

## 2. Current state of freight transport

### a) General situation

According to 2011 figures, around 102,000 tons of freight are transported every day in the Aburra Valley, amounting to over 37 million tons per year. This is a hefty increase over the 2004 figure of about 71,000 tons per day.

**FIGURE 45**
**PROPORTION OF FREIGHT TRANSPORTED**

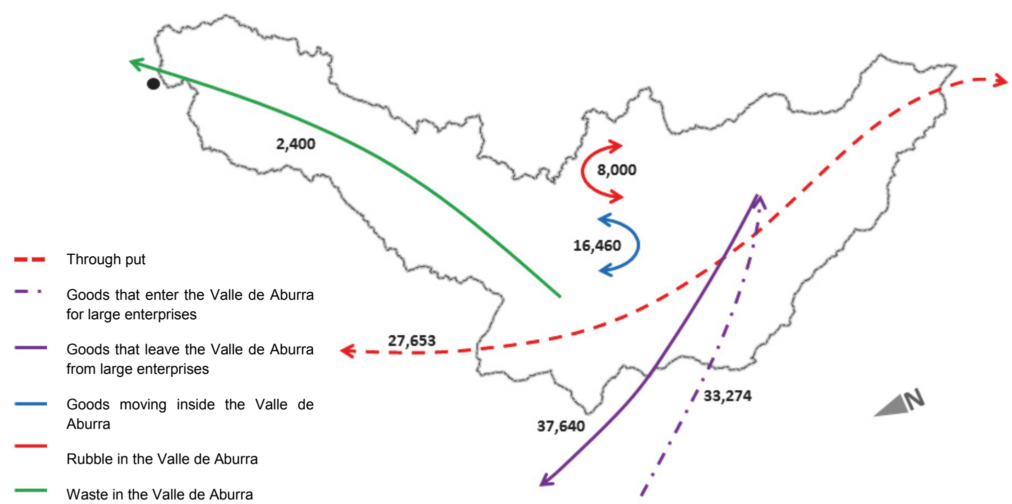



Source: Encuesta Origen y destino del Valle Aburrá. 2012. Área Metropolitana del Valle de Aburrá, 2012.

Freight is moved by some 30,000 trucks, at an average rate of 2.8 tons per vehicle. A large proportion of these goods are transported in high-capacity vehicles (over 5 tons).

The following figure offers a general overview of freight transport in the Aburra Valley.

**MAP 3**
**FREIGHT TRANSPORT IN THE ABURRA VALLEY**




Source: Aburra Valley Metropolitan Area, Origin-destination survey, 2012.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Circulation of trucks in the Aburra Valley accounts for 4% of total annual traffic annual (96% is passenger traffic), but 36% of PM2.5 emissions and 20% of total $CO_2$ emissions generated by mobile sources (AMVA, 2011, p. 131). PM2.5 is the worst pollutant from the point of view of health and $CO_2$ is the main contributor to global warming. With respect to sound emissions, a truck emits on average 10 dB more than a car in passing. Also important is that fact that freight vehicles in Colombia are 24 years old on average, which has a bearing on the high levels of pollution they cause and their poor energy efficiency.

### b) Transit freight flows using the Aburra pass

Most freight travelling through Colombia is transported by road (70% in 2011, Ministry of Transport, 2011). The public rail system fell into disuse several decades ago and river transport accounts for only a fraction of overall freight movement.

The configuration of the national highway network means that much of the freight travelling from south to north must come through the Aburra Valley. This presents a major extra transport cost, because the steep terrain in the Department of Antioquia forces vehicles to climb from 500 to 2,600 metres above sea level (masl) to enter and leave the Aburra Valley, before coming back down to 400 masl in the Caribbean region. These freight vehicles also have to enter the urban area, thus reducing their average speed, adding to road congestion and generating pollutant emissions.

In 2012, 27% of freight crossing the valley was through traffic. This added up to around 1,550 heavy vehicles of every type[66] in 2004.

Bearing in mind the magnitude and the impact of through freight on traffic levels, environmental conditions and energy consumption, alternatives must be sought that will be better for both transporters and the city in general.

### c) Internal freight transport

An origin and destination survey was conducted for the first time for the entire metropolitan area in 2012. It provides several figures that help to understand the importance of this issue in terms of mobility, air quality, energy efficiency and even the public space.

Around 22 million tons of local freight are moved in the Aburra Valley every day, originating in or going to commercial establishments in the city. Over 60% of this freight is transported on heavy trucks, which adds to traffic congestion. In addition, bearing in mind that most of these trucks are between 15 and 30 years old, according to national statistics (Ministry of Transport, 2006, cited in AMVA, 2012), it may be inferred that this also represents an environmental problem, especially in terms of harmful emissions and, of course, climate warming.

Lastly, another significant factor is that over 30% of loading/unloading is done improperly or illegally in the public space, which adds further complexities to the problem.

Another issue is that motorcycles, which form a large proportion of freight vehicles (as much as 25% of privately-owned vehicles), move only 4% of total freight. As with passenger transport, motorcycle freight seems to be increasing and must be taken into account when planning strategies for addressing congestion and air quality problems.

It may be concluded that local freight transport in the Aburra Valley has not yet been the subject of prospective planning taking into account the congestion generated, the time lost, the energy wasted and the pollution caused. The fact that the first origin and destination survey was not conducted until 2012 testifies to this, but it also suggests that the Aburra Valley may soon have a master plan for internal freight transport, which, in view of the analysis here, is increasingly urgent.

[66] These figures were calculated on the basis of the total tonnage transported between the administrative departments connected by the western trunk road, including a stretch through the city of Medellin (Ministry of Transport, 2004).

## C. Existing and planned solutions for improving energy efficiency

The challenges of modern cities lie in ensuring competitiveness and quality of life, in harmony with the environment. Cities worldwide have taken measures to stimulate economic growth, but these efforts have led to increasing movement of population and merchandise, pushed up demand for energy and increased pollutant emissions.

In this context, the problems are associated with the ways in which the population uses modes of urban transport, technologies and energy products to meet its daily transport needs. If urban transport cannot be made sustainable, the outlook becomes increasingly complex, bearing in mind that urban population growth, the associated economic dynamics and city expansion are unavoidable, and that some of the collateral impacts of transport will be irreversible.

Any roadmap for transport planning must therefore have a sound basis in strategic planning and sustainable development. Strategic planning needs to identify the real problems, the desired goal and a process of continuous improvement. This process must be economically viable, adaptable to the contextual dynamics and measurable. In view of the complexities, it must also be participatory and multidisciplinary.

Under a sustainable development approach, economic, social and environmental factors revolve around the same purpose: to improve the quality of human life. The social dimension refers to the capacity to adapt development to the demographic, cultural and social changes occurring within societies and to the labour market dynamics. The environmental dimension focuses on the stability of physical and biological systems and impacts on the environment and on health (Bruntland Commission, 1992). Under this approach, it is essential to consider matters of equity, education, health and ethics (Sachs, 1997).

In this context, strategic and sustainable mobility is the outcome of urban transport schemes capable of meeting the transport needs of the population and their goods in urban areas, with quality and in an accessible and economically sustainable manner, with minimal environmental impact, high energy efficiency, positive urban externalities and public health benefits (Velandia, 2013). Energy-efficient transport planning is essential in this process.

Although energy efficiency has not been the main guiding principle of transport policies and projects, it has gained directly from infrastructure and technology developments, and from regulatory progress. In view of the fact that per capita energy consumption for transport has actually decreased in the region in the past decade, despite the rapid growth of the vehicle fleet, solutions should aim primarily at achieving real urban sustainability, beyond the energy consumption figures.

The solutions put forward in the Aburra Valley have been aimed at improving transport supply, whether public or private, but they have also sought to improve the management and regulation of demand, especially on the part of road users. In this connection, a number of stakeholders have realized that solving mobility issues is not the business solely of transport and mobility departments. On the contrary, it requires a cross-cutting and parallel effort involving institution-building and urban development with an eye to transport matters and vice versa. It also requires understanding the limits of the current mobility and transport network, which means acting above all on supply and demand, bearing in mind that public transport must be attractive and efforts made to promote non-motorized modalities in particular.

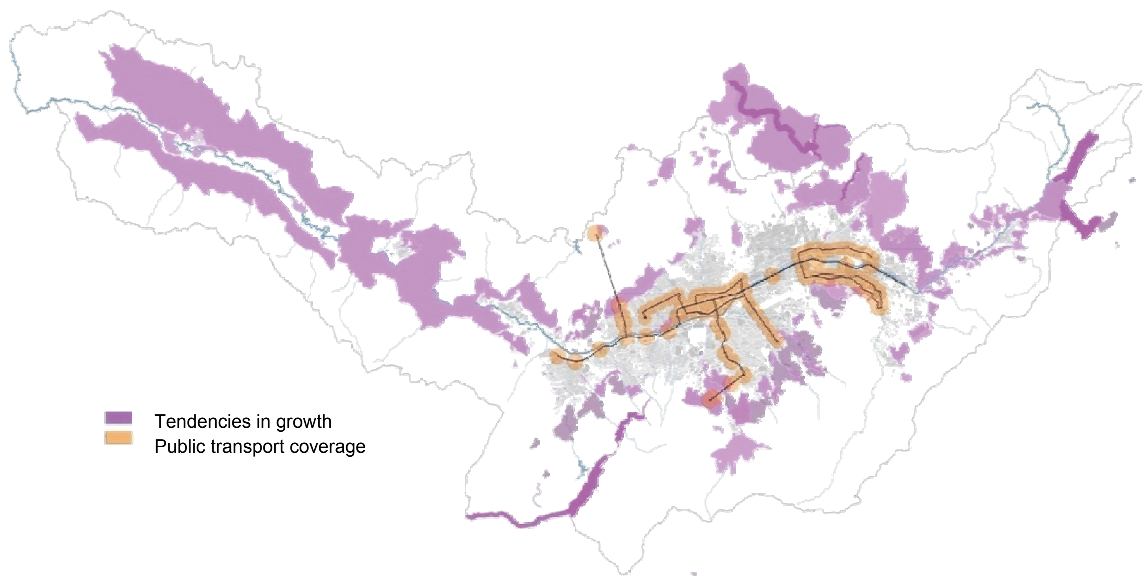
### 1. In terms of management and regulation

There have been diverse initiatives that, one way or another, have been aimed at improving transport-related energy efficiency.

**In terms of urban planning**, it must be understood that strategies for improving mobility are not necessarily based on mobility itself. This is why a number of land use planning documents such as the

Metropolitan Land Use Guidelines (DMOT, 2004) and the BIO 2030 plan (2011) have sought to channel urban development consistently with public transport, contrary to the current trend. This means concentrating urban development in the central part of the valley, where the infrastructure and services endowment are greatest. Accordingly, efforts are being made to redensify this central area and attract a variety of users, bringing the inhabitants closer to their places of work, study and leisure, which should reduce the time, money and energy spent on daily travel.

**MAP 4**
**URBAN AND SUBURBAN EXPANSION VS COVERAGE OF THE INTEGRATED TRANSPORT SYSTEM**




Source: Aburra Valley Metropolitan Area, Plan BIO2030, 2011.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

However, the rules specific to these developments impose a series of conditions that discourage the real estate sector, which tends to prefer the facilities for developing hillside areas. Consequently, development in the past few years has been concentrated on hillsides and peripheral areas of the city and redensification and urban renewal projects are slow to prosper.

The cost of land, construction and services in the city of Medellin are some of the factors that have encouraged urban and population growth and in the neighbouring municipalities. However, Medellin city centre continues to be a main trip destination, since that is where most jobs, administrative, political and judicial departments, large universities and other educational establishments, cultural centres and sports facilities are based. Accordingly, the number of trips between Medellin and its neighbouring municipalities is increasing. Longer travel distances represent a higher demand for energy.

**In terms of environmental management**, in the late 1990s the environmental authority, with support from multilateral agencies and academia, pinpointed the high costs associated with poor air quality in Colombia's main cities. Accordingly, Colombia adopted National Economic and Social Policy Council (CONPES) document 3344 of 2005, under which the policy on prevention and control of air pollution was drawn up. Later, CONPES document 3550 of 2008 set forth the ground lines for the comprehensive environmental health policy, including such aspects as air quality. Among this policy's objectives is a mandate to coordinate plans of action and management practices of the various agencies and develop and implement processes and procedures to strengthen inter- and intrasectoral management of environmental health. In addition, a unified environmental health information system (SUISA) was created.

With respect to emissions control, Resolutions 910 of 2008 and 2604 of 2009 defined emissions standards for mobile sources (light vehicles, heavy vehicles and motorcycles) and for public transport vehicles, respectively. Under the regulation, as from 2010 only Euro IV diesel buses or those with more advanced technology were allowed to operate in integrated mass transit systems. Euro IV vehicles produce 87% fewer emissions of particulate matter (PM) than Euro II vehicles.

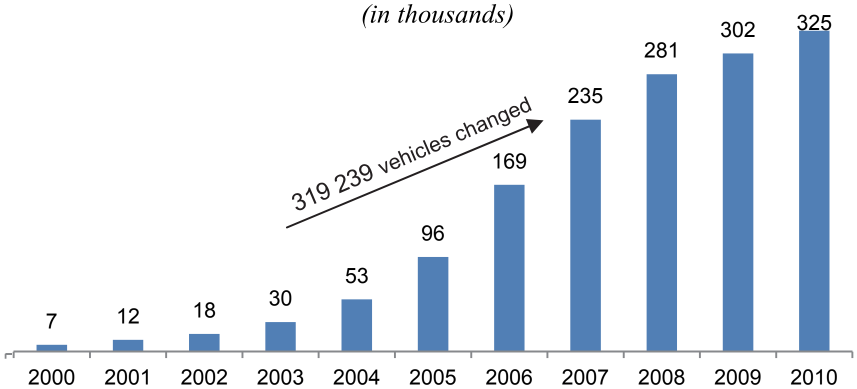
Meanwhile, Act 693 of 2001, regulated by Decree 3862 of 2005, defined standards on the use of fuel alcohols, created incentives for their production, sale and consumption, and laid down other provisions. Under the standard, by September 2005, cities with over 500,000 inhabitants, such as Bogota, Cali, Medellin and Barranquilla, had to use gasoline mixed with 10% fuel alcohol. Act 1205 of 2008 defined a plan for improving diesel quality in Colombia, such that integrated mass transit systems in all urban centres had to use diesel of under 50 ppm of sulphur as of 1 January 2010. As from 31 December 2012, it was prohibited to distribute, sell, consume or transport diesel fuel containing over 50 ppm of sulphur, except that imported or produced exclusively for export.

The Ministry of Mining and Energy has developed a scheme to promote the use of natural gas as automobile fuel, with a view to replacing more expensive and pollutant liquid fuels. With this in mind, Act 788 of 2002 (tax reform) extended VAT exemptions for gas service station parts and equipment and kits for converting vehicles to run on gas. At the same time, as subsidies on liquid fuels which can be substituted by natural gas (gasoline and fuel oil, ACPM) are gradually dismantled over the short and medium terms, the prices of these fuels will keep rising, making natural gas more competitive.

In 2005, the national government issued Decree 4570, which partially modified the customs tariff, authorized split tarriffs, and described and levied some subitems related to the vehicular natural gas industry. As a result, this sector has grown rapidly in Colombia, which is now among the 10 countries in the world with the most conversions in the past 10 years.

By 2010, conversions of gasoline-run vehicles to compressed natural gas (CNG) numbered 324,515 in Colombia. The table shows the number of vehicles converted to CNG in Colombian cities between 2000 and 2010 (Promigas, 2011). By 2012 almost 400,000 CNG vehicles were estimated to be operating in the country.

**FIGURE 46**
**VEHICLES CONVERTED TO CNG IN COLOMBIA 2000-2010**
*(in thousands)*




Source: Promigas, 2011.

As well as national level policies, the AMVA decontamination plan (2009) was created as a tool for researching, calculating and demonstrating the main foci of pollution affecting air quality in the Aburra Valley. Its basic purpose is to reduce emissions from the main sources of pollution, by setting down control and reduction measures in the short, medium and long terms, using local capacities and aiming to strengthen human, technical and logistical resources.

Under the plan, a series of actions have been established for improving air quality. Several of them relate to passenger and freight transport, in particular the following:

- Improvement of fuel quality: Through an agreement with Ecopetrol, the sulphur content of the diesel used in the city fell from 3,000 ppm to 50 ppm between 2006 and 2010. This measure had a major impact on air quality.

- Improvement of bus technology: Under national standards, new public transport vehicles had to have Euro IV technology, which improved energy efficiency and substantially reduced emissions.
- Sustainable transport: Under an agreement with the Clean Air Institute, strategies are being formulated to make urban public transport more sustainable. This includes developing a tool for putting a financial cost on environmental impacts and on energy efficiency savings achieved through different mobility projects.

Unlike Bogota, which under Resolution 2394 of 2011, taking into account Decree 035 of 2009, limited the use of two-stroke motorcycles, mopeds and scooters, the city of Medellin has not imposed restrictions on two-stroke vehicles. Notwithstanding, the Ministry of the Environment concluded that two-stroke engine technology emits between 5 and 15 times more hydrocarbons into the atmosphere than four-stroke technology, and between 50 and 100 times more than other motor vehicles.

Colombia’s energy matrix, the range of electrically powered mass transit systems, and the scrapping of the traditional public transport system have brought major benefits in terms of reducing greenhouse gas emissions. The Medellin metro system has thus benefited from the Clean Development Mechanism (CDM) and become a global benchmark for $CO_2$ reduction.

In terms of $CO_2$ emissions, a litre of gasoline is estimated to emit 2.3 kg and a litre of diesel about 2.6 kg (Generalitat de Catalunya, 2011). For Colombia, 0.28 kg of $CO_2$ is estimated per KWh of electrical energy (UPME, 2008). Importantly, the emissions factor of Colombia’s electricity sector includes the entire chain (production, transmission, distribution) and even some construction factors. By contrast, the emissions factors associated with fossil fuels are applied at the level of the user without counting additional emissions along the chain. In this light, the use of electric transport technologies in Colombian cities offers an opportunity to reduce total $CO_2$ emissions.

CNG vehicles emit less of the pollutants that affect urban air quality (particulate matter, total hydrocarbons and nitrogen oxides) than diesel vehicles; only carbon monoxide and ultrafine particulate matter are substantially higher in CNG vehicles (Behrentz, 2010). Among the transport options available, electric vehicles offer the greatest benefits given their zero urban emissions capability.

**In terms of managing vehicle demand**, the “peak and plate” measure was implemented in Medellin in 2005. This measure was intended to reduce traffic at peak times (for private automobiles it operated from Monday to Friday from 6.30 am to 8.30 am and from 5.30 pm to 7.30 pm). In principle, it was supposed to restrict traffic by 20%[67] of the fleet of private vehicles and taxis. In 2008, it was extended to two-strike motorcycles and the traffic reduction rose to 40%[68] at the same times of day. In 2013, the daily hours covered by the measure were reduced to three in total, from 7 am to 8.30 am and from 5.30 pm to 7 pm. The area covered was also reduced, from 100% to 64% of the city.

By Decree 1120 of July 2008, Medellin exempted duly accredited natural gas fuelled vehicles from its peak and plate rule. This benefit was also applied to range-extended battery-electric vehicles.

## 2. Technical solutions

Clean technologies in public transport. The use of efficient technologies, energy sources and configurations for urban transport is another strategy implemented in the city in the past decade. Initiatives in this framework are aligned with national policies on energy efficiency and emissions reduction.

Under the Programme for rational and efficient use of energy and use of non-conventional energy sources (PROURE) (Resolution 180919 of 2010), three strategies have been proposed specifically to reduce energy consumption in the transport sector:

67 Circulation was restricted for two plate numbers each day.
68 Circulation was restricted for four plate numbers each day.

Technology conversion: Upgrading the existing transport infrastructure with a view to making passenger and freight transport and private vehicles more energy efficient. The measure is aimed at modernizing the various fleets while ensuring that vehicles are suited to operational needs.

Means of transport: Given the complexity of urban mobility and all its implications, the process of improving transport efficiency has to be approached in an integrated manner. Urban mobility plans must include not only policies to supply better means of collective transport, but also regulation of private vehicle use, especially low-occupancy vehicles. Strategies to discourage automobile use include the development of integrated mass transit systems, the large-scale deployment of clean, efficient transport modes, such as electric bicycles, electric or low-fuel motorcycles and hybrid cars, and tariff incentives and breaks for clean, efficient vehicles. Measures such as congestion changes and parking management may also be studied, as may massive expansion of train use.

Best practices in transport: This comprises a range of actions aimed at getting drivers of all types of vehicles to adopt efficient driving practices. This applies both to new drivers, through the system of teaching driving prior to licensing, and to experienced drivers, through courses at licence renewal or when vehicles are being serviced.

The Aburra Valley has begun a process for incorporating clean technologies in transport, starting with the Medellin metro (1995) and later including the Metrocable (line J in 2004 and line K in 2008). In 2012 the Metroplús BRT (Bus Rapid Transit) system, whose buses run on natural gas, came into operation. This system is operating in part on its trunk corridor (12.5 km of dedicated lanes) and the southern pre-trunk road is currently being built in the municipalities of Envigado, Sabaneta and Itagüí.

The table below shows yields for different types of technology and KWh equivalents, taking into account operating system data and tests on transport units. The data shown suggest that mobilizing the population towards the use of electric transport systems would bring greater energy benefits than internal combustion technologies. In this regard, the low energy potential of natural gas generates higher energy consumption in equivalent terms. Nevertheless, the BRT system can gain energy efficiency by substituting old buses for natural gas models, combined with operational fleet management and rationalization of vehicle use through integrated mass transit systems.

**TABLE 61**
**ENERGY YIELDS IN ARTICULATED BUSES BY TECHNOLOGY TYPE**

| Transport unit | System | Performance |
|---|---|---|
| Articulated diesel bus | TM 2009 | 6.2 Km/gallons |
| Articulated buses CNG[a] | | 1.23 Km/m3 |
| Articulated trolleybus | Quito | 2.25 KWh/Km |
| Articulated trolleybus | Salzburgo | 2.50 KWh/Km |
| Bus articulated HEV[b] | | 7.5 Km/gallons |

Source: prepared by the authors, on the basis of Velandia and others, 2011.
[a] Technology RENNO 280 –Ecopetrol and UNAL tests (Zapata, 2006).
[b] HEV is estimated to yield 21% more than conventional diesel buses.

Considering the reference prices in Colombia and the yields of different technologies, electric buses are estimated to be the least costly in this regard; hybrid buses carry a cost 45% higher than electric buses with overhead lines; diesel buses cost 78% more than electric buses; and natural gas buses cost 96% more than trolleybuses (Velandia and others, 2011). At the same time, the multiple factors involved make it difficult to compare the operating and maintenance costs of the different vehicles. In São Paulo, EletraBus (2008) estimated that a maintenance costs for a diesel bus cost were 1.5 times higher than for a trolleybus and for a diesel hybrid, 1.3 times higher.

The table shows the energy consumption and $CO_2$ emissions by technology type for an articulated bus doing 80,000 km per year. Considering emissions factors and energy demand by technology type, electric-powered vehicles are found to offer the greatest benefits in terms of $CO_2$ emissions, and diesel technologies the least. CNG technologies generate a quantity of $CO_2$ equivalent to twice the emissions associated with electrical technologies but 30% less than diesel technology. Technically speaking, the emissions of electric vehicles are included in the emissions of Colombia's electricity sector.

**TABLE 62**
**FUEL CONSUMPTION AND $CO_2$ EMISSIONS BY TECHNOLOGY TYPE**

| Technology | Consumption / year | Tons $CO_2$/year |
|---|---|---|
| Diesel | 12 903 gallons | 129 |
| HEV diesel | 10 600 gallons | 106 |
| CNG | 61 538 m3 | 101 |
| Trolley Bus | 180 000 KWh | 51 |

Source: prepared by the authors, on the basis of Velandia and others, 2011.

The greatest difficulty in using electrical vehicles with overhead lines lies in the initial investment. Even though an electric bus has at least double the useful life of an equivalent internal combustion vehicle in mileage terms, the higher investments needed represent a barrier to operators, given that the city does not buy the vehicles. In this regard, where urban public transport is privately operated, clear incentives are needed for this type of technology or for others such as autonomous electric buses, in exchange for the environmental benefits and in recognition of the higher initial cost of the vehicles.

The Ayacucho tram line, which will act as an extension of the metro towards the east of the Medellin metropolitan area, is currently under construction. This will be complemented by two cable car systems (1.4 km and 1.1 km) connecting with neighbourhoods on hard-to-reach terrain. This tram-cable combination will be able to transport almost 96,000 users by 2020 (Master plan, Aburra Valley mass transport company, Medellin Metro, 2010), with almost a third of that transport provided by cable cars. Studies are also under way on a new 13.5 km corridor in the western part of the valley, connecting a very broad sector of the city (120,000 users projected by 2020) and forming the first half of the ring that would join the west and east sides, and providing longitudinal support for the metro system.

These measures have contributed to the consolidation of the Aburra Valley's integrated transport system from the point of view of the physical infrastructure. However, owing to a number of institutional difficulties, the physical and tariff integration has not been entirely worked out. In addition, over a hundred private bus routes have been integrated into the metro system. In 2012, 46% of users reached the metro system through integrated routes.

**TABLE 63**
**INTEGRATED ROUTES IN 2012**

| Capacity of intergrated routes | Working day |
|---|---|
| Day capacity of feeder routes | 29 May |
| Travels of the day in Metro:<br>(Study OD 2012) | 548 217 |
| Integrated travels of the day: | 248 129 |
| Percentage of integrated travels: | 46% |

Source: prepared by the authors, on the basis of Metro de Medellin, 2012.

In terms of energy efficiency, walking and cycling are the most efficient means of transport. Among motorized means of transport, mass public transport in the most energy efficient. Economy of scale, the use of electrical power, efficient operating schemes and fuel-saving mechanisms make public transport the means that consumes the least energy per passenger transported.

According to the figures in the table, metro and rail systems consume 0.15 KWh to transport a passenger 1 km; an articulated diesel bus consumes 0.40 KWh; and a gasoline vehicle 0.65 KWh. Given these energy demands, shifting the population en masse towards public transport systems, especially those powered by electricity, brings greater energy benefits than combustion-based modes of transport (Velandia, 2010). The benefits are just as apparent in terms of the urban space needed for mobility.

**TABLE 64**
**CAPACITY AND ENERGY EFFICIENCY BY TRANSPORT MEANS**

| Transport mode | Gasoline vehicle | Diesel | Articulated diesel | Metro |
|---|---|---|---|---|
| Units required for transporting 1100 passengers | 687 | 18 | 7 | 1 |
| Energy efficiency (kWh/passenger-km) | 0.65 | 0.50 | 0.40 | 0.15 |

Source: prepared by the authors, on the basis of Velandia, 2010.

**Transport by bicycle**. Under the Medellin strategic plan for bicycles (2011), seven strategies have been devised to increase bicycle use as a means of transport in the city: an infrastructure of cycle routes, public bicycles, public education, a bicycle mobility policy, institution-building with the establishment of a specialized office, bicycle parks and bicycle lanes.

Bicycle use is increasing thanks to various public and community initiatives. EnCicla, a public cycle system promoted by AMVA and EAFIT university (2011), aims to connect the cycle system to the metro, covering certain strategic sectors first (university areas). New corridors of cycleways are now being set up to cover some sectors and bring in new metro stations. This will add a total of 9 km to the existing 24 km of cycleways in the city of Medellin.

With a view to **mobility information and management**, a smart transport system was implemented, consisting of a Web 2.0 platform with cameras for surveillance, planning traffic light coordination and as a basis for the new integrated public information system. The intention is to monitor the state of the city's main road corridors and intersections, to have greater control over the state of roads and detect incidents or congestion rapidly. This is meant to offer a timely and constant flow of information, reduce accident rates, optimize traffic flows, and enable better routing decisions to reduce congestion and travel times.

**Electric vehicles**. During certain years (2009, 2010), the local authorities attempted to promote the use of electric cars and mopeds with different campaigns citing their energy efficiency and environmental benefits. Mopeds were the best received and around 1,500 are estimated to be in circulation the city today.

As part of this initiative, electric vehicles were exempted from circulation restriction (peak and plate). In addition, electric vehicles have benefited from tariff benefits countrywide (the Ministry of Finance's Economic and Fiscal Policy Council approved a tariff cut from 35% to 0% for a total of 750 electric vehicles per year for three years, and a similar number of hybrid technology and natural gas vehicles) and exemption from VAT for public service vehicles (buses, trains and taxis).

Companies such as EPM have a number of iMiEV-type electric vehicles for testing the technology and universities such as Universidad Pontificia Bolivariana de Medellin are running tests jointly with private firms to assess the opportunities for this type of technology in the city.

The following factors are barriers to the implementation of electric transport vehicles:

- Initial price. The high cost of the initial investment associated with the technology for mass public transport systems, collective systems and electric vehicles represents a barrier to short-term implementation. However, the increase in production, the incorporation of externalities into the analysis, the replacement of traditional, conventional-technology companies and the incentives programme will bring in criteria that should enable electric technologies to be selected under certain conditions.

- Battery life. The useful life of an electric vehicle is estimated at 20 years. Rechargeable batteries have an estimated useful life of between 2000 and 5000 cycles. However, the variety of rechargeable batteries and their characteristics could transfer risks to users in terms of less battery range, which would add extra cost to the vehicle.

- Autonomy. Electric vehicles have autonomy of less than 150 km, although there are pilots on the market that allow for more kilometers. New 100% electric technologies would not support longer journeys without a support structure of rapid recharging stations. In Colombia, travel distance is less than 20 km/day, which necessarily limits the use of electric vehicles to urban areas and leaves the charging responsibility with households. Autonomy is “limited” in the case of mass public and collective transport systems powered by electricity by their connection to the energy source. The slopes in some areas of the city represent a physical barrier to the use of battery electric vehicles (BEV). These vehicles are powerful enough to cope with the city’s terrain, but at a cost in terms of autonomy.

- Resistance to change. The market is likely to respond by developing low-price conventional vehicles. In fact, articulated buses with greater transport capacity and more efficient combustion technology are already a reality and reflect the market’s reaction to possible competition.

- Rapid charging stations. Rapid battery charging capability in electric vehicles represents an additional vehicle cost. In the long term, the electric power system must satisfy the requirement for temporary power storage to support new peaks of energy demand. The inexistence of public recharging points is an operational limitation for BEVs.

- Regulation. Connection and recharging systems are not covered by standards to ensure proper use of technologies. Yet many of the activities and procedures cannot be standardized yet, because progress in these areas is virtually continuous. In Colombia, the lack of research and development on electric traction systems has left gaps in regulation that need to be addressed in order to enable the entry of new technologies and guarantee quality.

- Vehicle certification. The approval and certification of vehicles and chassis under environmental and safety standards is essential for new vehicles to operate. This requires inspections and testing of prototypes and commercial models for each reference. Colombia, as a country that adopts technology rather than developing it, lacks protocols for technological certification.

- Legislation. This can act as a facilitator or a barrier. Legislation can be a barrier when it poses administrative obstacles associated with resistance to change or lack of knowledge of new technologies, or when it favours the continuation of low-cost programmes and interests linked to sectors that could lose out from the introduction of new technologies. In this regard, planning agencies and society at large need to orient their representatives to avoid difficulties with development plans and ensure that those with the greatest long-term benefits are implemented.

- Limitations of standardization. Conventional vehicles usually have standard components that can be used for different references for original or generic manufacture. In electric vehicles some components can be standardized, but batteries, power controllers and other components are part of each manufacturer’s own technology and can even be protected from handling and study once installed in the vehicle.

- Minimum-cost, short-term analysis as a standard for approving public transport projects represents a barrier insofar as it disregards the cumulative externalities associated with each alternative; if there are problems with the information and the models use to project traffic flows; and if political economy considerations interfere in the selection of initiatives, budgets and operations. On the other hand, electric vehicles have benefits associated with fuel cost savings, longer life and possibly tax and mobility benefits (implemented in some countries) that can offset the higher initial investment cost.

- A policy environment geared to the private automobile. A policy aligned with mass transport limits the resources available for developing private vehicle infrastructure, and vice versa. In this regard, a city transport policy that allows the unfettered development of private cars and motorcycles will lead to the failure of polices aimed at mass transport, energy efficiency and the improvement of urban air quality and living standards. Although electric vehicles would be the best suited to this scenario, it is important to emphasize that this will occur in the long term in the Colombian market and will depend mainly on the policy regarding substitution of conventional technology vehicles and the incentives attached to the new technologies.

- Waste management. The management of rechargeable batteries and of other components has become a challenge for the automobile industry, environmental authorities and maintenance businesses. There is no clarity today on possible recycling or final disposal of these products. There are waste management strategies, however, for which protocols must be developed in order to reduce environmental impacts.

## 3. Freight transport solutions

To reduce the adverse effects of freight transport in cities it is necessary, on the one hand, to find ways to reduce unnecessary through traffic in the Aburra Valley and, on the other, to reorganize the circulation of the freight that does need to circulate in urban areas.

BIO 2030 proposed reducing the through transit of cross-country freight in the Aburra Valley urban area, in order to reduce the volume of large vehicle traffic on the roads that serve the urban and metropolitan area. By building alternative regional highways for cross-country freight traffic and taking measures to relocate primary industry outside the Aburra Valley, the percentage of through freight should be reduced to less than 10% of the total freight now circulating within the metropolitan area.

The alternatives under consideration for avoiding road freight passing through the Aburra Valley Metropolitan Area include the Cauca contour road, and a direct trunk road between the Guarne and Girardota municipalities.

Bearing in mind the topographical difficulties of the existing roads, these two alternative roads would reduce fuel consumption and travel times for freight vehicles quite considerably, and would thus help to make national trade more competitive, ease road congestion and air pollution in the city, and make freight transport more energy-efficient.

Rationalizing heavy freight traffic in urban areas by building freight logistics centres: In order to reduce the number of heavy trucks on city roads, various planning documents (Mobility Master Plan-2006, Metropolitan Land Use Guidelines, 2006; and the BIO2030 plan) have proposed developing logistics centres at the main points of entry to the Aburra Valley. The exact location of these logistics centres, and their capacity, will depend, among other factors, on national level road infrastructure projects, such as mountain highways and multimodal logistics platforms located at the intersection of rail and river corridors.

Metropolitan logistics centres must serve as entry and exit points for heavy freight transport, for storage of goods and onward transport in utility vehicles suitable for urban roads. Goods storage points should be located so as to encourage establishments in the same area of operate jointly (economies of scale) and increase freight vehicle occupancy. Freight centres must have logistical functionality according to their location within the region.

Logistics centres must encourage the development of activities related to the logistical chain around them. They need to be serviced by good public transport that caters to this new employment source. Land use around logistics centres should be regulated to promote activities related to goods transport (garages, service stations, warehouses, etc.).

Given that around 70,000 tons of goods enter and leave the city every day to and from large firms and industries, reorganizing internal transport around logistics centres could contribute significantly to reducing atmospheric emissions and road congestion; however, these projects do not seem to be a priority on the metropolitan agenda.

## 4. Public information

There has historically been a great shortfall in every sort of information for users of the various modes of transport in the city. This has had consequences ranging from road congestion to the loss of potential public transport customers. It is also apparent that citizens are unaware of the economic or environmental implications of their choice of means of transport. To tackle these shortcomings, a number of institutions have run campaigns or projects to provide users with clear and timely information on which to base their decisions.

One of the main components of the smart transport system is a series of strategies for keeping users informed of the state of road traffic through the media (Medellin Transport Department, 2013).

The metro runs a campaign called Mi aporte Metro (miaportemetro.com) to advertise the benefits of using this form of transport. It uses figures and arguments on issues ranging from health and savings in time and money, to energy efficiency and environmental conservation.

The Aburra Valley Metropolitan Area (AMVA) has a programme called Date un respiro, which promotes behavioural changes among the public with the aim of improving air quality. The programme includes several ideas relating to the use of public and non-motorized means of transport. AMVA has also developed training and information schemes for strategic players in metropolitan mobility, such as bus and truck drivers and managers of automotive diagnostic centres.

In general, these measures are recent and it is still too early to gauge their impact. However, several institutions have recognized their own weaknesses in terms of informing the public in a simple and effective manner.

The traditional public transport system lacks a proper information system, with the result that it is extremely difficult for users to ascertain bus timetables and routes, in addition to the system's comfort and safety issues.

## 5. Financial and non-financial incentives

**Incentives for infrastructure construction.** In Colombia the State provides financial support for developing BRT-type medium-capacity transport systems. The infrastructure of the Metroplús system has benefited from that support, with the national government providing 70% of the financing and the various local entities the remaining 30%. This financing scheme does not apply to low-capacity systems, such as the cable car schemes, however. Most of these have been financed directly by the metro and the Municipality of Medellin, some with support from the Departmental Government of Antioquia and the Ministry of Transport. The table below details the contributions of each entity for the construction of the cable car systems.

**TABLE 65**
**FINANCIAL CONTRIBUTIONS FOR THE CONSTRUCTION OF MASS TRANSIT INFRASTRUCTURE**

| Project | Total estimated cost (millions of USD) | Contribution of Medellin Municipality | Contribution Metro of Medellin | Government of Antioquia | Ministry of transport | Others |
|---|---|---|---|---|---|---|
| Metrocable Line K (2km) | 24 | 55% | 45% | | | |
| Metrocable Line J (2.8km) | 47 | 73% | 27% | | | |
| Metrocable Line L (4.5km) | 21 | 38% | 34% | 17% | 9% | 2% |

Source: Prepared by the authors, on the basis of Dávila, 2013.

This table does not detail the total costs of the metro's recent projects. It does, however, give an idea of how important the municipality's role is in bringing these projects to fruition. The budget drawn up by the metro for each project also includes the accumulation of a percentage of the fares. In other words, it is users who pay for the metro's contributions to these projects. This generates a high user cost, not only in mass transit systems, but also in collective transport (buses), which leads some users to abandon the system.

**Incentives for rationalization (scrapping) of buses.** AMVA emissions reductions initiatives are funded from its own resources. None of these has benefited from or produced any type of incentive and many have been discontinued because of lack of resources or of political will. In the specific case of rationalizing the bus fleet, the public transport user is the main source of funding, because a percentage of the fare goes to a "rationalization" fund used to finance the measure.

**Disincentives for private car use.** The plate and peak system was implemented as a provisional non-financial measure to manage private vehicle use. This now obsolete system was questioned because of its perverse outcomes, inasmuch as, in an increasingly wealthy population, a considerable number of households simply started to buy a second vehicle in order to circumvent the plate and peak restrictions and use their own cars every day.

# D. Identifying the keys to success in energy efficiency measures

## 1. Monetary considerations —the cost of the solution

Medellin and its metropolitan region have aimed towards a technology-based sustainable mobility model. With different types of public transport (as well as the bus and taxi services, the Metro, Metroplús, Metrocable, and soon, tram) on offer, users have choices. Considering, in addition, the authorities' interest in promoting non-polluting forms of transport, this trend is improving not only mobility, but also air quality and, thus, quality of life for the city's inhabitants.

In order to set up a proper transport system based on sustainable technology, it is wise to conduct an analysis of what it has cost and could cost, assuming that the deployment of new systems and the operation of the existing ones draws on resources from fares and a proportion from advertising.

**TABLE 66**
**PASSENGER TRANSPORT CAPACITY AND CONSTRUCTION COSTS PER MEANS OF TRANSPORT**

| System | Capacity (passengers per hour and sense) | Value of unit of transport (USD) | Value of km of infrastructure (USD) |
|---|---|---|---|
| Metro | 60 | 6 million (1 100 passengers) | 40 million |
| Metrocable | 1 000 – 8 000 (installed capacity in Medellin 1 200 – 3 000 persons/hour/sense) | No information | 14.5 million |
| Metroplus Bus Rapid Transport | 20 000 - 25 000 | 200 – 300 thousand (170 passengers) | 7-10 million |
| Tranvía | Capacity (passengers per hour and sense) | 2.5 million (300 passengers) | 45 million |
| Conventional collective bus | 60 | 60 thousand (40 passengers) | No information |

Source: Author's elaboration, on the basis of Metro de Medellin, 2007, and Velandia, 2013.

In addition to the existing systems, studies are under way on the creation of new, medium-capacity public transport corridors, giving priority to BRT systems. Although these currently run on gas, it is still unclear what option would be preferred for the future. Metroplús has produced some figures showing the additional cost of an electric system. The firm conducted a study for the Belén-Aranjuez line, which found that the infrastructure for electric technology would cost US$ 24 million more to build and US$ 4 million more per year to maintain, as well as the visual impact and the incompatibility of the overhead lines with existing trees.

Although electric systems are more expensive to build and operate, they are cheaper in the long run. Nevertheless, the municipality of Medellin has opted for gas technology for the time being, bearing in mind the resources available.

The cost of solutions is still viewed in terms of financial costs, since the cost-benefit for the city in terms of emissions and public health has yet to be taken into consideration. Gas, although considered a “clean” fuel in Colombia, is not emissions-free. For that reason, the Metropolitan Area is now carrying out a study with advice from the Clean Air Institute in order to define the criteria for better assessment of the impacts associated with the different technologies. The findings of this study will be available in the course of 2014.

## 2. Feasibility

### a) Technical feasibility

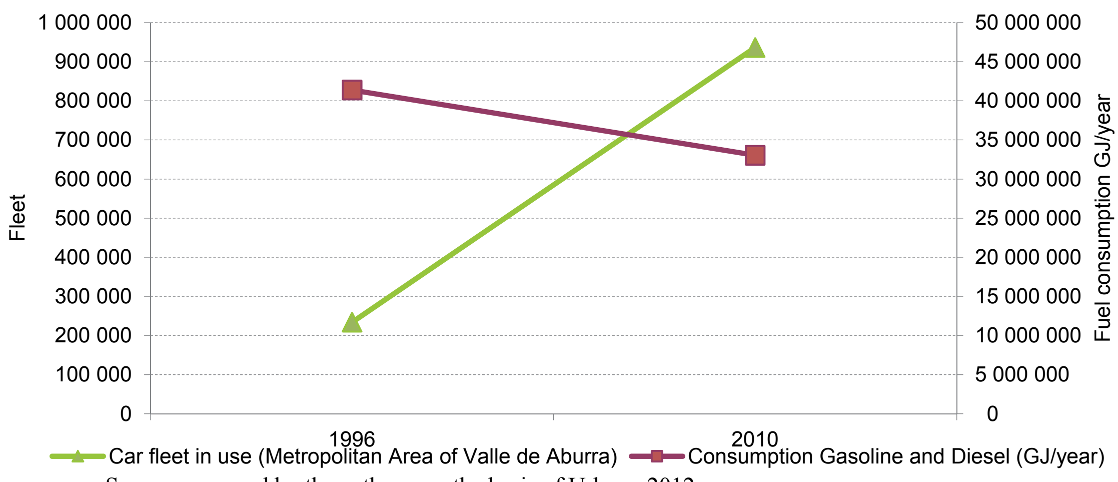
The use of clean public transport technologies, the consolidation of the Aburra Valley integrated mass transit system (SITVA) and fuel upgrading have been the result of measures to reduce the negative impacts of congestion and the transport sector’s gas and particulate matter emissions, which have, in turn, led directly or indirectly to improvements in energy efficiency.

The SITVA has more users today than a few years ago. The metro gained two percentage points, from 7% of trips in 2005 to 9% in 2012.

Despite growth in the vehicle fleet, less gasoline is consumed today than 15 years ago, thanks to higher energy yields of combustion technologies in new cars, fuel improvements, and the use of CNG and diesel in automobiles, trucks and taxis.

The measures taken have led to air quality improvements in the Aburra Valley and, indirectly, to better energy efficiency. This is evident in the apparent stability and even reduction in fuel consumption in the Aburra Valley despite the expansion in the automobile fleet.

**FIGURE 47**
**RATIO BETWEEN NUMBER OF VEHICLES IN CIRCULATION AND FUEL CONSUMPTION**




Source: prepared by the authors, on the basis of Urbam, 2012.

The use of CNG in vehicles in Colombia has become strategic in the transport sector, especially in urban transport, given that the fuel is available at a low price and costs that are reasonably stable over time. Compared with gasoline, gas offers significant savings, which become more significant for intensive energy users such as taxis, buses and fleets. Policies promoting use of natural gas have created economic incentives for conversion.

### b) Financial feasibility

The Medellin metro company is owned 50% by the Municipality of Medellin and 50% by the Department of Antioquia. Its board comprises representatives of the Department, the Municipality and the national government. The financial solidity of the Medellin metro during its years of operation have given it a very good financial rating, and afforded it access to ready borrowing and financing for building infrastructure. It is also one of the few metros in the world that is operationally self-financing.

Although the metro is known for its financial stability, as discussed earlier, the Municipality of Medellin has been a major financial partner for the metro's most recent measures and projects. For the cable system, the Municipality has invested as much or more than the metro itself. This is largely thanks to the Municipality's large financial capacity resulting from the profits from Empresas Públicas de Medellin (EPM). EPM belongs entirely to the Municipality of Medellin and provides water, sewerage, electric power and gas utilities. It also produces 20% of Colombia's electric power and has investments abroad. Like the metro, EPM enjoys a very good financial risk rating.

Between 2001 and 2011 EPM passed 50% of its profits to the Municipality of Medellin, and has become the foremost financier of the Municipality's projects, not only in transport infrastructure, but also for other public initiatives, such as parks, libraries, kindergartens, and so forth. Between 2010 and 2011, EPM contributed US$ 877 million for projects in Medellin. The table below shows the amounts transferred by EPM to the Municipality of Medellin between 2008 and 2011.

**TABLE 67**
**TRANSFERS BY EPM TO THE MUNICIAPLITY OF MEDELLIN 2008 – 2011**

| Transfers of the EPM to the municipality of Medellin 2008 - 2011 (COP in millions) | | | | |
|---|---|---|---|---|
| | 2008 | 2009 | 2010 | 2011 |
| Normal transfers | 333 227 | 399 519 | 509 343 | 437 346 |
| Extraordinary transfers | 187 500 | 187 500 | 337 500 | 360 200 |
| Total tranfers | 520 727 | 587 019 | 846 843 | 797 546 |
| Mean TRM per year | 1 966.26 | 2 156.29 | 1 897.89 | 1848.17 |
| Equivalent in million USD | 265 | 272 | 446 | 432 |

Source: prepared by the authors, on the basis of EPM, 2012 and Bank of the Republic, 2012.
Nota: EPM (Public Companies of Medellin).

### c) Institutional feasibility: mobility and transport, towards strengthening metropolitan authority

The Aburra Valley Metropolitan Area (AMVA) plays a very important role, through public policy, in measures to improve air quality and energy efficiency. AMVA's recognition of environmental issues and capacity for action in that area has enabled the development and deployment of specific pro-environment policy proposals with coordinated components (mobility and planning).

Similarly, the Municipality of Medellin has built up institutional and financial muscle through EPM and the metro, which allows it to develop infrastructure and clean technology projects for transport. It is common knowledge that "when the metro wants to develop a project, it does it". It must also be acknowledged, however, that this very clout and operational capability can be counterproductive. Many of the decisions the metro makes can override the AMVA transport authority. In this regard, given the institutional power of Metro de Medellin and the weak institutional capacity of AMVA, the metro company can sometimes actually complicate processes from which it stands to benefit. As the operator of the metro system, it has perceived its operations to be threatened by the new lines being developed in the Aburra Valley, has opposed new developments, and has even proposed that designs be changed in its favour.[69] It is

[69] A particular case of this sort was the trunk route from Avenida del Poblado to Industriales, where the metro opposed the entire Metroplús corridor on the basis that it would compete directly with the metro system. It warrants mention that this corridor, while it runs parallel to the metro, not only provides additional coverage, but would help to unburden the metro system, which becomes saturated at peak times.

clearly important to develop AMVA as a genuine transport authority, able to bring all the visions of the Metro, Metroplús, private transport operators and all the traffic-related departments together under single coordination. Major mobility-related measures and infrastructure projects obviously require consensus-building and agreement among different municipalities and a strong presence by the competent municipal and higher authorities. The construction of this new authority (which is different from the system and its infrastructure) is one of the great challenges for the next 20 years, because with the current division of competences and existing institutions it is impossible to rationalize mobility issues between municipalities, traffic and transport departments, and transport operators themselves. This is a problem insofar as without a clear normative framework and operational institutions, difficulties become much more acute.

### d) Acceptability to users

On the basis that the main strategy for reducing atmospheric emissions and increasing energy efficiency in the Aburra Valley has been building and extending the integrated mass transit system, there is evidence that it is well viewed by its users and by the inhabitants of the valley in general.

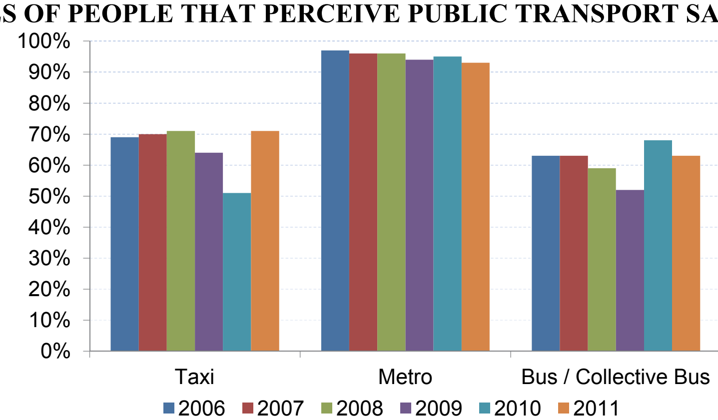
Firstly, the metro system was the first in Colombia and, in parallel with the development of its infrastructure and operation, it was able to develop the now well-known 'Cultura Metro' or metro culture, which meant a change in the forms of behaviour in public areas and on public transport in a city which had gone through difficult times in which its basic values were badly eroded. This mixture of technological innovation, quality of service and social impact have won the city numerous national and international awards, which has created among its citizens a sense of pride and ownership not often found in relation to transport systems in other cities or countries. This is what is meant by the often intangible "social" pillar of sustainability.

In more pragmatic terms, the public opinion survey 'Medellin cómo vamos' reiterates that the metro system continues to be the best evaluated by users (98% satisfaction rate in 2011). In addition, 50% of survey respondents said that the service had improved in the last year.

Given that road congestion is one of the city's major problems and that the traditional public transport system is generally perceived to be unsafe, the integrated mass transit system may be concluded to have a large potential for growth and user capture, and can be capitalized on to continue consolidating a clean and efficient transport network with the support of the public.

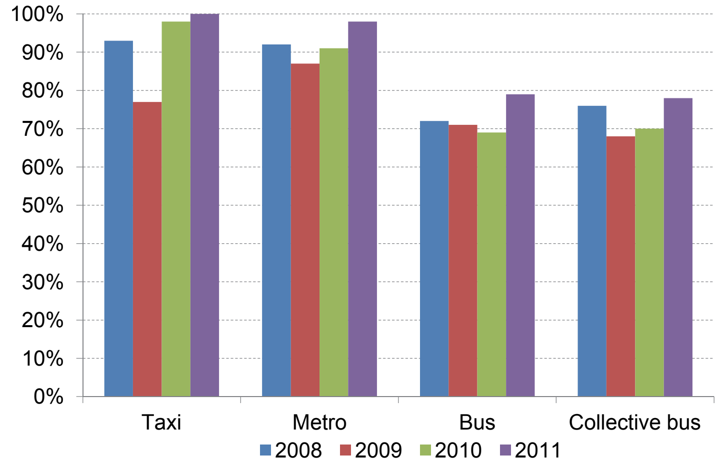
Paradoxically, problems such as air quality and noise levels in the city —both related to "traditional" means of transport— continue to be flagged as issues to which the municipal government should afford priority attention. This indicates, once again, that consolidating the integrated transport system, however clean and efficient, is not enough to achieve sustainable mobility in the city without measures to resolve the problems inherited from the last century: the number of private vehicles and their many negative effects.

**FIGURE 48**
**PERCENTAGES OF PEOPLE THAT PERCEIVE PUBLIC TRANSPORT SAFE, 2006 - 2011**




Source: Prepared by the authors, on the basis of the survey "Medellin cómo vamos?", 2012.

**FIGURE 49**
**PERCENTAGE OF PEOPLE THAT ARE SATISFIED WITH THE PUBLIC TRANSPORT THEY CURRENTLY USE, 2008 - 2011**




Source: Prepared by the authors, on the basis of the survey "Medellin cómo vamos?", 2012.

### e) Political acceptability

Most infrastructures for high- and medium-capacity public transport are located in the center of Medellin. This is because of the availability of resources and the technical appreciation that coverage must be provided for areas in which demand is high enough to ensure that the investment will be beneficial. Outside Medellin, the infrastructure has to cross several municipalities in order to capture enough demand. Although some of them are interested in these developments, not all are. One example is the case of the Envigado metro. When the metro decided to extend southwards to cover the municipalities of Enviga and Itagüí, the former objected to the station that today bears that name being built on its land. This led to a variety of cost overruns in the works, considering that the metro had to cross from the east side, where most of its infrastructure is, towards the west side.

Something similar is happening today with regard to Metroplús. The great progress so far has taken place in Medellin. Because it is a single municipality with substantial fiscal capacity, it has been able to build the existing trunk lines, notwithstanding some delays. Towards the south of the Aburrra Valley, Metroplús has run into difficulties for a variety of reasons. The infrastructure must cross different municipalities in order to ensure continuity along the main longitudinal axes and thus expand coverage. Some of them are willing, others less so, and delays have accordingly arisen in the design and implementation of works.

This is in addition to the fact that many of the municipalities holding up the works are the ones currently encouraging the construction of new housing. However, the infrastructure works are being planned to consolidate a compact city on flat plains, while most of the land being planned for housing is on the hillsides of these municipalities. This demonstrates inconsistency between the real estate market and the intentions of land use ordinance and infrastructure development.

### f) Land use planning

Although energy efficiency has not been the main motivation, some of the measures taken have led to public-transport-related developments and the rationalization of some bus routes. This was the case of the Santo Domingo cable system, which was built in an established area in which users were highly reliant on public transport. This set off a series of public measures that generated a dynamic around new sources of employment, local business and public amenities.

The metro system in the central area of the Aburra Valley has yet to generate such a dynamic around most of its stations. Only some of them have brought about changes in the use of the surrounding land.

The best known planning ambiguity in the Aburra Valley has to do with the weak authority of AMVA over municipal land use. In this regard, Act 128 awards AMVA the authority only to establish general guidelines, since municipalities' power to plan their land use at a more specific level than AMVA is enshrined in the Colombian constitution. This is how the peculiar situation arises in which the "agent" —as each municipality should be— actually has more regulatory power than the "principal", AMVA.

As a result, different visions of land use coexist in the Aburra Valley and there is little capacity to coordinate them. So, although AMVA is supposed to play a coordinating role, the municipal land use plans (POTs) complicate projects in the central area. The Metropolitan Guidelines suggest development along the lines of a compact city, seeking to concentrate as much urban development as possible in the central area, and this is pursued by encouraging partial plans (a land management tool for large-scale projects) and schemes in this area. However, extremely fragmented land parcels, the vested interests of municipal POTs and the specific rules of each of the partial plans impose a series of restrictions and conditions that discourage the real estate sector from becoming involved in these developments in the central area. This by default encourages development in the hillside areas of the Municipality of Medellin and other municipalities. In these areas, where real estate development has been concentrated, the control exerted by the authorities may not be sufficient, because the municipal and metropolitan authorities lack the technical and fiscal capacity to enforce rules.

The northeastern and northwestern areas of Medellin (unlike Pajarito) lack new projects. Most of the new formal urban development has, however, been concentrated in the comuna of El Poblado, on the southeastern side and around Loma de los Bernal and the upper part of Calasanz (southwestern and west-central areas, respectively), and on the hillsides of the municipalities of Envigado, Sabaneta, La Estrella, San Antonio de Prado and some hill areas in Bello. The development poles established in municipal POTs are mostly on the periphery, on expanding areas or areas available for urbanization. Those located in the central area are mostly poles of redevelopment and upgrading, which involve more complex treatment, because work is being done where construction already exists and where rules and divided land holdings make action more difficult.[70] This point is the weakness of the institutional fabric to manage land involving the redevelopment of urban land and the renewal of existing areas. Neither the metropolitan region nor the individual municipalities have the capacity to enable proper land management. New formal housing is thus concentrated today in hillside locations, while the valley floor, with its broad range of urban services, has fewer projects. Consequently, in the past few years, major real estate development has taken place largely on the outskirts of the city, or in municipalities other than Medellin where land is cheaper and rules are still not as strict.

Lastly, there are five institutional reasons for these land use planning challenges. First is the weak capacity to regulate land use because of a (relative) mismatch between the guidelines established by AMVA and what happens on the ground, so that the land use pattern often differs from what would be desirable. It is clear, in this regard, that Act 128 gives AMVA no more than general powers over land use planning, but it is also clear that the municipalities themselves have not offered commitments as they are allowed to do under Act 128 that would give AMVA a better chance of regulating on land use matters defined as metropolitan. In other words, member municipalities could give AMVA more powers over land use regulation, under the law.

Second, AMVA lacks the institutional capabilities to provide land use control and surveillance because it does not have operational mechanisms to oversee and sanction municipal planning offices and departments. So the plans established by the Metropolitan Guidelines are left powerless to control the urban sprawl.

[70] From a normative point of view, one of the main disincentives for developing the central area is the minimum frontage required to build in these poles. In most cases, securing the minimum frontage requires several landowners to come to an agreement with the builders. In San Joaquín and Bolivariana, for example, minimum frontage is required under POT rules.

Third, information systems on land use matters are a key element for consolidating metropolitan authority. Although AMVA does not have the power to handle municipal records, it does have an interest in updating management processes (and has done so) to boost its own income. But its main task in this regard could be to maintain updated information on metropolitan real estate structure, bringing together information from municipalities, the metro (on the river basin), on the hillsides and on public land. Only an updated database would make it possible to design more expedite public projects and detect land-related problems.

Fourth, this problem is related to the lack of specific capacities to move forward large-scale metropolitan projects. For a positive transformation in the Aburra Valley, large projects are needed requiring new management models. In this regard, progress has clearly been made in implementing certain smaller-scale neighbourhood improvement plans, but there has been less progress on issues such as logistics centres and new centralities, or on the development of riverside land and the longitudinal roads.

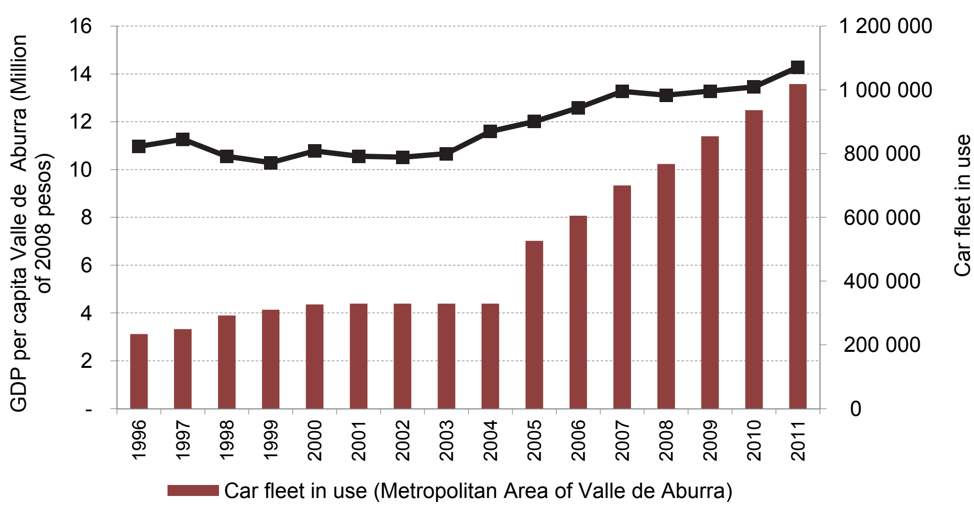
Fifth and lastly, a more compact city means shorter trips and more efficient transport. Although the Aburra Valley still has high population density in the consolidated urban areas (2,900 inhabitants/km2 on average for AMVA), the automobile fleet and the number of motorized trips have increased significantly, which is partly attributable to the type of growth the city is experiencing. And since fossil fuels still represent the largest share of total fuel consumption for transport, this pattern of mobility has an indirect impact on air quality.

The number of trips by motorcycle rose from 5% in 2005 to 11% in 2012, and those by car from 12% to 15% of all trips taken. This may be partly explained by territorial dynamics, the increase in housing location in the hardest-to-reach and furthest out parts of the city, by the resulting difficulty in guaranteeing access to these sectors by public transport (as shown in the coverage plans of mass public transport), and by the exodus of firms to peripheral municipalities.

However, there are also other factors, albeit not directly associated with the model of growth: public transport lacks comfort, its fares are high, there are no subsidies to reduce fares and so users have an incentive to use motorcycles instead. That is, there are factors directly associated with mobility management which tend to worsen the phenomenon, in addition to the growth factor.

The tendency towards urban sprawl should not, then, be interpreted as the sole cause of the rise in the number of motorized trips and the expansion of the automobile fleet. The figure below illustrates, for example, how economic growth in the city follows the same pattern of the fleet (cars and motorcycles) in circulation, and suggests that they are directly related. This is in addition to the fact that cars and motorcycles have become cheaper in the past few years, further strengthening the trend.

**FIGURE 50**
**RATIO BETWEEN GDP GROWTH AND EXPANSION OF THE AUTOMOBILE FLEET**




Source: Author's elaboration, on the basis of Urbam EAFIT, 2013.

#### g) Innovation in transport

The city of Medellin has been a pioneer in transport-related technological projects in Colombia. It was the first city to implement an urban electric rail system, aerial transport cables on hillsides with complex topography, a public bicycle scheme, and electric escalators to improve accessibility to certain areas of the city.

Electric buses with overhead cable have been installed on the campus of the Pontificia Bolivaria University in 2010. The aim was to promote the use of this technology in BRT corridors or as feeders for the metro system. Among its advantages are the longer life of its traction system and its lower operating and energy costs compared with diesel or CNG. It also offers high energy efficiency, zero urban emissions and better on-board conditions in terms of noise, vibrations, pulling away and temperature.

Universities and research centres in the region participate actively in projects to improve transport and transport-related energy efficiency. For example, projects have included the aerodynamic study of trains in the metro system to reduce energy consumption by altering train fronts and the logistical management of the rail and metrocable transport systems.

## 3. Direct impacts on users

There are no studies that would enable a direct evaluation of the socioeconomic impacts of the measures illustrated here. Although the underlying intention has been to reduce emissions, the measures have had effects in different areas. However, the perception is that impacts have been positive in some cases and negative in others. The integration of transport means towards the consolidation of the mass transit system, the reduction of transport costs (in money and time) and the lower accident rate are among the positive examples. There has also been a clear reduction in emissions.

#### a) Door-to-door travel time

Public transport is heavily used by the population in the north of the city and on its hillsides. For that reason, many of the cable projects in operation today have been developed in these sectors. Many of the current Metrocable users formerly used conventional buses. However, there are also many other former bus users who now use a motorcycle. According to some studies (for example, Dávila, 2013), some of the inhabitants of marginal sectors do not use the metrocable because they have another form of transport, such as a motorcycle. Others use the metrocable because they have no other means of transport.

As will be seen in the following section, however, the users of the integrated mass transit system (SITVA) are motivated more by cost savings than time savings.

#### b) Cost of door-to-door trips

Although the fare contributes to the capability to develop the system, this carries a cost in the form of a very high fare which represents a heavy burden for low-income sectors. The average monthly income in Medellin for a head of household at income levels 1 and 2 is around 700,000 Colombian pesos (US$ 350). These sectors are highly dependent on public transport, whether by conventional bus or SITVA. As the SITVA map showed, the system's coverage is still quite limited, although it could be broadened in the framework of the efforts under way to bring conventional routes into the system. Under current conditions, however, few users benefit from SITVA (10% of daily trips use SITVA. EOD, 2012). All the same, the situation before and after SITVA in certain sectors can be compared by means of a small exercise. There is little change in daily travel costs for a user who took only two buses before (one in the morning and another in the evening) and who uses SITVA today. Users in that situation now spend around 9% of their income on transport, compared with 10% before. However, for a user who used to take two buses each morning and evening, SITVA represents a large saving, from 20% of income previously to 10% now. Those who use the integrated bus-metro system may also see their travel expenses fall from 20% to 12% of their income. This is assuming that a single member of the household is travelling.

It bears mentioning that there are extreme cases, depending on need. There are users who buy integrated trips for 2,100 pesos (around US$ 1) and, since the integrated ticket actually includes two tickets (one for the bus and another for the metro or metrocable), they save 50% of the transport cost by walking and taking the metro in the morning, then walking and taking the bus part of the integrated system in the evening. These users can walk up to an hour per day to save 2,000 pesos. Their subjective valuation of time is estimated at 2,000 pesos (US$ 1) per hour, adding up to almost 60,000 pesos (US$ 30) per month, or 8.5% of the average income of a head of household in this segment.

There are other, more extreme cases in which people are willing to walk for an hour in the morning and another hour in the evening (2 hours per day), regardless of climate conditions.

While metro use has increased, among other reasons because of the construction of cable systems that connect with it, the use of conventional buses fell between 2005 and 2012. Motorcycle use has risen proportionally, as well. This is one of the consequences of the lack of coverage of the SITVA, added to higher incomes and the favourable purchase costs of motorcycles.

According to Metroplús, by 2014 the integrated fare will allow users to take a feeder bus and the metro or Metroplús for a fare of 1,550 pesos, without the surcharge as occurs today.

### c) Comfort and convenience

As a tool for improving public transport conditions, SITVA is still in the consolidation phase. There have been major advances, which contribute to improving user comfort and energy efficiency.

However, attention should be drawn to certain drawbacks of the current system and their possible consequences. The metro system is underused according to the Medellin metro company.[71] Yet it has already reached saturation point at peak times. For this reason, some users have opted to return to the bus, abandon the public system or even walk very long distances.

Some users mention the inconvenience of long queues to buy tickets, recharge their travel cards or get on board. This is reflected in some sectors and at certain busy times of day, and is worse at some times of the year and in tourist areas, which contributes to the saturation of the system and leads regular users to question its sustainability (for example, the metrocable in the northeastern area). Although the metro calls upon users to be prepared for peak tourist times by buying their tickets ahead, people still buy their tickets around weekly or monthly paydays which do not necessarily coincide with the recommended times.

This is in addition to access difficulties at some stations. The metro regulations sometimes limit convenient and safe access to the system by restricting the use of elevators to persons with physical disabilities.[72]

With regard to user comfort, mass transit systems in theory allow greater benefits: better accessibility, less noise and better air quality on-board; infrastructure designed for a safe service; seating and facilities for persons with disabilities; and a better user experience during acceleration and deceleration. Some of these features are truer of electric technologies (metro and aerial cables).

### d) Improving safety

There is no doubt that urban areas have improved around the SITVA stations. This, added to appropriation of surrounding areas in some cases, has contributed to improving safety in some areas. For example, inhabitants of the areas around the metrocable have noted lower levels of gang violence, better children's recreation, new places for young people to meet and a rise in rentals. There is, however, a general feeling in some low-income sectors that the system transmits the image of safety in

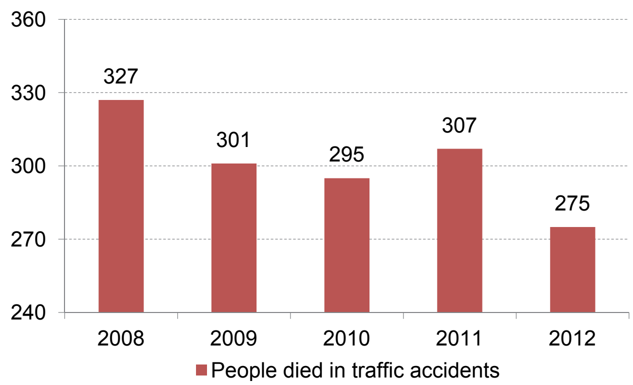
[71] The metro has a total capacity to carry 800,000 passengers per day, and is transporting close to 550,000 today.

[72] Only 40% of stations have elevators. The others have an electric system attached to conventional stairways to enable access for persons with reduced mobility.

its immediate area, but that this perception changes and urban violence continues and throws doubt on the impact of the institutional presence.

On the other hand, from the point of view of road safety, although there are no studies or specific measurements, the number of fatal accidents has fallen in the past two years. This could be the result of the smart traffic management system, or processes that are occurring in parallel. In 2012 there were 35 fewer road accident deaths than in 2011 and 20 fewer than in 2010 (Transport Department, 2013).

**FIGURE 51**
**REDUCTION IN ROAD ACCIDENT DEATHS**




Source: Prepared by the authors, on the basis of Transport Department, Medellin, 2013.

### e) Increasing personal safety

Like in the previous points, there are as yet no studies analysing impacts on personal safety. However, many users feel safer travelling via SITVA than by bus. An inhabitant of the Andalucía sector who uses the metrocable-metro combination every day feels that there is a difference between the cable and the bus "because there is surveillance on the stairs and around the station". Another user argued that, "The metro didn't improve just the line it travels along, but the whole metropolitan area. You didn't feel the presence of law enforcement before. Now you do. It's safer now, you can travel more safely".

### f) Impact on access for those on low incomes

The impact on those who use public transport and SITVA in particular has been analysed in terms of travel times and costs.

It is also important to mention that the implementation of the public bicycle system, which was intended as an emissions reduction strategy, has not only increased the number of people using the system itself, but has also drawn attention to the cycle paths the system uses, so that they are being used more by people with their own bicycles. Rather than environmental reasons for these trips, users tend to cite cost and time savings.

### g) Impact on access for people with limited mobility

Medellin has almost 50,000 inhabitants with some type of disability (Dávila, 2013). At the outset, the metro system did not make preferential provisions for persons with disabilities. However, since 2003, the metro has been taking steps to ensure accessibility for the disabled. Electromechanical platforms have been installed (Metro de Medellin) on 15 stretches of stairs, both inside and outside stations. Another 14 stations have lifts for the use of persons with limited mobility.

Both current users and researchers into accessibility for persons with limited mobility question the way in which these sorts of infrastructure are being approached, however. They also point to the need for active participation by potential limited mobility users at the design phases as well as the operative stage. It is argued that the solutions offered by the metro are not the best ones and, being remedial in nature, are expensive. They signal the risks run regarding some types of disability and conclude that all the obstacles generate an avoidable dependence that is irritating for people who have to ask for help.

Some users complain that only (reduced mobility card-carrying) users with disabilities are allowed to use the elevator system, while anyone accompanying them must use the conventional access points, queuing, taking the stairs, and so forth.

Today SITVA has around 1,000 users with a reduced mobility card, to whom the metro offers discounts of around 30%.

## 4. Indirect impacts on users

### a) Increased regional prestige

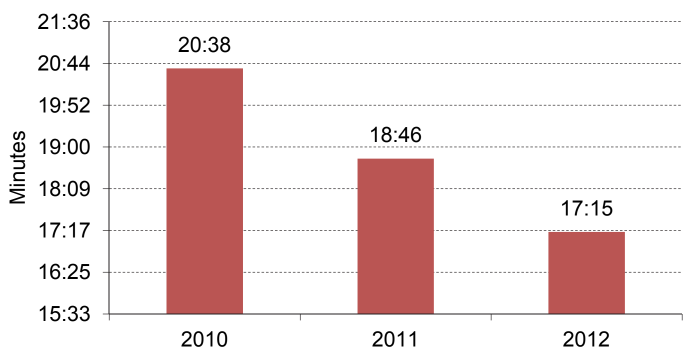
Medellin is recognized today for projects that have gone beyond the conventional, in terms not only of technology but also of connection between the transport system and integrated urban projects developed on the outskirts of the city.

### b) Decongestion of corridors

Measures such as the rationalization of the bus fleet help to reduce congestion in some corridors. One of the sectors under restructuring in the Metroplús system is to remove some 600 conventional buses from circulation and replace them with 250 new buses. Sector 6 covers an area of northeastern districts, where much of the low-income population lives and public transport is crucial for daily travel.

At the same time, the smart transport system has provided a more efficient response to traffic incidents, making it possible to clear congestion more quickly in the affected area. Average congestion time is the square of the time taken by the original incident (Cohen 2004).

**FIGURE 52**
**RESPONSE TIME TO TRAFFIC INCIDENTS**




Source: Prepared by the authors, on the basis of Medellin Transport Department, 2013.

### c) Shift towards more sustainable systems

Medellin and its metropolitan area are engaged in various processes of consolidation and change in terms of technologies and their applicability and the adoption of new systems. The start-up of metrocables which connect with the metro, and bus systems that are in the process of being set up, suggest a clear trend towards more sustainable medium- and high-capacity public transport.

However, it is apparent that these measures are not enough. Despite everything, motorcycles are gaining a great deal of ground, as are private cars. This is a consequence of the poor quality of conventional public transport by bus, as well as Colombia’s economic growth.

Alternative transport means, such as bicycles, are also gaining strength. This is promoted by AMVA institutions, through the EnCicla public bicycles project.

Lastly, although it is clear that progress has been made and there is a clear tendency towards the consolidation of SITVA, many challenges remain from the social, institutional point of view. Economic growth will continue and so will parallel growth in the vehicle and motorcycle fleet.

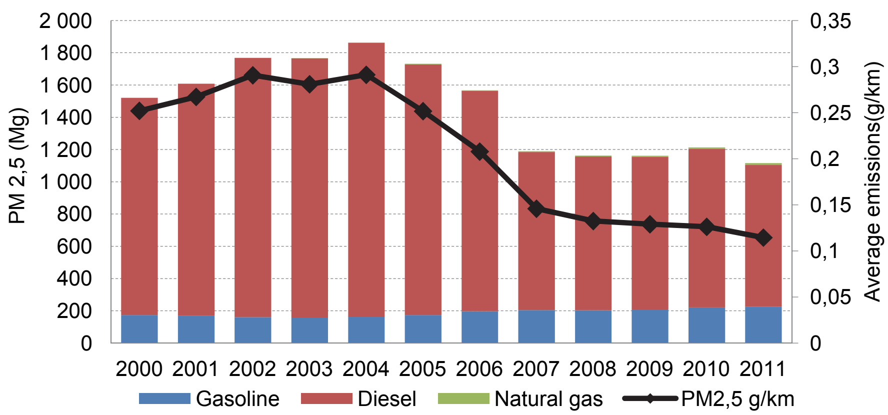
## E. Analysis of lessons learned in Medellin in terms of factors affecting energy efficiency

Institutional support, reflected in financial backing for project development, has been one of the great keys to the progress made in reducing emissions and increasing energy efficiency.

This is in addition to the institutional weight of AMVA, which as the environmental authority for the metropolitan area has gained recognition for its pro-environment measures. It is through AMVA that many local environmental policies have been continued, including transport policies affecting air quality.

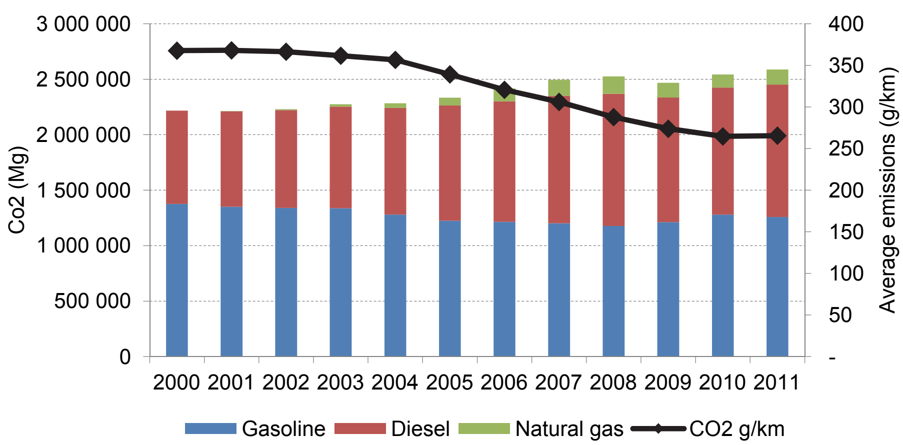
The policy of improving air quality is beginning to yield very good results. First, there is the direct impact of public policy in the form of the reduction in emissions in the past few years. The figure below illustrated the results in terms of emissions.

**FIGURE 53**
**CHANGE IN EMISSIONS OF FINE PARTICULATE MATTER**




Source: prepared by the authors, on the basis of en AMVA, Inventario de Emisiones Atmosféricas del Valle de Aburrá, base year 2011.

**FIGURE 54**
**CHANGE IN CARBON DIOXIDE EMISSIONS**




Source: prepared by the authors, on the basis of en AMVA, Inventario de Emisiones Atmosféricas del Valle de Aburrá, base year 2011.

There is also a direct link between emissions reduction and lower consumption of energy, as illustrated in the figure below. Yet gasoline consumption has been tending to rise since 2009, because the measures implemented have not sufficed to offset the steady rise in the number of gasoline-fuelled vehicles.

Although great progress has been achieved in carrying forward transport projects, supported by the financial and institutional muscle of the metro and EPM, these resources are not infinite. Aware of this, Medellin is now beginning to explore other forms of credit and financing.

Public transport measures cannot be treated as the only way to improve air quality. Alternatives must also be explored, such as managing vehicle demand through urban tolls and an urban development model based around consolidated or planned public transport corridors.

# IX. Mobility and energy efficiency in small island economies —Jamaica and Trinidad & Tobago

## A. Introduction mobility patterns of passengers and goods within the Caribbean (CARICOM)

Agreements within the region such as CARIFTA (Caribbean Free Trade Association), CARICOM (Caribbean Community) and other institutions have been implemented and developed over the past half century allowing for coordination and development between the small island States in the region. Currently, the 15 islands which make up the Caribbean Community include Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts-Nevis-Antilles, Saint Lucia, St. Vincent, Grenadines, Suriname and Trinidad and Tobago (CARICOM 2011). The agreements and institutions compile policies for different sectors among the regions in order to develop recommendations for the countries to work together more efficiently. One sector includes energy, a growing importance for the region in consideration of different types of energy including: renewable energy, investments in energy, energy efficiency, and rationalization of the energy sector (CARICOM 2013). The CARICOM energy policy created in March 2013 dedicates an entire chapter to the energy used for transportation. The chapter recommends to, "promote fuel switching in the transportation sector to cleaner energy sources and encourage greater efficiency of energy use in the transportation sector" (CARICOM 2013).

As stated in the CARICOM Energy Policy, all islands with exception of Trinidad and Tobago rely on the importation of petroleum products for the use of energy sources. This dependency, but also the importance of mobility for economic and social development and environmental implications for Small Island Developing States (SIDS), justifies a closer look into the Caribbean as part of this study.

Two countries have been chosen for more detailed case analysis based on population, GDP and data availability. Jamaica, being the largest island by population in the Caribbean Community with approximately 2.712 million people (2012), intra island travel by air and land will be measured in the first case study. Trinidad and Tobago, accounting for nearly 1.337 million people (2012) has been selected to compare mobility options by ferry and airtransport between the two islands. A description of each transport sector allows a better understanding.

This chapter focuses on three mobility options: air, land and waterborne[73], used for domestic passenger and goods transported. The purpose of the two case studies is to identify the amount of energy being consumed between two cities on each of the islands, allowing for a better understanding of the Caribbean region in terms of transport mobility related to energy efficiency.

## B. Jamaica

Jamaica aims to make the country the "place of choice to raise families, live, work and do business" (Ministry of Mining and Energy, 2010). In order to make this vision a reality, the government conducted an assessment analyzing mobility pattern and transport development as the key focus of the transformation (MTW JAM, 2011). Jamaica has a GDP of US$14.84 billion (2012) and a total population of 2.712 million (2012) (World Bank, 2013). The transport sector, including land, air and maritime, has a major impact on the country's national development (MTW JAM). The ability to manage this sector efficiently can provide beneficial results to the overall growth of the country's economy.

Jamaica's transport system is made up of road network (15,394 km), air infrastructure (two international airports and four domestic aerodromes), railway network (331 km of track) and maritime transport infrastructure (14 seaports). For the focus of this case study, the sectors including air and road will be analyzed to determine the relationship between the amount of passengers transported via these modes and the amount of energy consumed. ECLAC's study on Energy Efficiency in Latin America and the Caribbean: Situation and Outlook reveals that the overall transport for Jamaica consisted of 42% of total energy demanded for the island. Within the sector the study shows rail and road using volume comparable to what is needed for the public grid and maritime and air transport using one third of the country's consumption (Carpio, 2010).

Transport between two of the major cities in Jamaica, Montego Bay and Kingston, is analyzed in this case study to determine the fuel efficiency per transport mode used by passengers traveling this route. The city population for Montego Bay, capital of St. James parish, is a total population of 110,115 and area of 595 km2 in 2012. The city population in Kingston, capital of Kingston & St. Andrew parish, is 584,627 and area of 453 km2 in 2012 (Statistical Institute of Jamaica, 2012). Kingston has a population density of almost 7 times the amount of Montego Bay.

**TABLE 68**
**SOCIOECONOMIC CHARACTERISTICS, 2011**

| Total Area | Area [km2] | Population [inhabitants] | Population Density [inhabitants/km2] |
|---|---|---|---|
| Montego Bay | 595 | 110 115 | 185 |
| Kingston | 453 | 584 627 | 1 291 |

Source: Author, based on Jamaica City Population, 2011.

[73] Aviation transport: Passenger and cargo are transported via private, personal or commercial aircraft between airports or aerodromes. The Caribbean region includes associations dedicated to aviation transport such as the ALTA (Latin American and Caribbean Air Transport Association). The airlines within ALTA represent over 90% of the region's commercial traffic (ALTA, 2013). One of three main objectives for ALTA is the promotion of environmentally friendly air transport in the Caribbean region. Working with organizations such as Air Transport Action Group, the Caribbean region is working to reduce aviation carbon emissions by 2050 to half of the level in 2005 (Benefits Beyond Border, 2013). Land transport: Passenger and cargo transported on land are using trucks, trains, cars, buses, taxis or two wheeled vehicles. CARICOM emphasizes that land transport is crucial for the development of the SIDS within the individual territories in order to increase the overall economic growth in the region. Investments have been made in some of the islands on the roads and highways in order to increase the amount of flow and service providers for transportation. This as a result reduces the cost for transport with the land transport mode (Erskine, 2010). Waterborne transport: This type of transport also includes passengers and cargoes with main modes of service offered by boats, ferries, cruise ships, containerships, barges and personal watercraft such as jet skis or canoes. It is common in Caribbean islands where bridges are not available to use ferries to provide transfer of passengers and auto vehicles from one road to another, crossing a river or ocean. Vehicles used for maritime transport also require gasoline and made up a large share of total emissions for transport in the region.

Montego Bay is located near two main roads allowing access to other main cities on the island. The city has many buses, taxis, passenger vehicles and private cars that transport citizens from one place to another. The airport in Montego Bay, Sir Donald Sangster International Airport, is Jamaica's largest airport and a major tourist hub for visitors to the island. For the purpose of this report, domestic transport will be monitored for passengers moving between Montego Bay and Kingston. The largest city in Jamaica, Kingston, is home to the Norman Manley International Airport and Tinson Pen Aerodrome which services domestic flights. The major road of 230 km connecting Montego Bay and Kingston is the Highway 2000 which will be further described in the following sections.

The transport sector which is responsible for one third of the country's energy consumption is separated in the different usages for road and rail transport mode and other (shipping, aviation and other manufacturing) as shown in the figure below. This figure provides a historical timeline of the petroleum consumption for each sector in Jamaica. As shown, the rail and road modes accounted for 5.9 MBOE of total fuel consumption and other modes (shipping, aviation and other manufacturing) accounted for 6.15 MBOE in 2009. The following sections of this case study analyze data concerning the transport sectors mentioned for Montego Bay and Kingston in order to determine the energy and fuel consumptions for transport between the two cities (Ministry of Energy and Mining, 2010).

**TABLE 69**
**JAMAICA'S NATIONAL PETROLEUM CONSUMPTION BY ACTIVITY**

| Inputs | History | | | | Base |
|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 |
| Total fuel imports (MBOE) | 27.33 | 29.16 | 29.09 | 27.80 | 22.10 |
| Electricity | 6.55 | 6.39 | 6.65 | 6.27 | 6.66 |
| Bauxite industry | 9.8 | 9.55 | 8.81 | 9.39 | 3.39 |
| Road and rail transport | 6.25 | 6.37 | 6.08 | 5.84 | 5.9 |
| Other (shipping, aviation and other manufacturing) | 4.73 | 6.85 | 7.55 | 6.3 | 6.15 |
| Growth | -- | 6.70% | -0.20% | -4.40% | -20.50% |
| Cost of fuel imports (M US$) | $1 397 | $1 837 | $2 007 | $2 007 | $1 350 |
| Composite average cost per barrel of crude | $56 | $59.77 | $61.64 | $61.64 | $61.09 |

Source: Author, based on Ministry of Energy and Mining Oil Import Statistics 2010.

## 1. Mobility Options and Comparative Analysis

### a) Air Transport

Air transport is controlled by one major regulator on the island, the Jamaica Civil Aviation Authority (JCAA). Since 1996, JCAA has been responsible for addressing the safety and orderly development of air transport in Jamaica (MTM JAM). Regulation for air navigation, safety, security and abiding by laws set by ICAO are the main objectives of this authority. This is demonstrated by two major areas concerning flight safety and economic regulation. As development of JCAA in both international airports and the four aerodromes has improved, further advances have taken place such as the traffic management system for all aircraft.

For the focus of the route between Kingston and Montego Bay, the two main passenger airports accessed are Sangster and Norman Manley. These are the two airports which will be analyzed in this case study. As shown in table below the movement of passengers for 2010 is available for each airport. The major aircraft used is the Boeing 737-800 for both passenger and freight shipments. Considering that air transport between Montego Bay and Kingston used the same type of aircraft, calculations for the total energy consumption were possible. The result of fuel consumption per passenger is provided in table below revealing the rate of 13.86 fuel consumption per passenger. From this data, the carbon intensity indicators have been determined in regards to the Boeing 737-800 aircraft.

**MAP 5**
**AIRPORTS IN JAMAICA[a]**


Source: Author, based on Google Earth, 2013.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.
[a] Airports: Sangster International Airport, Montego Bay and Norman Manley International Airport

**TABLE 70**
**TOTAL PASSENGER MOVEMENT IN SANGSTER AND NORMAN AIRPORTS**
*(Number of passenger)*

| Airport Traffic Jamaica | 2010 |
|---|---|
| Sangster | |
| Disembarked | 1 593 827 |
| Embarked | 1 563 412 |
| In transit | 81 636 |
| Norman | |
| Disembarked | 748 213 |
| Embarked | 738 942 |
| In transit | 15 818 |

Source: Author, based on Jamaica Airport Authority, 2010.

**TABLE 71**
**TOTAL AIRCRAFT MOVEMENT IN SANGSTER AND NORMAN AIRPORTS**
*(Number of flights)*

| Aircraft movement | 2010 |
|---|---|
| Sangster | |
| International scheduled commercial | 16 541 |
| International non scheduled commercial | 535 |
| Domestic commercial | 1 406 |
| Military | 4 218 |
| Private | 4 705 |
| Total | 27 405 |
| Norman | |
| International scheduled commercial | 19 177 |
| International non scheduled commercial | 8 040 |
| Domestic commercial | 7 171 |
| Military | 300 |
| Private | 5 157 |
| Total | 39 845 |

Source: Author, based on Jamaica Airport Authority, 2010.
Notes: Fields include international scheduled commercial flights, international non scheduled commercial flights, domestic commercial flights, military uses, and private flights.

**TABLE 72**
**ENERGY EFFICIENCY AND GHG INTENSITY PER AIRCRAFT FOR JAMAICA**

| Aircraft | Fuel Consumption (ltr/hr) | Number of Seats | Fuel Used per Passenger (FC/passenger) |
|---|---|---|---|
| Boeing 737-800 | 2 135 | 154 | 13.86 |

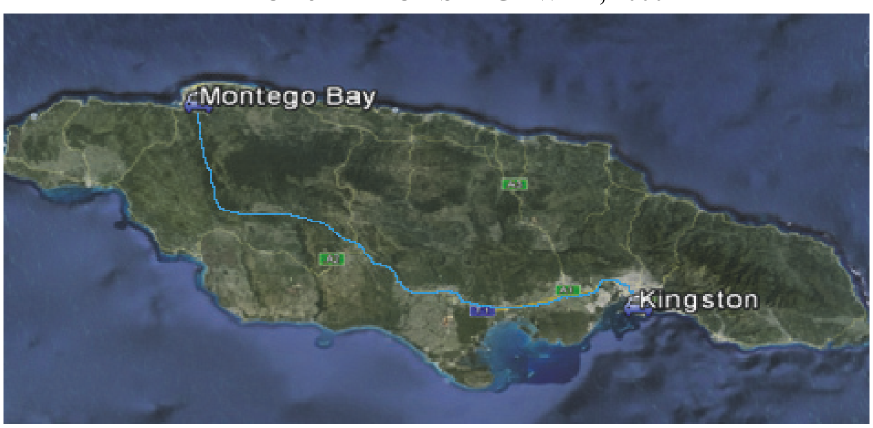
Source: Author, based on Freight Metrics Pty. Ltd, 2010.
Note: calculations are based on max capacity.

The Boeing 737-800 has a total passenger capacity for 154 seats. The total fuel consumption while the aircraft is en route is 2,135 liters per hour. Additional considerations for fuel consumption which are not included in the en route consumption shown in table 72 include the average fuel burn rate for arrival management at 2803.8 liters per hour, stationary ground at 884.6 liters per hour, active taxi out at 1153.8 liters per hour (Freight Metrics Pty. Ltd, 2010). These additional indicators are necessary when computing the overall fuel consumption from total departure to arrival. However, for the purpose of this case study, the measurements were based on the en route flying distance between Kingston and Montego Bay. This consumption rate can be compared to other case studies such as the Trinidad and Tobago case study to determine which route is most efficient in fuel consumption of in-flight travel distance for the aircraft used.

### b) Road Transport

Omar Davies of the Ministry of Transport for Jamaica stated that Highway 2000 has “become the norm of transport” and provided “savings on gasoline and time for transport” (Gleaner, 2012). The 193 km route between Montego Bay to Kingston previously required up to 3.5 hours and now the Highway 2000 revised route of 157 km allows for a reduced travel time. This allows for not only time savings for passengers but also the reduction of gasoline used and greenhouse gas emission exposed. This highway allows four to six lanes of controlled and tolled motorway sections which connect some of the main cities of Jamaica (NROCC, 2009).

**MAP 6**
**MAP OF JAMAICA'S HIGHWAY, 2000[a]**




Source: Author, based on Google Earth, 2013.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.
[a] Blue route represents Highway2000 Access for Car, Bus and Taxi Transport.

The vehicle fleet for private and public transport has increased in all vehicle types from 2000 to 2008 as shown in table 73. The country’s national policy for energy in 2010 discouraged imports of inefficient motor vehicles by taxing mile per gallon for each vehicle type. This tax was implemented with intent to reduce the amount of vehicles imported into the country which require high fuel for low miles driven. As shown in table 69, the import of fuel for the country exceeds 5.84 (Mtoe) for land transport in 2008 amount. By restricting the import amount of high fuel consuming vehicles, less fuel is needed as the cars driven demand lower fuel. Also, public awareness for the increasing amount of fuel consumption within the country allows for change in the habits of drivers and use of more efficient fuel consumption resulting with an overall reduction in the demand for fuel.

Solutions like these are already being put in place within the country through policies and entities such as the Island Transport Authority and Jamaica Urban Transit Company (JUTC). The public transport system operated by JUTC has implemented 100 new Volvo buses into the fleet as a way to increase the standards for public bus transport in the city of Kingston. In addition, measures are being implemented in order to bring pride and satisfaction to the general public and indentify the use again for public transport. These measures include color coordination for the buses and taxis, training of the driver fleet, and the integration of bus and taxi stands (Henry, 2009). Regarding the route between Kingston and Montego Bay, limited options are available with bus transfers. Many tourists travel between these routes via air, due to the time constraints and limited availability of bus options.

**TABLE 73**
**JAMAICA'S MOTOR FLEET**

| Vehicle Type | 2000 | 2005 | 2008 |
|---|---|---|---|
| Motor Car | 270 005 | 355 091 | 408 269 |
| Motor Cycle | 20 272 | 26 009 | 33 155 |
| Motor Tractor | 443 | 818 | 1 728 |
| Motor Truck | 91 498 | 120 883 | 139 481 |
| Trailer | 2 757 | 3 815 | 4 050 |
| Total | 384 975 | 506 616 | 586 683 |

Source: Author, based on Jamaica's GHG Mitigation Assessment, 2010.

**TABLE 74**
**SUMMARY OF VEHICLE KILOMETERS TRAVELLED, VKMT**
*(Estimates from surveys)*

| Survey | Fuel | Vehicle Type | VKMT (km/y) |
|---|---|---|---|
| MTW | Diesel | Motor Car | |
| | | Motor Cycle | 0 |
| | | Motor Truck | 31 477 |
| MTW | Petrol | Motor Car | 29 961 |
| | | Motor Cycle | 33 786 |
| | | Motor Truck | 21 193 |
| PIOJ/STATIN | Not Specified | Motor Car | 7 956 |
| | | Pick up | 6 604 |
| | | SUV | 5 876 |
| | | Minivan/Bus | 12 740 |
| | | Motor Cycle | 7 748 |

Source: Author, based on Jamaica's GHG Mitigation Assessment, 2010.

Taxis are available on the island and can be hired for transfer between these two points. Table 75 below provides a list of only five companies which offer these services in order to show the average rate offered for this route with taxi. The price includes four passengers and when necessary considers Kingston city center to Montego Bay city center. As the fleet of taxi vehicles is between 75 to 160 vehicles per company interviewed, the vehicle type varies to include sedans, economy, compact, midsize and more. In order to calculate the fuel and energy consumption for travel on this route via taxi, the standard economy car (Hyundai Accent, 2009) is computed for the fuel consumption rate per vehicle in Table 76. The fuel consumption calculated by the liters per hour is 4.88 for a standard car. With five seats (four passengers and one driver), the fuel consumption per passenger is 0.98.

**TABLE 75**
**TAXI SERVICES FROM KINGSTON TO MONTEGO BAY**

| Company | Fare (J$) | Fare ($US) | Passengers | Trip Type | |
|---|---|---|---|---|---|
| Apollo Tours & Taxi Service | 16 000 | 157.64 | 4 | 1-way | |
| Safe Travel Taxi | 15 000 | 147.79 | 4 | 1-way | |
| Express Taxi Service | 18 000 | 177.34 | 4 | 1-way | |
| Mortec Taxi Service | 14 000 | 137.93 | 4 | 1-way | |
| On Time Taxi Co Ltd | 18 000 | 177.34 | 4 | 1-way | |
| Average Fare | 16 200 J$ | | Average Fare Per Passenger | | 40 US$ |
| Distance | 157 km | | Average Fare Per Kilometer | | 1 US$ |

Source: Author's elaboration, based on Soprin, 2013.

**TABLE 76**
**TAXI TRANSPORT FLEET**

| Car type | Fuel consumption (ltr/hr) | Number of seats | Fuel used per passenger | No. of cars in fleet* |
|---|---|---|---|---|
| Standard | 4.88 | 5 | 0.98 | 150 |

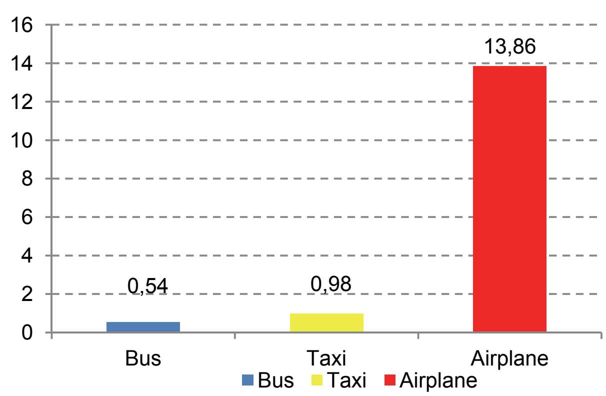
Source: Author's elaboration, based on Soprin, 2013.
Note: Number of cars in fleet is the average taxi count per Company.

**TABLE 77**
**BUS TRANSPORT FLEET**

| Bus type | Fuel consumption (ltr/hr) | Number of seats | Fuel used per passenger (FC/passenger) | No. of buses in fleet* |
|---|---|---|---|---|
| Coach | 24.5 | 45 | 0.54 | 35 |

Source: Author, based on Henry, 2009.
Note: Number of buses in fleet is for the Knutsford Express Company.

**FIGURE 55**
**JAMAICA TOTAL FUEL CONSUMPTION BY TRANSPORT MODE**



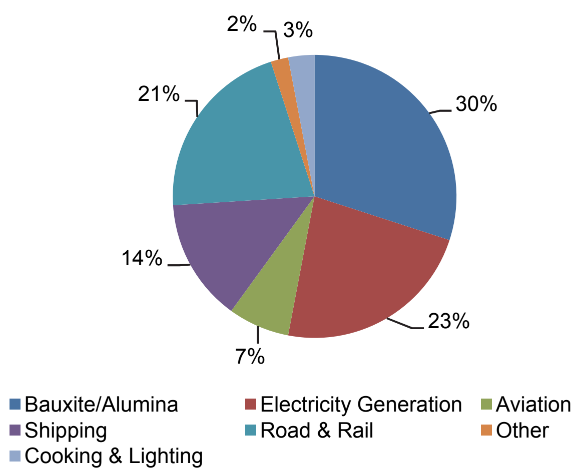

Source: Author's elaboration.

Bus transport between Kingston and Montego Bay while available, has limited service providers for this route. Some bus companies will offer private mini buses to transport passengers on this route however most are used only for local transport. Knutsford Express is one bus company that offers bus service from Kingston to Montego Bay. The price for one adult traveling from Kingston to Montego Bay is 21USD. According to Knutsford Express other services are offered between these two cities or bus transport in the city but for bus transport between Kingston and Montego Bay, his company is the main operator used. "We offer transport with coach buses which takes on average five hours for the trip." (Peterkin, 2013) To provide perspective for the amount of fuel on average between the bus and car modes analyzed above transport for, "one passenger over 100 kilometers with buses requires 0.6 to 0.9 liters of diesel fuel whereas a diesel car will consume 5.9 liters of fuel and a gas powered car 7.6 liters of fuel" for the same distance (Davis, 2010). Maximum capacity for the buses was considered for the analysis of the data in table 77. When the bus is operating at less than maximum capacity, the fuel consumption per passenger will increase reducing the potential available per bus. Nevertheless bus transport compared to car transport (taxis) offers a better fuel consumption per passenger.

### c) Maritime Transport

Water taxis and ferry services are available on the island. The majority of passenger maritime transport on the island is for short hop services between major cities such as Montego Bay and Kingston to smaller resort islands or beach towns. These large cities are also frequented by large cruise ships and freight containerships bringing cargo and freight to the island. Freight considerations for the imported and exported cargo at the Jamaican ports could be used to measure efficiency of container ship and bulk ships servicing the ports. For the scope of this case study, concentration was limited to passenger transport with limited information provided for air freight transported.

**FIGURE 56**
**TOTAL PETROLEUM CONSUMPTION BY SECTOR**




Source: Author' s elaboration, based on Smartmovecampaign, 2010.

## 2. Recommended Solutions to Improve Energy Efficiency

### a) Regulatory Framework

The Ministry of Water, Land, Environment and Climate Change published a draft report in June 2012 on the subject of energy and transport with considerations for a green economy. In line with an earlier report (Ministry of Transport and Works, 2008) one of the goals in developing a green economy through these two sectors was through the enhancement of current institutional frameworks and implementation of sustainable development through the political offices.

Key strategies to be implemented in order to provide green transport in the country include traffic management and air pollution control, reduction of fossil fuels in transport sector and reduction in ship borne waste. Energy security is another focus in order to reduce the fuel usage and, "ease the oil burden on the country" (Ministry of Transport and Works, 2008). Almost 90% of the energy needs of the country are met by imported oil. Figure 56 above shows the total petroleum consumption by sector, for which total transport modes account for 42% of overall consumption. Measures taken to provide green transport and reduce the reliance on petroleum include alternative fuels to gasoline such as natural gas. With an increasing rate of 4.3% for automotive fuels (gasoline and diesel oil), the use of natural gases and other alternatives will provide a good alternative to counter the increasing demand and provide a more sustainable green transport network.

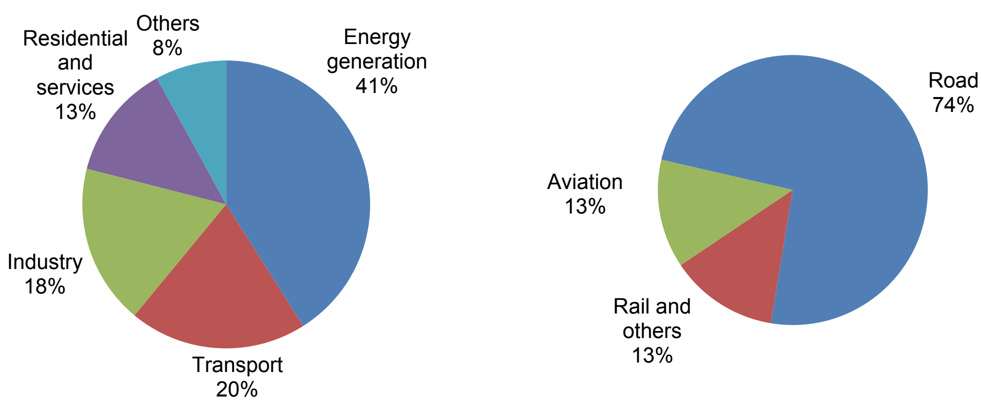
Road transport includes 15,394 km of road by private vehicles and public transport system (buses and taxis). Within multiple entities involved in the road transport sector within Jamaica, three will be discussed in this case study as they are associated with public transport. These include Jamaica Urban Transport Company (JUTC) for Kingston, Montego Bay Metro Limited (MBM) for Montego Bay and Transport Authority (TA) for the island. Another entity, the Toll Authority (TA) is important to mention as they are responsible for implementing the Highway 2000 project. The number of vehicles on certified roadways for 2007/2008 was 420,265 (MTW JAM, 2012). The importance of these public transport motor vehicles is due to the recent survey concluding that nearly 75% of households in Jamaica do not own a motor vehicle (MTW JAM, 2012).

**TABLE 78**
**ENERGY EFFICIENCY AND GHG INTENSITY INDICATORS FOR JAMAICA**

| Transport model | Fuel type | Energy factor | Heat value | Energy consumption | GHG intensity |
|---|---|---|---|---|---|
| | | Based on value | Lower heat | Fuel used | $CO_2$ emisions |
| | | kg $CO_2$/ GJ | GJ/ liter | FC/passenger | (FU)(HV)(EF) |
| Car (taxi) | Gasoline | 69.25 | 0.0344 | 0.98 | 2.334556 |
| Airplane | Aviation gasoline | 69.11 | 0.0343 | 13.86 | 32.854756 |
| Bus | Diesel | 74.01 | 0.0371 | 0.54 | 1.4827163 |

Source: Author's elaboration, with conversion factors from World Energy Council (n.d.).

**FIGURE 57**
**JAMAICA TRANSPORT'S CONTRIBUTION TO CARBON DIOXIDE EMISSIONS**




Source: Shenoy, 2012.

Figure above shows Jamaica's carbon emissions by sector with the transport sector accounting for 20% of the total $CO_2$ emitted. Carbon emission intensity is relevant to the transport sector as 20% of all $CO_2$ emissions are accounted for by this sector. The carbon emission intensity of aviation is relevant for the efficiency of airlines for emissions per unit transported. With 13% of overall transport, this sector while having room for carbon emission improvement is currently not the major concern for the transport modes. A major concern for the airline companies is the rising cost of fuel which results in higher prices for the customers. As customers traveling for vacation purposes have more flexibility to decide on the destination, the flight expenses are a factor in many vacationers' purchases. Thus airlines compete to offer lower airline tickets as a way to attract more customers. With high fuel prices fixed in the cost of the ticket, the margin for revenue reduces.

However, road transport with 74% of overall carbon emissions for the transport sector produces a substantial amount of carbon emissions and therefore creates the largest concern. This sectors large carbon emission can be attributed to factors such as the public and private transport fleet of cars, taxis and buses used. The lack of public awareness of emissions per vehicle results with high use of personal transport for day to day travel without concern for the amount of emissions each car is producing. Thus even with rising oil prices, cars and taxis are still being used rather than alternative and lower emission modes such as bicycles, walking, or public transport with buses or trams. The Ministry of Water, Land, Environment and Climate Change started a bus advertising campaign in order to spread this awareness to the public by creating the logo "Climate Change We have to Change!" on the local buses in Kingston (Bus and Coach, 2013).

### b) Technical Solutions

A solution for the specific route of analyzed in this case study between Montego Bay and Kingston via air includes the use of alternative aircraft. A recommendation to use more efficient aircrafts (e.g. an ATR 72 in place of the Boeing) would provide benefits to the operation. This includes reduction of fuel consumption, increase of energy and fuel efficiency, and reduction of CO emissions. For this short haul flight, planes such as the ATR 72's provide a more sustainable option which allows the airlines to capitalize on the higher margin of profit as the fuel expense is reduced per flight. LIAT, the Antigua based airline carrier which flies to 21 destinations in the Caribbean has introduced these new models in the pan-Caribbean network.

### c) Financial / Non-financial Incentives

Jamaica's energy policy for 2009 to 2030 includes ten fundamental elements in which the strategic vision for the future is dependent. The sixth element is allocated to databases which allow forecasting and management of the energy sector related to the transport sector. As listed as one of ten key priorities needed for the overall future planning for the country's energy policy, the importance for how much the transport sector depends on the energy sector is apparent (Ministry of Energy and Mining, 2010).

**TABLE 79**
**JAMAICA'S ENERGY DEMANDS**

| Jamaica's Energy Demands | | | |
|---|---|---|---|
| Year | GDP growth (%) | Energy demand growth (% pa) | Energy demand (million boe) |
| 2005 | 1.0 | 6.5 | 28.0 |
| 2006 | 2.7 | 3.9 | 29.1 |
| 2007 | 1.4 | 0.7 | 29.9 |
| 2008 | -0.6 | -7.0 | 27.8 |
| 2009 | -2.3 | -5.0 | 22.0 |
| 2010 | 0.1 | 0.2 | 22.0 |

Source: Jamaica Vision, 2009.

## 3. Energy Efficiency Measures: Identifying Success Criteria

As stated in Jamaica's energy policy the "successful implementation of the policy will require linkages to be made between the energy sector and transport" (along with other sectors) (Ministry of Energy and

Mining, 2009). The proposed solution from this case study suggests the same, for a linkage to be made between the transport of passenger and cargo within the island and the energy sector for consumption and efficiencies. Within Jamaica, the focus on road transport to improve by reducing the amount of carbon emissions should first be addressed. A solution to provide public awareness of the large amounts of emissions per vehicle is recommended in order to increase interest and invoke the concern for change in this transport sector. The PCJ National Energy Efficiency Unit (NEEU) has already created public awareness education programs for the energy consumption on the island (Carpio, 2010). However, these programs do not focus on the transport sector and energy emissions and consumption uses. This example reveals the missing link which currently exists between the transport and energy sectors. Solutions regarding the integration of these two sectors to share concepts and concerns are necessary to benefit from reduction of emissions. Such solutions include the government increasing the participation by not only using the policies already created but implementing these policies through regulations which are enforced at the local level. The Jamaican Ministry of Transport and Works provides an example of this as this entity has a corporate plan which focuses on energy efficiency and environmental management in the transport sector. Through the removal of outdated vehicles and improving current inefficient public transport services, this ministry provides an example of solutions needed throughout the island (Carpio, 2010).

## 4. Lessons Learned: Jamaica

The government of Jamaica has been making considerations for energy in relation to transport in recent years. Clear policies need to be implemented in order to increase energy efficiency practices throughout the country. Three dimensions of energy policy include process, context and content. Process is the continuance of planning, forming, implementing and controlling energy efficient practices. The context encompasses the environment in which process and content are embedded. Third, the content includes the policies and strategies agreed by parties of interest in order to provide sustainability for the country (Nestor, 2010). Objectives are measured through different analysis based frameworks calculating the efficiencies, consumption rates, resource outputs and other related energy metrics. Green transport as measured in Jamaica analyzes the fuel efficiency of public and private vehicles (PCJ, 2008). This effort is included in the energy and transport policies with focus to use more clean fuels in transport, minimize pollution emitted and provide more sustainable transport solutions within the country. An example of these solutions introduced includes the change to natural gas as an alternative fuel to gasoline or diesel. The Jamaican government is working with Trinidad and Tobago in order to import natural gas and reduce the demand for gasoline and diesel fuels. As these policies are implemented and partnerships are developed between the islands of the Caribbean to work together to reduce the demand for energy in the region, Jamaica will achieve its goal to provide a more efficient and sustainable living environment for its citizens.

# C. Trinidad and Tobago

Trinidad and Tobago is the major producer in the Caribbean of petroleum, natural gas and related products (CARICOM). Trinidad and Tobago have a GDP of $23.99 billion (2012 USD) and total population of 1.337 million (2012) (World Bank, 2013). Transport between the two islands for passengers is the main focus of this case study. The Ministry of Transport for Trinidad and Tobago, established in June 2011 is responsible for transport by land, sea and air. As with any country, the ability to successfully manage these modes and provide efficient public transport will allow for growth and sustainability in the country's economy.

**TABLE 80**
**TRINIDAD AND TOBAGO CHARACTERISTICS (2011)**

| Total Area | Area [km2] | Population [inhabitants] | Population Density [inha/km2] |
|---|---|---|---|
| Trinidad | 4 821 | 1 291 150 | 267 |
| Tobago | 300 | 55 200 | 184 |

Source: Author's elaboration, based on Trinidad City Population, 2011.

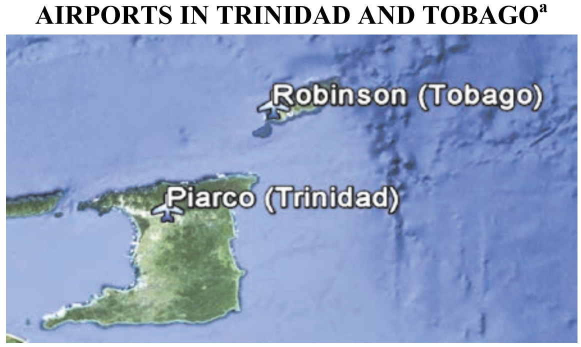
Trinidad and Tobago's public transport system includes a commercial airport on both islands, a road network of 5,600 km of main roads and 2,000 km of agricultural access roads (Ministry of Works and Transport, 2010). The sea transport sector includes main ports connecting Port of Spain with Scarborough and San Fernando. Railway transport does not currently exist in the country, although there have been ongoing proposals and discussions for a rapid railway transit within the islands. For the focus of this case study, the sectors including sea and air area analyzed in relationship to passengers transported via these modes to determine the amount of energy consumed. ECLAC (2011) reveals that overall energy efficiency in Trinidad and Tobago is not being promoted as there is not a shortage of supply of energy, with the country being a top oil producer in the region. The government has agreed to medium term goals for energy efficiency for sustainable development within the country. Though, for the present time period this allows a better understanding for the high energy consumption rates found (Carpio, 2010). Further information in this case study will provide the recommended solutions each mode can provide in order to successfully integrate energy efficient standards in the country's public transport sector.

## 1. Mobility Options and Comparative Analysis

### a) Air Transport

The two international airports are managed by the Airport Authority of Trinidad and Tobago. Piarco Airport has been in operation since 1931, servicing both islands and the southern Caribbean. In 1992, after government investment in the then named Crown Point airport and services began for international flights in what is now called A.N.R. Robinson Airport (Airports Authority of Trinidad and Tobago, 2013). The authority's mission for both airports is to "develop and manage safe, secure, efficient and customer oriented airport estates" (Airports Authority of Trinidad and Tobago, 2013). As administered by the International Civil Aviation Organization (ICAO), the authority provides high quality services and facilities which include concerns for the economic and environmental aspects.

**MAP 7**
**AIRPORTS IN TRINIDAD AND TOBAGO[a]**




Source: Author, based on Google Earth, 2013.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.
[a] Piarco Airport in Trinidad and Arthur Napoleon Raymond Robinson Airport in Tobago.

Caribbean Airlines, based in Port of Spain, acquired a new fleet of aircrafts in 2011 to service the domestic route between Trinidad and Tobago. This new fleet includes nine of the ATR 72-600 series which allows for cost efficient and fuel saving air transport (Airports Authority of Trinidad and Tobago, 2013).

Concentrating on the airport traffic of passengers, goods and aircraft movement can be analyzed in the context of energy efficiency. In table 11 through 13 below, the data for 2010 is provided regarding the traffic movements between Piarco and Robinson airports. Traffic flow and type of aircraft is needed in order to measure overall energy efficiency. It should be noted that calculations are based on the distance between Piarco and Robinson for being approximately 95.1 km or 51.32 nm.

**TABLE 81**
**TOTAL PASSENGER MOVEMENT IN PIARCO AND ROBINSON AIRPORTS**

| Airport Traffic Jamaica | 2010 |
|---|---|
| PIARCO | |
| International | 1 621 584 |
| Domestic | 629 560 |
| In transit | 253 325 |
| Total | 2 504 469 |
| ROBINSON | |
| International | 69 816 |
| Domestic | 40 313 |
| In transit | 629 423 |
| Total | 739 622 |

Source: Author's elaboration, based on Airports Authority, 2010.

**TABLE 82**
**ENERGY EFFICIENCY AND GHG INTENSITY PER AIRCRAFT FOR TRINIDAD AND TOBAGO**

| Aircraft | Fuel consumption (ltr/hr) | Number of seats | Fuel used per passenger (FC/passenger) |
|---|---|---|---|
| ATR 72-600 | 810.1 | 72 | 11.25 |

Source: Author's elaboration, with fuel consumption and maximum number of seats based on Freight Metrics Pty Ltd, 2013.

The ATR 72-600 has a total passenger capacity of 72 seats. The total fuel consumption while the aircraft is en route is 810.1 liters per hour. Additional indicators are necessary when computing the overall fuel consumption from total departure to arrival. These measures which are not included in the en route consumption shown in Table 14 are the average fuel burn rate for arrival management at 646.2 liters per hour, stationary ground at 307.7 liters per hour, active taxi out at 384.6 liters per hour. This case study measures the en route flying distance between Piarco and Robinson airports.

### b) Maritime Transport

The maritime transport sector for Trinidad and Tobago offers two main routes including the inner island between Port of Spain and San Fernando and connecting the islands by Port of Spain and Scarborough. The route between Port of Spain and San Fernando by ferry service offers a comparison of overall efficiency with the connecting islands route. To provide a basic overview, table below provides the distance in nautical miles and amount of services by vessel servicing each route.

**MAP 8**
**PORTS OF TRINIDAD AND TOBAGO**


Source: Author's elaboration, based on Google Earth, 2013.
Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.
[a] Port of Spain and San Fernando in Trinidad and Scarborough in Tobago.

Water taxi and ferry services are provided to connect passengers from the islands of Trinidad and Tobago. The current fleet available for water taxis from Port of Spain to San Fernando, within Trinidad, includes HS Carnival Runner, HS Paria Bullet, HS Calypso Sprinter and Trini Flash (National Infrastructure Development Company Ltd., 2012). These vessels and their sailing schedules will be used for the content of this case study in order to analyze the energy consumed within this example of maritime transport. The current fleet connecting the islands between Port of Spain and Scarborough includes T&T Express, T&T Spirit, Panorama and Warrior Spirit (Government of Trinidad and Tobago, 2012). The Warrior Spirit is a RO/RO conventional vessel used to transport passengers as well as cargo between the islands. This should be considered when analyzing the energy efficiency as the weight is greater than the other vessels due to cargo onboard (T&T Inter-Island, 2010).

In order to determine the overall efficiency of the vessels, fuel consumption is measured. It is worth noting that fuel consumption is effected by several factors which include energy efficiency (specific fuel consumption), propulsive efficiency (propeller or water jet efficiency), hull efficiency (shape) and weight (related to tank capacity and to be kept at a minimum (Wake, M., 2013). The following fuel consumption provided in the table below is based on the fuel tank of series 2000 type, used for the water taxi vessels in the region.

**TABLE 83**
**ENERGY EFFICIENCY AND GHG INTENSITY FOR VESSELS**

| Vessel | Max passenger | Ave. Service speed (knots) | Fuel consumption [l/hr] | Distance (nm) | Trave l time (hr) | pass.nm | L/pass | Fuel used L/pass.nm |
|---|---|---|---|---|---|---|---|---|
| T&T Express | 762 | 36 | 356.1 | 70.2 | 2.5 | 53 492 | 1.17 | 82.01516 |
| T&T Spirit | 900 | 39 | 356.1 | 70.2 | 2.5 | 63 180 | 0.99 | 69.4395 |
| Panorama | 650 | 14 | 356.1 | 70.2 | 5.5 | 45 630 | 3.01 | 211.5234 |
| W. Spirit | 650 | 18 | 356.1 | 70.2 | 5.5 | 45 630 | 3.01 | 211.5234 |
| C. Runner | 402 | 35 | 356.1 | 27.75 | 0.5 | 11 156 | 0.44 | 12.29076 |
| Paria Bullet | 402 | 31 | 356.1 | 27.75 | 0.5 | 11 156 | 0.44 | 12.29076 |
| C. Sprinter | 402 | 34 | 356.1 | 27.75 | 0.5 | 11 156 | 0.44 | 12.29076 |
| Trini Flash | 402 | 26 | 356.1 | 27.75 | 0.5 | 11 156 | 0.44 | 12.29076 |

Source: Author, based on T&T Inter-Island Transportation CO, 2013.

## c) Road Transport

Over 30,000 new and/or foreign-used cars are imported to Trinidad each year since 2008 (Manning, 2008). This influx of vehicles has impacted the roads and land transport sector for the island. Traffic increases, accident rates are growing, destruction of infrastructures and roads are some of the effects of this influx. The Ministry of Transport has reacted by providing a new fleet of buses to shift some of the traffic from individual cars to public transport sector. This bus fleet has doubled in the past 5 years as a result. With more cars and buses on the road, the aim for green transport throughout the country is an important focus of the government and organizations such as the Natural Gas Vehicles Task Force. The cars used in calculations for this study include car vehicles for standard, 5 passengers; bus vehicles vary for mini bus and deluxe coach. The standard car is based on the 2005 Toyota Camry, being the common model/type of taxi used. The mini bus taxi is based on the 2000 Toyota Coaster and the coach bus based on the 2005 Toyota Hiace. In 2011, this task force announced a shift for the motor vehicle population to use more compressed natural gas (CNG) instead of diesel and gasoline (Guardian, 2013). Entities among transport and energy sectors have been pushing for the use of CNG as a cost effective incentive to reduce the country's emissions.

# 2. Recommended Solutions to Improve Energy Efficiency

## a) Regulatory Framework

Trinidad and Tobago's transport sector is responsible for reducing carbon emissions by altering the fuel consumed for transport, as stated in the Draft Renewable Energy Policy for the country. The Government of Trinidad and Tobago has announced the plan to move towards the development of CNG in order to reduce the high liquid fuel consumption for vehicles in the country (Ministry of Energy and Energy Affairs, 2011). Other measures will include research and development for biofuels such as diesel and ethanol to determine the amount of reduction these fuels would allow in terms of reducing GHG emissions. Also, considerations for importation of cars that run on alternative energy are being made, since the last policy in 2010 authorized imported cars as old as six years allowed in the country. The government implemented a CNG Task Force in order to ensure that a minimum of 100,000 vehicles would use natural gas by 2016. Though while the current fuels for transport are subsidized by the government, there is little effort from citizens to make changes in current consumption. There is a need for public awareness in order to provoke interest in the reduction of high fuel consumption and concern for reducing energy consumption.

The relationship between energy consumption and GDP is particularly important for Trinidad and Tobago. As shown in table 84, the intensity levels of energy and $CO_2$ of transport to GDP have increased since 2009, while the $CO_2$ emissions per capita have declined from 2010 to 2011. In order to continue with the decreasing trend for emissions per capita and to decrease the intensity levels of transport to GDP for future years, policies which consider these measures will need to be implemented. The current policy regarding energy emissions and consumption focus on this through developing committees and promoting use of alternative fuels and energy technologies in order to reduce these indicators. Shifts in these policies are evident and necessary in order to phase out existing practices and move the country toward a more sustainable and efficient consumer of energy.

In the air transport sector, efficiency measures are being taken through the investment of fuel efficient aircraft with the ATR 700 (Pilot Career Center, 2010). An overview of the energy efficiency currently in Trinidad and Tobago for the years 2009 to 2011 in Table 16 below provides the $CO_2$ intensity and emissions for GDP and per capita. The average trend increases for the three years revealing that the energy intensity of transport based on this key indicator has room for improvement in order to reduce these intensity levels for the future years.

**TABLE 84**
**ENERGY EFFICIENCY OF TRANSPORT SECTOR FOR TRINIDAD AND TOBAGO**

| Energy Efficiency Key Indicators | 2009 | 2010 | 2011 |
|---|---|---|---|
| Energy intensity of transport to GDP (at ppp) | 0.030 | 0.033 | 0.033 |
| $CO_2$ intensity of transport to GDP (at ppp) [1] | 0.089 | 0.099 | 0.097 |
| $CO_2$ emissions of transport per capita [1] | 2.05 | 2.29 | 2.21 |

Source: Author, with conversion factors from World Energy Council (n.d.).

Figure 9 above shows the energy efficiency of transport compared to GDP for Trinidad and Tobago from 1990 to 2011. As shown, the efficiency has improved since 2006 and meeting the efficiency levels of the world in 2010 and 2011. The world efficiency trend decreased from 2005 to 2011. Also it is important to consider current levels of oil production. In 2007 and 2008, production of crude oil fell sharply with output down to around 114 000 b/d, which is considerably lower than the output of 300,000 b/d in 2005.

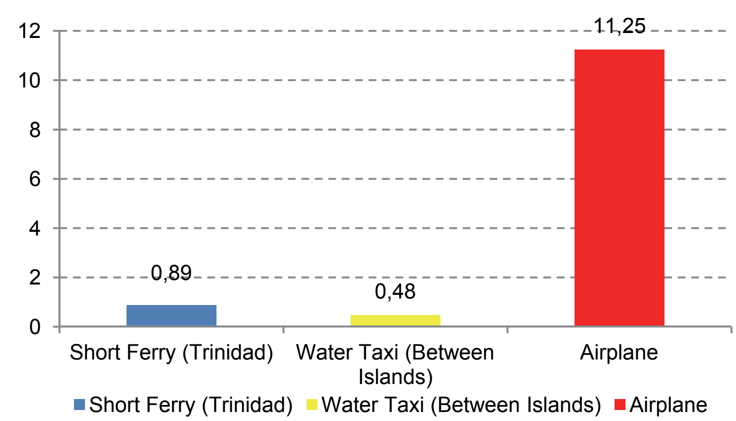
Energy in Trinidad and Tobago is dependent on natural gas for fuels and other sectors. However for the transport sector, petroleum products account for the majority of fuel for energy consumption. The country's National Draft Climate Policy addresses the issue of high dependence of transport on this finite resource. Table 85 below shows the inter island and intra island transport options by mode providing the fuel type, energy factor which is based on value of (kilogram of $CO_2$ per gigajoule), heat value which is based on the lower heat (gigajoule per liter) and energy consumption or fuel used (fuel consumption per passenger) in order to calculate the total GHG (green house gas) intensity.

**TABLE 85**
**ENERGY EFFICIENCY AND GHG INTENSITY INDICATORS FOR TRINIDAD AND TOBAGO**

| Transport mode | Fuel type | Energy factor | Heat value | Energy consumption | GHG intensity |
|---|---|---|---|---|---|
| | | Based on value | Lower heat | Fuel used | $CO_2$ emissions |
| | | kg $CO_2$/ GJ | GJ/ liter | FC/passenger | (FU)(HV)(EF) |
| Inter Island from Port of Spain, Trinidad to Scarborough, Tobago | | | | | |
| Airplane | Aviation Gasoline | 69.11 | 0.0343 | 11.25 | 26.66782125 |
| Water Taxi (Between Islands) | Diesel | 74.01 | 0.0371 | 0.48 | 394.3750887 |
| Intra Island of Trinidad: Port of Spain to San Fernando | | | | | |
| Short Ferry (Trinidad) | Diesel | 74.01 | 0.0371 | 0.89 | 33.74552559 |
| Maxi Taxi (Mini Bus) | Diesel | 74.01 | 0.0355 | 0.28 | 0.07356944 |
| Bus (Deluxe Coach) | Diesel | 74.01 | 0.0371 | 0.12 | 0.32949252 |

Source: Author's elaboration with conversion factors from World Energy Council (n.d.).

**FIGURE 58**
**TRINIDAD AND TOBAGO TOTAL FUEL CONSUMPTION BY TRANSPORT MODE**




Source: Author' elaboration, based on Trinidad Ministry of Energy and Energy Affairs, 2011.

## b) Technical Solutions

The Trinidad Port Authority currently has a contract for service operations with Bay Services (management company for ferry services). The Port Authority recently upgraded the T&T Express vessel for $30 million in order to provide fast service to passengers traveling between Trinidad and Tobago. Since the implementation of the service, there has been a large shift in demand for the use of ferries compared to the 20 minute air service. The fast service for two and a half hours is also in higher demand than the five hour slow service. With future economic growth on the two islands, travel and transport between the islands can also be expected to grow. In such cases, the technical solution is to invest in another fast vessel service and sell off the slow steaming vessels to more effectively compete with air travel. This could allow for further investment for the water taxi service from Port of Spain to San Fernando. This would allow less congestion on roads as passengers could use the fast ferry option (with or without their cars) to travel between these cities (Guardian, 2012).

### c) Public Information

As the country is now beginning to spread awareness on energy consumption to the public, the energy efficiencies topics regarding transport have yet to been introduced to public scene. Campaigns including the MEES "My energy, My responsibility" were created in order to provide the general public with information regarding energy (Carpio, 2010). The focus to educate the public on the source of energy, renewable energy options available and ways that energy saving can take place in order to provide a more sustainable future for the islands. Further, a renewable energy team was set up in order to provide capacity building and generate public awareness regarding the topic. Further steps are needed involve local and national government entities working together to address the renewable energy concerns and fund media to raise more awareness and facilitate implementation of energy saving techniques (Carpio, 2010).

### d) Financial and Non-financial Incentives

Trinidad and Tobago's current energy policy outlines the recommendations for the transport sector regarding ways to reduce carbon emissions in transport. These recommendations include promotion of research and development for alternative fuel options, importation of hybrid and energy efficient vehicles, alternative energy to reduce transport emissions and phase out of existing subsidies on gasoline (Ministry of Energy and Energy Affairs, 2011). By implementing these into the country's job sector allowing positions for research teams, energy experts, fuel and alternative fuel research and marketing, opportunities are created providing high-value jobs in the nation and attracting foreign exchange and funding as a result (Ministry of Energy and Energy Affairs, 2011).

## 3. Energy Efficiency Measures: Identifying Success Criteria

Creation of a new energy policy along with agencies and entities tasked with assessing the current energy consumption and finding fuel efficient solutions for more sustainable uses for the future are examples which reveal Trinidad and Tobago is on the right track to link energy efficiencies with the transport sector. Reacting to previous increases in traffic on roads, deterioration of road infrastructures have resulted in increased public transport options and concern for public awareness in the transport sector. Improvements for the country include the current agencies and organizations which have been established to address the energy efficiencies in transport working together with national government entities in order to agree on best policies for energy sustainability. The next step would then include the policies being implemented through regulatory actions in order to ensure these solutions are in fact integrated in the day to day consumption (Ministry of Energy and Energy Affairs, 2011). Along with the implementation, further public awareness is needed in order to create change in the behavior of the citizens and have public commitment to carry out these policies and benefit from energy efficiency, environmental management and green transport practices.

## 4. Lessons Learned: Trinidad and Tobago

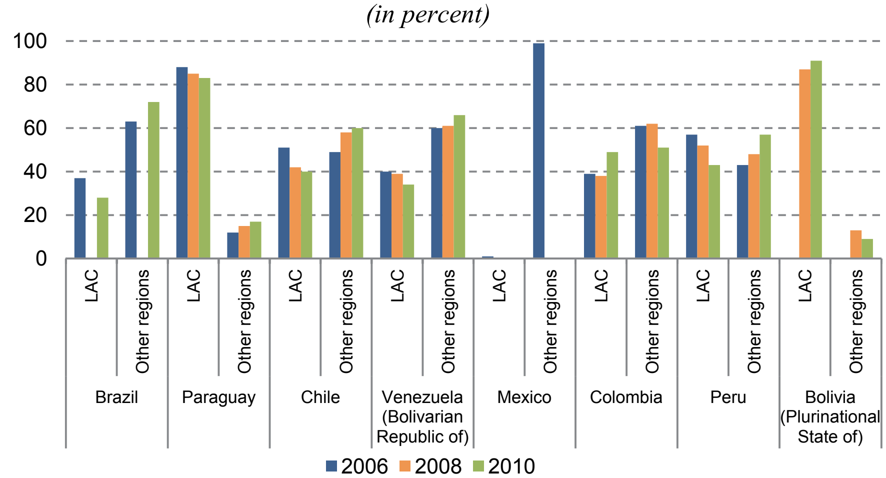
In the new policy for 2011-2015, Trinidad and Tobago's government introduces strategies for economic growth that include policies for energy efficiency targeted at educating, raising awareness, and promoting the use of available technologies (ECLAC, 2010). In countries that are exporters of energy or using controlled utility markets, the incentive for citizens and businesses to participate in a reduction of energy use is, however, limited. Not only in the large businesses and oil companies, but also in the day to day usage of citizens consuming energy in their transport from place to place. Public awareness for the importance of energy efficient measures is just starting to appear. Incentives such as a decrease of subsidy for oil by the government or taxes on imported cars aim to increase the use of the public transport system. Increase of traffic on the roads and deteriorating infrastructures are also pushing more passengers to consider ferry or taxi options.

# X. Existent policy solutions and future challenges to increase energy efficiency in mobility of goods in Latin America

## A. Overview of current situation

Latin America and Caribbean countries have witnessed a historic transformation driven by global trade and a significant increase in population, namely in urban areas. The region experienced an increase in the demand for consumer goods which led the private sector to reconfigure business supply chains. For LAC, trade as a percentage of GDP has expanded almost two-fold from 1960 to 2010 when it averaged 42% of national output (WDI, 2011). This has been not only been driven by reduced institutional barriers to trade and regional integration initiatives but also by improvements in transport and communication technologies. In this regard, the role played by the supply chain management, logistics and distribution processes has been crucial in helping reduce costs and time of trade flows across countries (BID, 2011). Over the years, the movements of goods in Latin America countries have shown small variations in the regions of trade according to geographical location of each country.

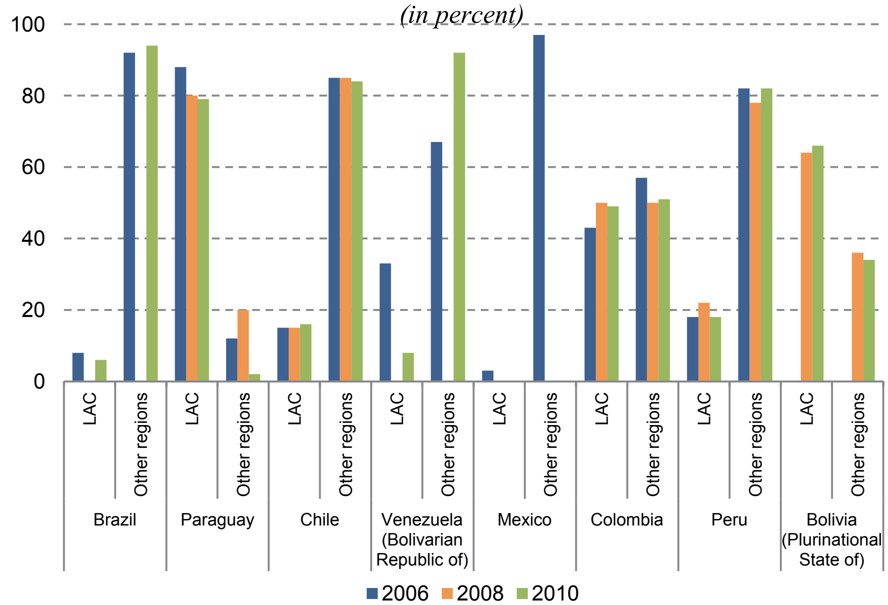
**FIGURE 59**
**IMPORTS FROM LATIN AMERICA COUNTRIES**
*(in percent)*




Source: Author; adapted from: Sánchez et al., 2009, Sánchez et al., 2010, Wilmsmeier and Hesse, 2012.

Brazil, for example, has been suffering a reduction in both, the imports from and exports to LAC countries but increased its share in the imports from and exports to other regions (in 2010, the biggest share in the imports, approximately 39% were from Europe and the exports were to Asia, almost 64%). In terms of products, this translates into the import of mainly manufactures goods from outside LAC and exports of agricultural and raw materials. Imports from the LAC countries are chiefly food items and agricultural and raw materials and in turn manufactured goods and agricultural and raw materials are exported. In 2010 Brazil, followed by Argentina, was the country with the highest volume of imports (with almost 50% of its trades, decreasing since 2006). For Paraguay on the other hand, the LAC region is the most important import partner (although it has been decreasing since 2006 around 2% per year) as well as export partner. Paraguay exports mainly to Uruguay, Argentina and Brazil, namely food items and agricultural and raw materials, not unexpected due to its geographical location. A similar situation can be encountered for Bolivia. According to the data available (2006), Mexico's trades were carried out essentially with other countries outside the LAC region, importing 95% of its products from North America (manufactured goods), and exporting almost 94% to the same destination (manufactured goods and smaller percentage of food items and crude materials, excluding fuel). Its proximity to North America facilitates these movements, but also the North American Free Trade Agreement (NAFTA) established between Canada, United States and Mexico.

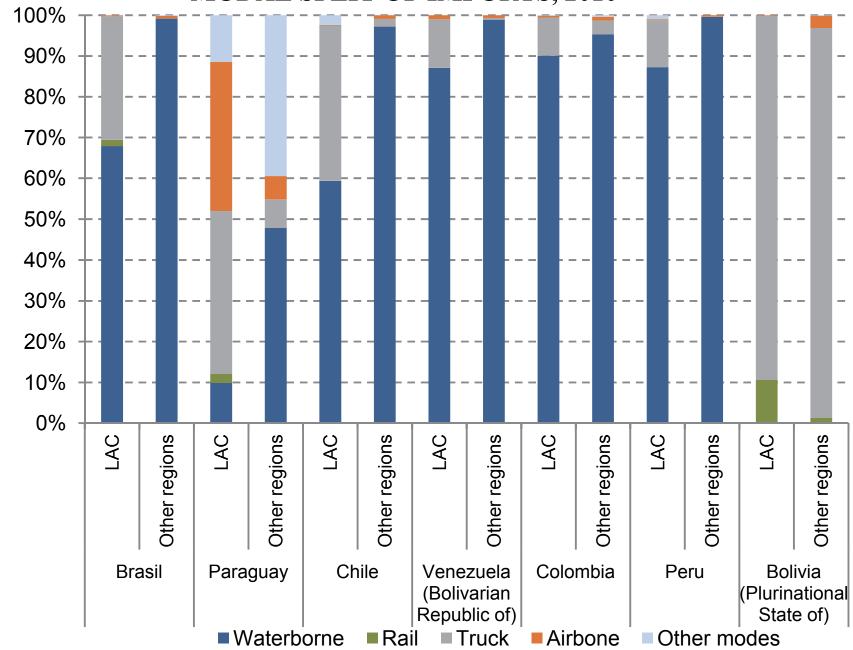
**FIGURE 60**
**EXPORTS TO LATIN AMERICA COUNTRIES**
*(in percent)*




Source: Author; adapted from: Sánchez et al., 2009, Sánchez et al., 2010, Wilmsmeier and Hesse, 2012.

It is interesting to have a look at the modal split for the movements previously presented. With respect to the imports from LAC countries and other regions, it can be seen that waterborne transport is the most relevant mode used. A few exceptions can be seen in Paraguay, where road and air transport are more important as well as in Bolivia where road transport assumes almost all of the movements. This can be easily understood due to Paraguay's and Bolivia's status as land locked countries.

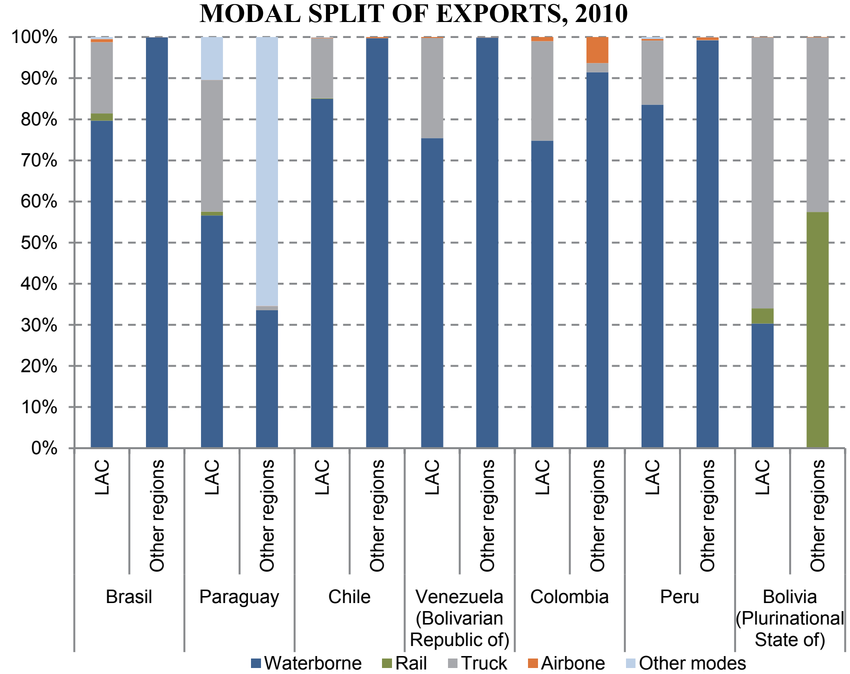
**FIGURE 61**
**MODAL SPLIT OF IMPORTS, 2010**




Source: Author; adapted from: Sánchez et al., 2009, Sánchez et al., 2010, Wilmsmeier and Hesse, 2012.

Exports that have LAC or other regions as a destination as well demonstrate that waterborne transport is the most common mode, especially if exports have other regions in the world as a destination. Between LAC countries, Paraguay and Bolivia make also use of road transport (32% and 66% respectively). For other regions Bolivia also relies on rail with a relevant share of 57%, followed by truck with 42%.

**FIGURE 62**
**MODAL SPLIT OF EXPORTS, 2010**




Source: Author; adapted from: Sánchez et al., 2009, Sánchez et al., 2010, Wilmsmeier and Hesse, 2012.

Considering the context of a globalized work, competitiveness is a key to success and it depends on the efficiency in performing all activities involved in the production, distribution and marketing. Strengthening logistics efficiency in Latin America has not only the potential to increase energy efficiency but could also help to increase the region's competitiveness on the global marketplace. Although much of the movements of goods are made using maritime transport, there is an opportunity for rail for transport within Latin America but diverse challenges in terms of the network would have to be overcome. Multimodal transport, it is normally consolidated in the ports through the following combinations: truck - maritime port and train - maritime port (overseas or ferry boat) (for exportation) and maritime port - train/truck (for import). Combining truck and train is rare due to the lack of infrastructure for cargo transfer, and also the direct competition between these two modes in many countries that makes impossible to take advantage of complementarities (Valencia, 2009).

For example, in Mexico, there is a multimodal potential due to the geographical location of the country and the free commerce treaties. Thus, advances such as the 2004 National Agreement on Multimodal Transport (with 22 participants, public and private) to work in the logistic chain integration are going into the right direction. Projections indicate multimodal transport for 2030 (34.000 million tonne-kilometres) could save 71% in fuel consumption, while emissions of pollutants would also be significantly reduced, pointing out particularly the benefits of rail in freight movements (Rascón Chávez, 2010).

## B. Regulatory framework and its impact in energy efficiency

Latin America is a diverse region with differently structured economies in each case with the logical consequence that guidelines and strategies on energy and energy efficiency are likewise diverse. As outlined above, there are regulatory attempts in some of the countries but some issues would be better dealt with by a regional, systemic approach.

Brazil has implemented in 2008 the National Climate Change Plan (NCCP) that largely focuses on reducing greenhouse gas emissions from deforestation. The plan also contains provisions regarding energy efficiency and renewable energy. Overall, it seeks to increase energy efficiency across various sectors of the economy in line with best practice and to maintain the high renewable energy mix in Brazil's transport and electricity sectors. The National Logistics Plan for Transports, that is part in the NCCP has also objectives of improving the cargo transport matrix in the country, promoting the use of rail and waterborne modes, considered to be more efficient in larger distances and total weight of cargo. Prior to that, in 1991, CONPET - The National Programme for Energy Efficient Use of Petroleum and Natural Gas Derivatives - has defined improvement of energy efficiency in the use of petroleum and natural gas derivatives as a target. The program had specific actions outlined for the transport sector, with education programs and evaluation of fleets, which can be certified with a Green Stamp recognized by the State and other municipalities. Following this plan, in October 2011 the National Energy Efficiency Plan was approved with actions that will follow the CONPET programme and also contribute to the renewal of the fleet of cargo transport companies for more efficient vehicles and improvement in the quality of fuels, which will globally also contribute to achieve more efficiency (CONPET, 2013).

In Mexico, a country that works for more than 25 years on energy efficiency measures namely in the electric sector, the Energy Sustainability Fund (Fondo de Sustentabilidad Energética, see FSE, 2013) was developed that is in operation since 2008, its objective being to enhance research, development and deployment (adoption, innovation, assimilation and development) in 4 main areas that include energy efficiency, renewable energy, clean technology use and diversification of primary sources of energy. The National Strategy for Energy Transition and the Sustainable Use of Energy defined in 2009 defines 5 objectives that overall intend to promote the definition of measures for energy efficiency with the diversification of primary energy sources and information for the population on best appliances/vehicles related to energy consumption. It also provides for the development of various planning tools, including the National Program for Sustainable Energy (PRONASE) that identifies seven areas of opportunity with transport included. Each area includes several lines of action; in the case of transport sector three main actions were defined: efficiency standards for new heavy duty vehicles, mechanical and/or environmental standards that would authorize the circulation of imported used vehicles and the promotion of best practices when using the vehicle.

Chile has released its National Energy strategy (2013-2030) with a new plan, called “Energy for the Future” (Energy for the future, 2012), that outlines six priority areas the administration will focus on to make Chile’s electricity sector cleaner, more secure and more cost-effective in the long term. It defines the Energy Efficiency Action Plan, which intended to be a guide for the public and private sectors to realize the potential of energy efficiency identified for this decade and the next. The Action Plan defined as the goal a 12% decrease in the projected energy demand for 2020 and included for the transport sector a few actions on the compilation and systematization of data on energy use, in order to encourage greater efficiency in passenger transport and freight. A vehicle labelling system and the setting of minimum energy efficiency standards for vehicles are also put in place. In 2009, policies relating to energy efficiency on freight transport have focused on three aspects: incentives to promote the renewal of the freight transport fleet (through subsidies and soft credit with the aim of replacing 500 trucks in 2009-2010); eco-driving training (with the aim of training 1 000 drivers by the end of 2009); and the provision of technical assistance in terms of maintenance and fleet management for urban and inter-urban freight transport companies. Chile expects a reduction between 5% and 10% in the fuel consumption of those participating in eco-driving (IEA, 2009). AchEE, the “Agencia Chilena de Eficiencia Energética” (ACHEE, 2013), was created with the mission to promote, strengthen and consolidate efficient use of energy and communicating it to the relevant actors at national and international level. AchEE has defined several programs within different areas of action, including the transport sector to promote the incorporation of energy efficient management tools in the freight transport, nationwide in all sectors and regions.

Although in Paraguay hydropower is the main source of national energy, the demand for fossil fuels is still relevant with 14.5% of total merchandise imports. A few isolated measures have been implemented in order to achieve better energy efficiency, in this case through the use of alternative fuels. A mixture of alcohol in gasoline started in the '80s and has taken up in the '90s, being currently a mixture of 24% (Cazal, 2010). Also, a blend of biodiesel has been produced, although the mixture has not reached the minimum of 1%. In 2008, the Government passed the Decree 12240 reducing the VAT on biodiesel and ethanol to 2%. In 2011, the National Energy Efficiency Committee was created consisting of the national energy sector institutions with the objective of preparing and implementing the National Plan for the efficient use of energy in the Paraguay Republic. This plan defines steps and actions through the Plan de Uso Eficiente de la Energía with the implementation of communications campaigns for the population, mostly dedicated to the rational use of electricity. Nevertheless, no measures related to the transport sector were found (only for public transport).

In Panama, the Law for the rational and efficient use of energy (Uso Racional e y Eficiente de la Energía, see UREE, 2013) approved in October 2012 but not enacted until recently, started the trajectory on energy efficiency and is expected to improve efficiency by 10%, results which can only be seen later. This new law has amongst others the objectives to promote energy conservation and efficiency, as well as to develop new technologies. Nevertheless, it contains no specific reference to the transport sector.

## C. Future challenges towards energy efficiency

In terms of national strategies and policies it is noted that several efforts have been made over the last 9 to 10 years in the Latin America region, although the transport sector was only blessed with minor measures and few incentives namely at the transport companies level (whose potential contribution is significant). It would be important to define specific targets for this sector and develop the mechanisms to monitor them as well as evaluating its results in order to analyse the sustainability and feasibility. The existence per se of laws and regulations does not guarantee success. It is essential to implement, monitor and enforce regulation. In this sense, indicator systems should be devised for the transport sector with a coherent set of success criteria to inform future energy strategies. At a supra-national level (regional level), there is a strategic importance for the harmonization and integration of different regulations as some issues of energy efficiency cannot be dealt with by only one country.

Some challenges in freight mobility are (Barbero, 2010):

- The region's transport network presents structural deficiencies, related not only to its reduced spatial coverage but also its physical state. Over the years, the increase in traffic growth due to business activity, trade and motorization rate here had its consequences. The expansion, rehabilitation, modernization and maintenance, as well as it capacity increase requires considerable financial and management efforts. It's important to analyse carefully the road network developments since, at the end, a pure expansion of this mode may result in unintended effects
- The trucking industry is inefficient in many of its sectors has also implications in other links of the logistic chain. Road freight is the most important mode of domestic transport in the region and improvements in this area could generate spill over effects and economies of scale;
- 80% of all international trades pass through the ports. But although many of them have worked on their efficiency performance, organizational problems persist, namely in the coordination among actors and in their relationship to the hinterland. The potential impact of improvements is important, not only in costs and operational performance, but also in terms of energy efficiency;
- Rail transport has in many countries not taken part in modernization and is mostly specialized in the transport of raw materials; it has big potential as an energy efficient transport model. It may have significant impact in bulk logistics but may also play a role in main container transport corridors connected to domestic and international multimodal transport;
- Considering the overall road, rail, and port conditions and capacities, the sheer geographical expansion of Latin America, geological obstacles and current fuel price levels, air transport may continue to look increasingly attractive to many governments. This mode, however, represents higher energy inefficiency and, thus, should be filled by other transport modes, also considering that some Latin American cities are many hundreds of meters above sea level, meaning that planes use much more fuel to take off and land.

The potential in this region is significant but overall there's a need in a more concerted action, so that Latin American maritime, air and road transport orators can increase their share in international transport corridors. Regional integration is necessary and for that combined strategies should be developed. As a first step, it is long overdue for countries to develop and implement national policies taking into account competitiveness and productivity of goods and services. The freight transport modal split projections for 2050 developed by the OECD predict an increase in road transport and a decrease in rail transport use, with an average growth rate of 2.5% in energy use between 2008 and 2035 for the region. In this sense, it's clear that if appropriate measures are not taken, the current situation will continuously degrade with consequences that have an impact on citizens and its quality of life.

## D. Vision and strategy for urban transport in Latin America

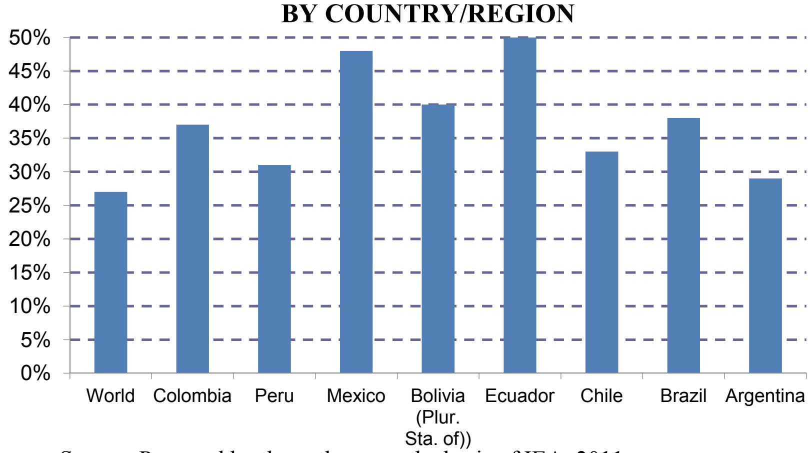
People's travel needs and the movement in goods in dynamic, modern and increasingly globalized societies are a constant across the globe, and generate challenges and often externalities within society. Several variables or factors influence the sorts of energy used for that travel, the combination of means of passenger and freight transport, the technologies used, the levels of urban motorization and the transport culture, as well, to an extent, as the demand for energy for transport. In a sense, energy demand in the transport sector can also be an indicator of regional and urban competitiveness.

The transport sector's share in the energy matrix in the various Latin American countries is highly variable, accounting for almost 50% in Mexico and Ecuador, for example. By contrast, in Chile and Argentina, transport takes a smaller share of energy use, closer to the world average. Colombia is very close to the average for this indicator, although its transport sector is becoming less energy-intensive.

The global average, as well as the transport sector's share in the energy matrix in European and OECD countries, is similar to that estimated for countries such as Argentina and Chile. These figures may be associated with policies for efficient energy use in public transport, mass use of electric means of freight and passenger transport (trains, trams, trolleybuses), and heavier use of non-motorized transport such as bicycles, or other efficient transport initiatives such as the use of hybrid and electric vehicles, scrapping policies, best practices (such as carpooling), sound traffic management and good driving practices.

A large share of bicycling and walking in urban transport schemes is desirable in energy, environmental, social and public health terms. Cities where people make intensive use of these options offer healthy, equitable, integrated and competitive environments.

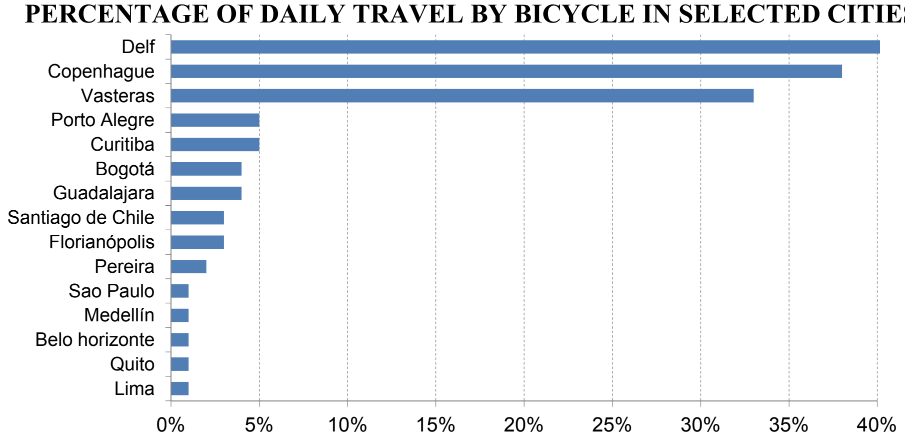
**FIGURE 63**
**PERCENTAGE SHARE OF THE TRANSPORT SECTOR IN PRIMARY ENERGY DEMAND BY COUNTRY/REGION**




Source: Prepared by the authors, on the basis of IEA, 2011.

In Medellin travel on foot represents a small share of total transport and bicycling only a marginal one. Although this is not particularly encouraging, it is an unfortunate fact repeated in cities across Latin America. As the figure below shows, the share of bicycling in urban transport is no more than 5% in some cities, far lower than in European reference cities.

**FIGURE 64**
**PERCENTAGE OF DAILY TRAVEL BY BICYCLE IN SELECTED CITIES**




Source: Prepared by the authors, estimated figures based on reports by transport departments in the cities of Bogota, Medellin, Santiago, Lima and Guadalajara. Others adapted from Ballesteros (2010) and information on Brazilian cities, OMU-CAF, 2010.

Latin American cities such as Medellin may differ from cities in European and OECD countries in terms of urban development, culture, society and economy, but people's travel needs and benefits and opportunities for using bicycles are similar in Europe and Latin America. The economic limitations faced by the Latin American population could even be seen as an additional incentive for using such an economic and accessible means of transport as a bicycle.

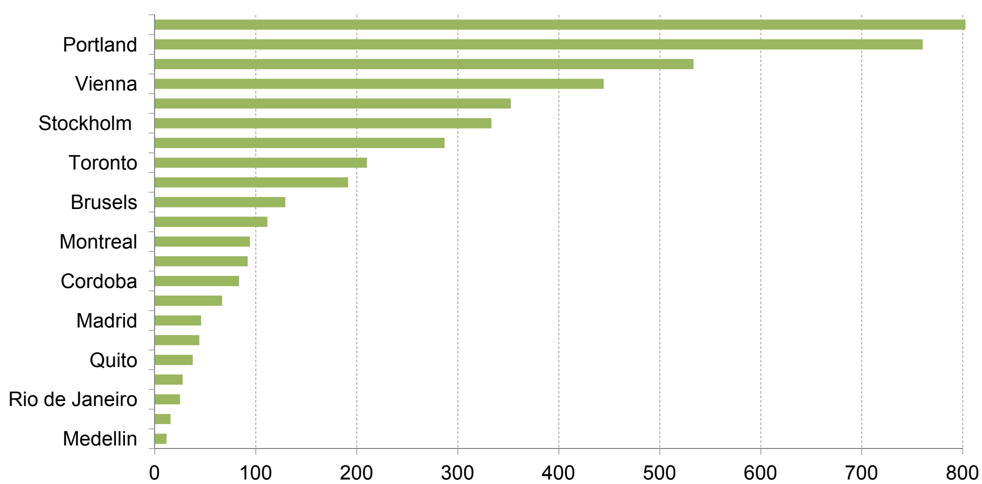
However, in the twentieth century, many Latin American cities defined their urban transport structure in terms of motorized options and have limited infrastructure and education for bicycle use. Mental models have formed that stigmatize those who cycle on a daily basis and cities rarely offer even the minimum safety conditions for travel by bicycle, and planning does not include cycling among the range of transport options. Other factors also bar alternative means of transport from gaining ground and becoming positioned in the region's urban transport schemes: infrastructure policies built around the concept of transport rather than mobility, the lack of integrated, strategic and pro-sustainability planning, short-term planning swayed by external influences, and the economic growth potential surrounding the private car.

In this regard, Bogota stands out in Colombia and in Latin America as a city that has adopted significant policies and measures to advocate cycling as a daily means of transport; by 2012 it had the longest distance of dedicated cycle paths (350 km), electric bicycles were beginning to be seen as options among certain social groups in the city, the bicycle was integrated with the BRT system and was gaining a moderate share of the urban transport scheme (4%), outperforming mopeds and matching taxi services. These indicators are the result of over a decade of promoting travel by bicycle.

However, indicators such as kilometres of cycle paths per million inhabitants and the length of bicycle routes per square kilometre of city area are still lower than in the European countries used as a reference for urban mobility. In terms of urban area coverage, Bogota's figure is positive, not so those of other Latin American cities. Although dedicated infrastructure for cyclists is not the only strategy for making the bicycle a widely used means of transport, it is one that could be implemented to great effect in the region's cities, inasmuch as urban road infrastructure and driver behaviour pose risks to bicycle users and represent barriers to bicycle use.

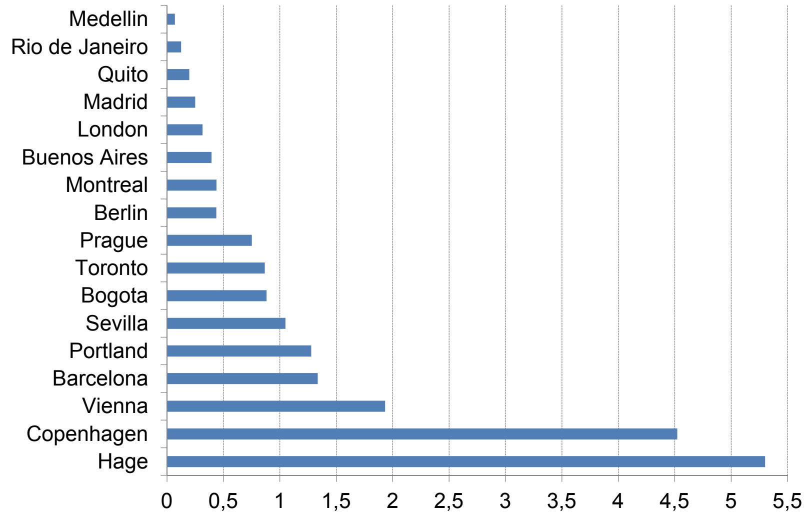
Medellin is visibly lagging in terms of bicycle use management and the share of cycling in the transport matrix, and indeed has particular challenges in this regard owing to its mountainous terrain. Nevertheless, the city is spearheading the public bicycle project in Colombia, offers transport for bicycles in the metro rail system, has recently set out a policy for cycle mobility and is planning measures to promote bicycle use.

**FIGURE 65**
**LENGTH OF CYCLE ROUTES PER MILLION INHABITANTS**
*(Km/million inhabitants)*




Source: Prepared by the authors, on the basis of Velandia, 2013.

**FIGURE 66**
**KILOMETRES OF CYCLE ROUTES PER KM2 OF URBAN AREA**




Source: Prepared by the authors, on the basis of Velandia, 2013.

Regarding the share of other means of transport in the urban transport matrix, the table shows that Medellin has a notable share of collective and mass transport, which is positive in terms of energy use, travel times, pollutant emissions and transport-related costs. Even so, the share of collective and mass transport is smaller than in other reference cities.

**TABLE 86**
**MODAL DISTRIBUTION IN LATIN AMERICAN CITIES**

| City | Private transport/ individual/others | Walking | Public and massive transport |
|---|---|---|---|
| Buenos Aires | 51% | 9% | 40% |
| Medellin | 46% | 26% | 28% |
| Belo Horizonte | 27% | 35% | 38% |
| Curitiba | 37% | 35% | 28% |
| Porto Alegre | 31% | 27% | 42% |
| Sao Paulo | 34% | 33% | 33% |
| Santiago de Chile | 26% | 35% | 39% |
| San Jose | 28% | 24% | 48% |
| Mexico | 24% | 24% | 52% |
| Guadalajara | 32% | 37% | 31% |
| Lima | 22% | 25% | 53% |
| Bogota | 28% | 15% | 57% |
| Caracas | 27% | 19% | 54% |

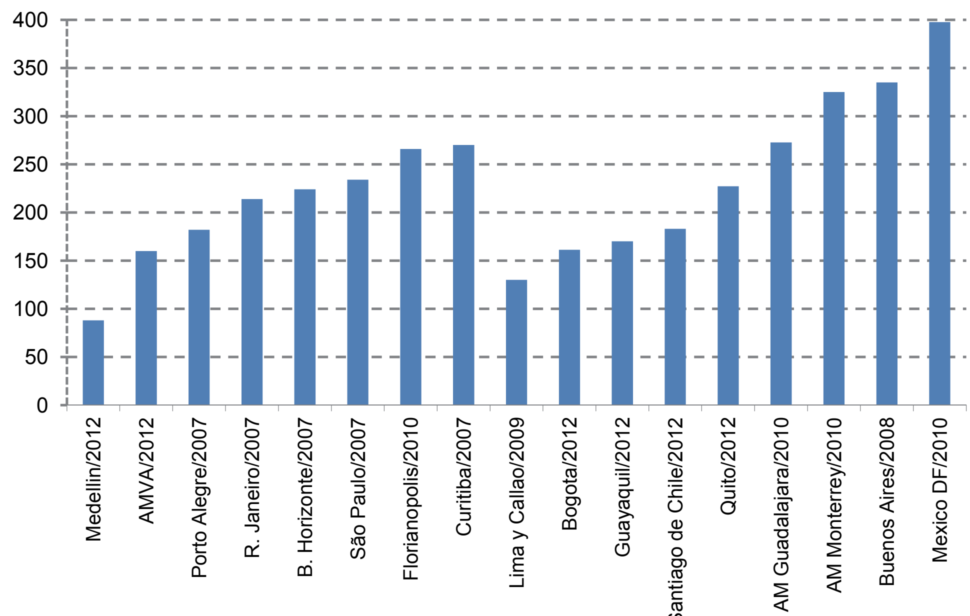
Source: Prepared by the authors, on the basis of OMU-CAF, 2010.

The use of electric transport technologies (metro system and aerial cables), the use of natural gas in city buses, oversight of the passenger fleet, regional integration of the metro system and the regulation of the mass transit segment of the fleet are some factors that favour transport energy management in the Aburra Valley.

Regarding the use of private transport options, the car and the motorcycle account for a large share of the urban transport scheme. Measured per thousand inhabitants in the metropolitan area, motorcycles have a particularly large share compared with other cities not only city in Colombia, but in Latin America generally. The motorization rate (number of automobiles per thousand inhabitants) is low for the city and moderate for the metropolitan area. Importantly, the municipalities bordering Medellin, such as Envigado and Itaguí, account for a large share of the higher-income population within the metropolitan region, which increases car ownership in these areas.

Motorization rates in the Latin American cities mentioned are low for the regions of Lima-Callao, Bogota, AMVA and Guayaquil, and higher in Mexico's cities and regions, in Buenos Aires, Curitiba and Florianópolis. The highest motorization rates in Latin America are still lower than those in North American cities, which shows the importance of measures to discourage car purchase and generate rational use of the automobile. In this regard, if the current congestion and pollution problems and collateral costs of urban transport are already seen as considerable in Latin American cities, the problems could get worse given the increase in the private vehicle fleet during the past few years.

**FIGURE 67**
**AUTOMOBILE OWNERSHIP IN LATIN AMERICAN CITIES**
*(Automobiles per thousand inhabitants)*




Source: Prepared by the authors, on the basis of official figures from the cities of Bogota, Medellin, Santiago Guayaquil, Lima, Buenos Aires and Quito. Mexican cities, ITDP, 2010; Brazilian cities, OMU-CAF, 2010.

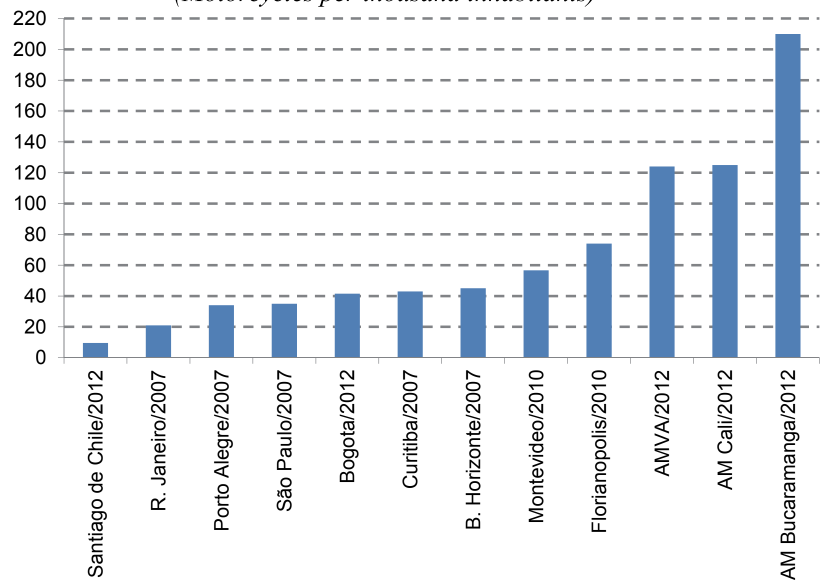
As a result of use of vehicular natural gas (7% of the AMVA fleet), restrictions on daily circulation of automobiles and the short daily trips made using cars, the existence of other urban transport services (school and business routes) and the notable use of motorcycles, energy demand in the private transport segment is not particularly high. The average daily distance a car is driven in the metropolitan area is estimated at less than 15 km (Londoño and others, 2011), and a light car in Envigado (a municipality with high car ownership), 12 km per day.

Another factor that affects energy demand in the private transport sector is vehicle age. Although little information is available at the local level, according to the Ministry of Transport (2012), 40% of the national vehicle fleet (4.02 million automobiles, including SUVs and vans) has been in service for no more than 10 years. This is the result of rises in the fleet of cars manufactured in the last five years, whose most noticeable effects are severe congestion problems in the country's main cities.

However, it is estimated that 30% of the fleet has been in service for over 20 years, which is a negative factor in terms of energy efficiency, safety and emissions.

In relation to the ratio of motorcycle ownership per thousand inhabitants, the Metropolitan Area of Bucaramanga stands out among the Latin American cities mentioned. Colombia's cities and regions have high rates of motorcycle ownership per thousand inhabitants compared to the Latin American average, while Santiago and Rio de Janeiro report lower figures.

**FIGURE 68**
**MOTORCYCLE OWNERSHIP IN LATIN AMERICAN CITIES**
*(Motorcycles per thousand inhabitants)*




Source: Prepared by the authors, on the basis of Ministry of Transport of Colombia, RUNT 2012. Official institutions in Santiago and Montevideo. Brazilian cities, OMU-CAF, 2010.

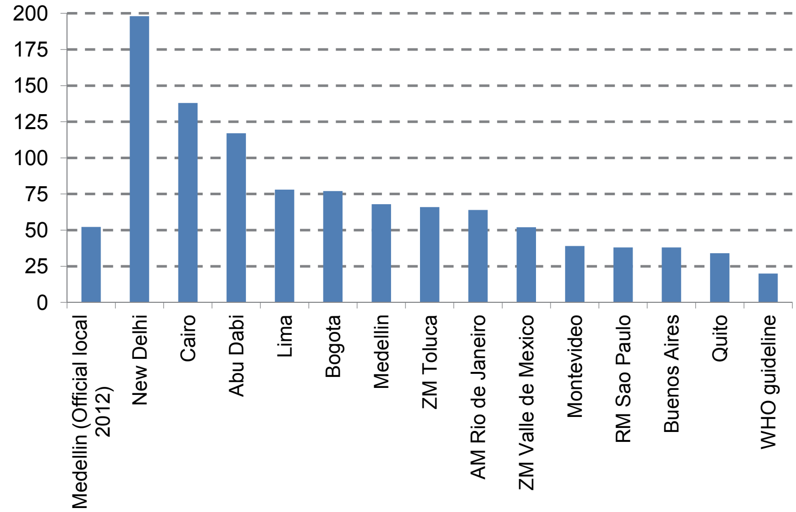
Among motorized private transport options, the motorcycle offers the greatest energy efficiency. A 150 cc gasoline-fuelled four-stroke motorcycle can yield close to 150 km to the gallon, contrasting with an automobile which gives around 35 km to the gallon of gasoline. Considering that on average a car transports 1.5 persons, and is therefore inefficient in terms of energy, use of urban space and pollutant emissions, the motorcycle offers better levels of service, at a lower operating cost for the user and lower per capita energy costs for the city. However, given that over half of motorcyclists today are former users of the collective and mass transit systems, the use of the motorcycle represents a loss of energy efficiency, especially when the motorcycle used to be a metro user.

As a result of the combination of private motorization levels, fuel type and quality, traffic conditions, type of vehicles and the urban context (terrain and hydroclimatic), AMVA has recorded an average annual level of PM10 concentration (ɥg/m3) above the 20 ɥg/m3 limit recommended by the World Health Organization (WHO).

With respect to other Colombian cities, Medellin has average annual level of PM10 concentration (52.2 ɥg/m3) 9.7% higher than Bogota, and 37.8% higher than Bucaramanga. Mexico City has a higher concentration 14.4% higher than Medellin, but just 0.4% higher than Santiago (CGM, 2013).

In 2011, WHO published the report "Urban outdoor air pollution database", which reported an annual average concentration of particulate matter of less than 10 ɥg/m3 in 1,099 cities in the world. Medellin ranked in position 130, with an annual average concentration of 68 ug/m³ in 2007, exceeded by Latin American cities such as Bogota with 77 ug/m³ and Lima with 78 ug/m³ (CGM, 2013). All the cities of the region reported on here are over the WHO recommended limit.

**FIGURE 69**
**CONCENTRATION OF PARTICULATE MATTER UP TO 10 µM (PM10) COMPARED TO REFERENCE CONDITIONS, WHO CLASSIFICATION, SELECTED CITIES**
*(In µm/m3)*




Source: Prepared by the authors, on the basis of CGM, 2013.

In the past five years, however, PM10 concentrations have tended to fall and measurements since 2010 yield figures below the national standard. This positive trend reflects a number of initiatives such as the decrease in the sulphur content of diesel (today less than 40 ppm), the use of clean transport technologies in electric cars and motorcycles, use of natural gas in the urban fleet, urban traffic management and the installation of filters to reduce emissions in public transport vehicles.

For the past two decades, Medellin has managed a process of change on several fronts: social, urban, economic and cultural. This has allowed the city to position itself not only nationally, but also globally. After years of study, investment in infrastructure and technology, alternative urban designs, and civic and policy advocacy, what is in evidence today is not a quick fix for local transport-related issues, but efforts and results that show that sustainable city planning is possible and that urban transport offers multiple opportunities in this regard.

Velandia (2012) argues that there is no “perfect formula” for guaranteeing urban mobility in the framework of strategic planning and sustainable development, but that the path towards that aim needs to be supported by multiple measures in different sectors, and with different beneficiaries, within an interdisciplinary process that engages the public. Given the diversity of concepts and interests, the complex social nature of human beings, resource limitations and the demand for action in the planning process, urban mobility needs priorities to be set within a long-term planning scheme. It needs debate and consensus-building between actors, coordination of measures, continuous oversight of impacts, and capability for innovation and adaptation to new demands over time. In this demanding context, two conditions must be satisfied: political will and the will of society to evolve and progress.

Bearing in mind the international experiences and the underlying principles of building sustainable cities, Medellin has put together a proposal for improving urban conditions as described below. This proposal could be considered in relation to a vision and strategy or Latin America, on the basis of the lessons learns in terms of replicability and feasibility:

**From the perspective of planning.** The city has taken measures to plan its own urban growth and its connection with the other municipalities of AMVA, as well as integrated infrastructure planning. Particularly important measures were the redensification of the city of Medellin (20,450 inhabitants per km2 by 2012), the development of mixed-use areas, start in recent years of planning around transport and the application of smart urban development concepts.

The concept of integrated mass transit was built up as a support for movement around the city and connectivity with neighbouring municipalities, as well as the promotion of school and business transport, the design of new plans for promoting bicycle use and plans to fully regularize collective transport under a single urban public transport scheme connected with rail options (metro and tram), BRT and aerial cables.

Lastly, urban, landscape, social, economic and transport aspects have come together to generate greater benefits from transport projects, as in the case of the cable cars connected with the metro system in formerly marginalized areas with accessibility problems, economic constraints and difficult social conditions. The associated projects include libraries, parks, safety, public areas and improvement of urban conditions.

**From the perspective of regulation.** The city has designed and implemented different tools to promote the rational use of automobiles and traffic management. The building of infrastructure that reduces the space available for automobile use, favouring instead public areas and mass transit schemes, the launch of a traffic calming plan and pedestrianization. Special rules have also been established for circulation of cars and parking in some areas and/or corridors of the city, and new measures are planned to establish possible zero emissions areas and high-occupancy vehicle lanes. Lastly, rules are in place for management of freight to and from the city, and for the distribution of goods and merchandise in the urban and metropolitan area.

**From the economic perspective.** The city has imposed levies to make car drivers pay for the costs generated by their use of the road and the damage caused to society. These measures include taxes on liquid fossil fuels, taxes on property and areas of paid parking on public roads. By contrast, benefits have been created to increase the use of less polluting automobiles (electric powered and natural gas fuelled), regularize the operation of collective transport and scrap old buses.

**From the perspective of education.** The city has notable plans of academic and cultural education. This type of measure seeks to change behaviour through programmes such as Cultura Metro. The city also runs awareness-raising schemes and programmes to inform the public of mobility-related measures, and implements policies on public participation, technological resources such as the Internet and user information systems to manage mobility.

**From the perspective of technological resources.** Technology is a powerful tool for improving service standards and lowering the collateral costs of transport. The city stands out at the national and regional level for its continuous technological development in mass transport, and today advises internationally on sustainable systems with high social integration value and technological impact. The participation of universities and research centres in transport planning and operational optimization is to be commended. Academia has been involved in energy efficiency plans in the metro system, in optimizing fleet operation, in researching electric vehicles and in implementing pilot schemes for public bicycles and buses with overhead cables.

These are some of the initiatives Medellin has taken to become more competitive through urban transport management. Many of these have not been easy to implement and have needed decisive leadership to build a modern and efficient transport system, no easy objective in a situation with limited resources and day-to-day problems that cannot be postponed.

The city and its surrounding municipalities aligned with each other to generate synergies, with positive outcomes for the metropolitan area, and have made the best possible use of backing from the national government. As an objective in itself, mobility has been integrated with other aims, such as reducing greenhouse gas emissions, improving air quality, reducing accident rates, increasing energy efficiency in transport and boosting economic development. Today the public approval ratings earned by urban transport plans and the other indicators mentioned in this document testify to the success of planning in the city of Medellin and AMVA.

# XI. Conclusions, recommendations and outlook

## A. The challenges in decoupling mobility and energy consumption

### 1. Decoupling Mobility and Energy

"The widely held belief that you need to cut mobility to fight climate change is simply not true. Competitive transport systems are vital (...) to compete in the world, for economic growth, job creation, and for people's everyday quality life. Curbing mobility is not an option; neither is business as usual. We can break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility. It can be win-win". Vice-President of the European Commission, Siim Kaan (European Commission), 2006.

The citation above sets the objective of transport policy in a new era of „smart mobility", where infrastructure, transport modes, people and goods are increasingly interconnected towards increased transport mobility and less energy consumption (European Commission, 2013).

Mobility is the cornerstone of economic interactions and regional integration determining the dynamic of everyday life around the world. International trade increased substantially in the last decades as emerging countries grew economically and opened up. Increased goods movements to and from international markets resulted in increased reliance on freight transport, as goods are transported to and from the region's sea – and airports with trucks, ships, planes and trains. With a further trade expansion, current transport systems are supposed to operate on full capacities resulting in the extensive use and higher maintenance frequencies of existing transport modes as well as higher greenhouse gas emissions on national, regional and global levels. Hence, transport systems will have to be improved and adapted to increased trade flows as well as to future challenges such as technological change, population growth, increasing energy prices and climate change. Policy makers, environmentalists, and representatives from the private sector need to understand the future challenges of freight transport to improve mobility while decreasing energy consumption in the transport sector.

An objective for transport policy makers should be to increase potential mobility and decrease realized mobility. Thus, providing individuals and industries with a wider range of transport possibilities and letting them chose their optimal one subject to cost, time and emissions.

## 2. Current Trends

Traditional transport planning, transport market dynamics and policy-making in favor of carbon-intensive transport and industries often inhibit the provision and use of sustainable transport modes.

Firstly, transport policies are primarily focused on road transport. This focus emerged mainly due to relatively low sunk costs of road network expansions and its rapid construction. Furthermore, road transport meets demands for passenger and freight mobility at the same time. Hence, policies orientated towards road transport respond faster to infrastructure needs of economic growth. However, the more transport policies are limited to road transport, so called policy lock-ins emerge. These lock-ins are characterized by as well as awarding long-term concessions and contracts to transport providers.

Greater mobility and more efficient energy use in the transport sector is currently inhibited by the increase in geographic distances transport has to overcome as well as an increase of the desire for speed in freight and passenger transport. The increase of distances of freight and passenger transport is associated with the expansion and opening up of new markets as well as due to the expansion of cities, the associated urban decentralization and the emergence of the middle class in the emerging economies. The increase of desire for speed of transport is associated with the spread of just-in-time strategies, the increase in exports of fresh food products from the region and the associated minimization of time and the intensification of competition among businesses on a global scale. These trends are mirrored by the increase of the number of faster ships, long-haul trucks and the use of aircrafts and an increase in energy consumption.

Thirdly, sectors related to carbon-intensive transport are highly favored by the heavy consumer fuel subsidies as well as by the ineffectiveness of international agreements on phasing out fossil fuel subsidies. Hence, per unit prices for carbon-intensive transport modes are artificially undercutting prices for low-carbon intensive modes and inhibiting the transition to sustainable mobility. In terms of the sustainable development towards low-carbon economies, carefully designed policies towards phasing out fossil fuel subsidies are essential and would free up government expenditures, which could be redirected towards policy measures orientated towards sustainable development.

Mobility can be enhanced by reducing unnecessary trips and distance, the promotion of alternative transport modes and the increase of energy efficiency due to technological innovation. Freight transport trips, for instance, can be reduced by more efficient utilization of containers or carriers via sharing them through central planning and outsourcing of logistic activities. Integrating low energy intensive transport modes as inland waterways in existing supply and logistic chains energy use can be reduced. Transport policies can intervene and guide this integration by building up and using alternative transport modes to roads allowing for direct connections to ports as well as by taking active part in the positioning of logistic centers and dry – and seaports, thus reducing distances (Banister, 2008).

Furthermore, Banister (2008) contrasts the conventional approach of transport planning to the sustainable mobility approach and proposes the following shift in transport policy making:

In a more practical manner, the European Commission (2011) issued the Transport 2050 Initiative for reaching more mobility and less energy consumption in the European Union. The initiative has the target of banning conventionally fuelled cars in cities via using cleaner cars and cleaner fuels. To cut carbon emissions even further low carbon fuels should be used for up to 40% in aviation while emissions from the shipping industry should be reduced by 40% as well. Furthermore, 50% of medium distance intercity passenger and freight transport should shift away from road towards rail and waterborne transport. Finally, all emissions cuts should lead to an aggregate 60% reduction in greenhouse gas emissions from the transport sector by 2050.

**TABLE 87**
**CONVENTIONAL APPROACH OF TRANSPORT PLANNING VERSUS THE APPROACH TO SUSTAINABLE MOBILITY**

| Conventional approach – transport planning and engineering | Alternative approach – sustainable mobility |
|---|---|
| Physical dimension | Social dimension |
| Mobility | Accessibility |
| Traffic Focus, particularly on cars | People Focus, either in (or on) a vehicle or by foot |
| Large in scale | Local in scale |
| Street as road | Street as space |
| Motorized transport | All modes of transport |
| Forecasting traffic | Visioning cities/ regions |
| Modeling approaches | Scenario development and modeling |
| Economic evaluation | Multicriteria analysis to take account of environmental and social concerns |
| Travel as derived demand | Travel as valued activity |
| Demand based | Management based |
| Speeding up traffic | Slowing down traffic |
| Travel time minimization | Reasonable travel times and travel time reliability |
| Segregation of people and traffic | Integration of people and traffic |

Source: Author, based on Banister (2008).

## 3. Challenges ahead

A transformation of transport policies towards enhanced sustainable mobility is essential for the future of the Latin American and Caribbean region. Most importantly, transport planning must involve the stakeholders from targeted industries and the energy sector to create an understanding for the importance of a transformation of the transport system as well as to create motivation for behavioral change towards avoiding unnecessary trips and distances. Public acceptability is essential to the successful implementation for a change in public transport planning.

To achieve the necessary new balance between transport modes and sustainable mobility as discussed above the following policies are recommended in general: 1) paving out fossil fuel subsidies, 2) incentivizing modal shift, while improving provision of low-carbon modes, 3) reducing unproductive mobility and distances, 4) reducing externalities of transport infrastructure.

To prepare a transformation of transport policies making the following steps should be taken into account:

Firstly, costs, time-of-delivery, energy use, and emissions from intermodal transport as well as the trade-off between these factors have to be quantified

Secondly, optimal transport routes have to be defined within the transport system of the region's countries based either on the minimization of costs, time, energy or emissions or their combinations.

Thirdly, an evaluation of the adaptability of the infrastructure network according to current or future energetic, environmental and economic challenges has to be undertaken. Adaptability will allow operators to respond to changes in the utilization of infrastructure capacities of each transport mode via innovation and technological progress in logistics and distribution services, operations and maintenance.

Fourthly, transport policies should be orientated towards expansion and modernization of railway systems and waterways as well as their connection with other transport modes, thus increasing connections between seaports and the hinterland.

Finally, modal shift towards low-energy modes have to be promoted especially on long-distance and congested corridors, when appropriate. Moreover, unproductive mobility and distances have to be avoided via optimized integrated logistics and distributional planning and management, thus securing efficient use of modes and their combinations as well as transport units along the entire supply chain. Improvements making each mode towards greater environmental friendlier, safer and more energy efficient have to be undertaken. Transport policies should be market-oriented, while considering social aspects of the region, thus increasing regional integration and social inclusion. However, caution has to be taken, since the IPCC Working Group III suggested the positive environmental effect of a simple shift away from roads towards railways and shipping might be offset by the negative effect of a growing transport sector due to increasing international trade and economic growth (IPCC, 2007). Hence, an integrated view on energy and transport infrastructure is necessary. Only, if energy consumed by a sustainable transport mode comes from a renewable energy generation source, this transport mode can be fully regarded as being sustainable. In this way a policy shift towards decoupling (fossil fuel) energy from transport growth can be satisfactory overall.

## B. Towards a joined agenda in energy efficiency and mobility

The importance of mobility for energy consumption around the world and particularly for Latin America and the Caribbean cannot be underestimated. Given historic and current developments, potential gains from increased energy efficiency in transport are significant. The Sustainable Energy For All (SE4ALL) initiative by the United Nations provides an opportunity for governments in the region to study more in depth the current status quo of energy efficiency in the transport sector, to research best available options and to develop targeted measures for improvements.

In order to develop and implement complementary and integrated policies, ECLAC proposes a comprehensive view of energy efficiency in mobility based on the so called ASI-approach.

- *A: Avoid trips and increase the system's efficiency;*
- *S: Shift mobility to more efficient modes to increase travel efficiency;*
- *I: Improve fuel efficiency to augment vehicle efficiency.*

Only by thinking mobility systemically, sustainable energy efficient solutions can be found. Policy design needs to be integrated between the transport and the energy specialized entities in order to be sustainable and capture non-energy-related mobility considerations in policy making.

Understanding of and collaboration with the markets and market development are essential in order to design policies so that they are appropriate, targeted and sustainable.

Institutional capacity is an important pre-condition, but also a weak element in the majority of LAC countries. Public administrations play a key role in shaping transport markets in general and in particular the framework for improving energy efficiency, notably in the enforcement of existing regulation.

Setting fuel taxes appropriately, abolishment of fuel subsidies, prioritization of funds and R&D incentives encourage markets that favor energy efficient solutions. The case of fuel subsidies deserves particular attention among the tools for improving energy efficiency. But fuel subsidies often are meant to serve a variety of purposes: From climate change mitigation to promotion of local energy sources, industrial policies and the attainment of social issues (e.g. keeping low inflation rates). Also, fossil-fuel subsidies (gasoline and diesel) and fuel subsidies for non-fossil fuels (e.g. bio-fuels subsidies, LNG subsidies, etc) must be treated separately, due to the different impacts and implications in terms of energy policy. Fossil fuel subsidies are usually impeding advances in energy efficiency. The case of non-fossil fuel subsidies, however, is not yet clear due to the lack of systematic research; case studies indicate that subsidies could help to increase the share of alternative fuels in the market, if limited in time. However, policy objectives and implementation strategies need to be clear, medium and long - term and comprehensive.

While goals can be complementary in many cases, there are times when policy makers have to decide whether they aim for a) energy efficient mobility; b) mitigation of greenhouse gas emissions; or c) mobility with low consumption of crude oil-based fuels.

In the search of good (and bad) practice examples one can look at different experiences worldwide and in LAC. In Latin America a key challenge is to obtain appropriate data to actually be able to understand and analyze the local context. Data are crucial to make founded recommendations and well informed decisions that effectively fit the context.

The current pathways of energy consumption in mobility of the LAC countries vary and require different approaches and solutions. But each individual country irrespective of its size and state of economic development faces eminent pressure to curb energy consumption of mobility without jeopardizing social and economic welfare and development.

Transport services and the related infrastructure are key for the integration for the region in the global market. However, effective policies directed to reduce and manage energy consumption and emissions are widely absent in the region. With maritime transport being one of the most energy efficient possibilities of transport, great importance should be given to making this mode more environmentally friendly, energy efficient and competitive to other modes.

Furthermore, infrastructure for several transport modes and multimodal transport is not developed adequately. Often, the decision to opt for a more energy efficient mode is impeded by a significantly higher travel time, high costs, or lack of quality and security. This is particularly true for urban transport – where the current focus on passenger mobility should not obstruct the view on urban freight movements that are equally important and growing in numbers.

Consequently, close cooperation between energy and transport experts is needed urgently to research functioning best practices worldwide targeting an increase of energy efficiency in mobility with the goal to propose locally adapted solutions in the quest of decoupling of energy consumption and mobility.

This will require technical solutions but should not stop at those. Including also a change (shift) in strategy and mindset (avoid) of decision makers and within the population as a whole is crucial to succeed. Only this will help shifting mobility to more sustainable transport modes and ultimately to avoid some of the demand for mobility in the future. We need to think energy and mobility systemically and change from myopic activities to long term sustainable strategies.

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