Comparative analysis of European Union and Iranian CO_2 reduction policies in transportation sector

A Dissertation

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Table of Contents

List of figures

List of tables

Acronyms

ACEA	European Automobile Manufacturers' Association
AFV	alternative fuel vehicle
AQCC	Air Quality Control Company
AQI	air quality index
BAU	business as usual
BEV	battery-electric-vehicle
BOE	barrel of oil equivalent
BP	British Petroleum
CAFÉ	Corporate Average Fuel Economy
CCS	carbon capture and storage
CNG	compressed natural gas
CO	carbon monoxide
COP	Conference of the Parties
CV	contingent valuation
DMC	direct medical cost
E85	blend of gasoline with 85% ethanol
ECMT	European Conference of Ministers of Transport
EEA	European Environment Agency
EU	European Union
EU-ETS	EU Emissions Trading Scheme

EUROPIA	European Petroleum Industry Association
FCV	fuel cell vehicles
FDI	foreign direct investment
FOB	free on board
FYDP	fiver year development plan
GDP	gross domestic product
GEFI	Global Fuel Economy Initiative
GHG	Greenhouse gas
HDV	heavy duty vehicles
HEV	hybrid-electric vehicle
IANGV	International Association for Natural Gas Vehicles
ICARC	Islamic Consultative Assembly Research Center
ICCT	International Council on Clean Transportation
ICE	internal combustion engines
IEA	International Energy Agency
IFCO	Iranian fuel conservation company
IKCO	Iran Khodro Company
ILUC	indirect land use changes
IPCC	Intergovernmental Panel on Climate Change
Iran-DOE	Iranian Department of Environment
ISIRI	Iranian National Standard Organization
ISQI	Iran Standard and Quality Inspection Company
ITF	International Transport Forum

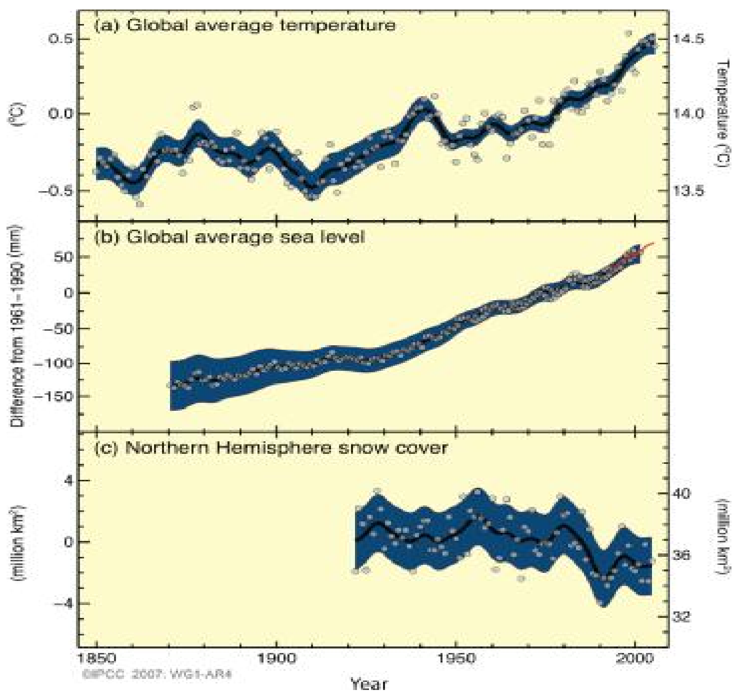
JAMA	Japan Automobile Manufacturers' Association
JTRC	Joint Transport Research Centre
JV	joint venture
KAMA	Korean Automobile Manufacturers' Association
LCV	low carbon vehicles
LDV	light duty vehicle
LPG	liquid petroleum gas
LULUCF	Land use, land-use change and forestry
MBOE	million barrels of oil equivalent
MIMT	Ministry of Industry, Mine and Trade
MOE	Ministry of Energy
MTOE	million tons of oil equivalent
NAMA	Nationally Appropriate Mitigation Actions
NEDC	New European Driving Cycle
NHTSA	National Highway Traffic Safety Administration
NIOC	National Iranian Oil Company
NIOPDC	National Iranian Oil Products Distribution Company
NIORDC	National Iranian Oil Refining and Distribution Company
NG	natural gas
NGV	natural gas vehicle
NOx	oxides of nitrogen
OECD	Organization for Economic Co-operation and Development
OICA	International Organization of Motor Vehicle Manufacturers

PHEV	plug-in-hybrid-electric-vehicle
$PM_{2.5}$	particulate matters that are 2.5 μ in diameter and smaller
PM_{10}	particulate matters that is smaller than 10 μ and larger than 2.5μ
SAIPA	Société Anonyme Iranienne de Production Automobile
SRP	Subsidies Reform Plan
SUV	sport utility vehicle
SWOT	a strategic planning technique stands for strengths, weaknesses, opportunities and threats
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNPD	United Nations Population Division
US EPA	United States' Environment Protection Agency
VAT	value added tax
VOCs	volatile organic compounds
VOSL	value of statistical life
VKT	vehicle-kilometer traveled
WLTP	World Harmonized Light Vehicle Test Procedure
WTO	World Trade Organization
WWO	World Weather Organization
ZEV	zero emission vehicles

1. Introduction and Background

1.1. Introduction

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC),[1] the climate system is indisputably warming. This is evident from observations of increases in global average air and ocean temperatures, the widespread melting of snow and ice, and a rising global average sea level.[2] Over the last 250 years or so, human activities such as the burning of fossil fuels, the removal of forests that would otherwise absorb carbon dioxide and their replacement with intensive livestock ranching have released a range of greenhouse gases (GHGs) into the atmosphere. As a result, the capacity of the atmosphere to absorb heat and emit it back to earth has been substantially increased (Figure 1.1).



Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).

Figure 1.1 Changes in temperature, sea level and Northern Hemisphere snow cover.

Source: IPCC (2007)

[1] The IPCC is a scientific intergovernmental body that was established in 1988. It is responsible for providing scientific assessment of current scientific, technical and socio-economic information worldwide about the risk of climate change caused by human activity, its potential environmental and socio-economic consequences, and possible options for adapting to these consequences or mitigating their effects.

[2] Intergovernmental Panel on Climate Change (IPCC), (2007), *Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* . Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p.6. Retrieved July 10, 2010, from www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf

The IPCC reported that average Northern Hemisphere temperatures during the second half of the twentieth century were very likely higher than during any other 50-year period in the last 500 years, and likely the highest in at least 1300 years.[3] Based on their investigations into trends of supplying and consuming fossil fuel resources, the average global temperature is predicted to increase between 1 to 3.5 degrees Celsius by 2100.[4] This fact means that we should expect more tremendous natural disasters emerging from climate change in the future. According to the official reports of reputable institutions, the most important and comprehensive agreement that has been developed by international bodies is the Kyoto Protocol. This is an international agreement linked to the United Nations Framework Convention on Climate Change.

The United Nations Framework Convention on Climate Change

The United Nations Environment Program (UNEP) and World Weather Organization (WWO) established Intergovernmental Panel on Climate Change (IPCC) in 1988. According to the reports of the IPCC, the international community responded to climate change by developing the United Nations Framework Convention on Climate Change (UNFCCC) in 1994. This body sets an overall framework for intergovernmental efforts to tackle the challenges posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and greenhouse gases. The Convention has nearly a universal membership, with 194 countries having ratified it by May 2011.

The Kyoto Protocol

The Kyoto Protocol is an international agreement linked to the UNFCCC. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing GHG emissions. However, it is important for economies to find ways that are not only feasible technically, but also attractive economically.

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[3] Intergovernmental Panel on Climate Change (IPCC), (2007), *Fourth Assessment Report, Synthesis Report*, Retrieved May 5, 2013, from: www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html

[4] Hosein Taghdisian and Saeid Minapour, (2003), *Climate Change: What we must know about*, Iran-EPA and Iran's Climate Change Office, Tehran, Iran.

The major distinction between the Protocol and the Convention is that, while the Convention encouraged industrialized countries to stabilize GHG emissions, the Protocol commits them to do so.

In fact, developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere, the result of more than 150 years of industrial activity. Hence, the Protocol places a heavier burden on these countries under the principle of 'common but differentiated responsibilities.'

The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. 192 Parties (191 States and one regional economic integration organization) to the Convention had ratified the Protocol by April 2013. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh in 2001 and are called the 'Marrakesh Accords.'

On 8 December 2012, at the eighth session of the conference of the parties held in Doha, they reached an agreement to extend Kyoto Protocol from 2012 to 2020 (the second commitment period). The amendment introducing the second commitment period has not entered into legal force yet.[5]

Carbon dioxide as a greenhouse gas

According to the IPCC, carbon dioxide (CO_2) is the most important anthropogenic GHG. The significant growth in GHG emissions between 1970 and 2004 has come from energy supply, transport and industry, while the residential and commercial buildings, forestry (including deforestation) and agriculture sectors have been growing at a slower rate.[6] The Kyoto Protocol mentions six greenhouse gases that global emissions commitments should focus on (table 1.1).

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[5] Intergovernmental Panel on Climate Change (IPCC), (2013), *Doha Amendment to the Kyoto Protocol*, UNFCCC, Retrieved April 11, 2013 from: www.unfccc.int

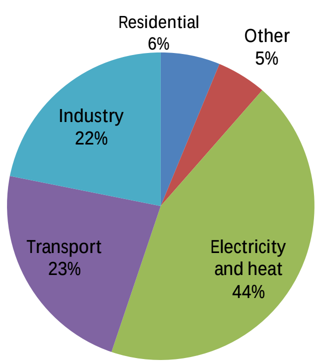
[6] Intergovernmental Panel on Climate Change (IPCC), (2007), *Synthesis Report: An Assessment of the IPCC*, Spain, p.14. Retrieved September 10, 2010, from: www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

Table 1.1 Global Warming Potential of the greenhouse gases

Greenhouse gas	**Chemical formula**	**GWP (for over 100 years)**
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons	HFCs	140 - 6300
Sulfur hexafluoride	SF_6	34900
Perfluorocarbons	PFCs	6500 - 9200

Source: UNFCCC

Consuming energy produced from fossil fuels is known to be the main reason for greenhouse gas emissions.[7] The energy sector (oil and gas production, power plants, refineries, petrochemicals, etc.), heavy industries, transportation and other sectors (e.g. household) are the main consumers of fossil energy. According to the IEA, the combined share of the electricity and heat generation and transportation sectors represented over two thirds of global CO_2 emissions in 2012. The share of transportation has reached more than one fifth of total carbon dioxide emissions (Figure 1.2).[8]



* Other includes commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere.

Figure 1.2 World CO_2 emissions by sector in 2011

Source: IEA (2013)

[7] I use 'carbon dioxide' and 'greenhouse gases' as synonyms in this research. It should be mentioned that in the transportation sector, carbon dioxide is by far the most significant greenhouse gas.

[8] International Energy Agency (IEA), (2013), *CO_2 Emission from Fuel Combustion: Highlights*, Paris, France, p.11. Retrieved December 31, 2014, from: www.iea.org/co2highlights/co2highlights.pdf

Because of the inherent complexity of the transportation sector in comparison to most other branches of economic activity – millions of travelers are involved – policy measures often have to be taken at a local level, respecting local particularities. In such cases, instead of concrete quantified proposals, it is possible to provide policy guidelines only, pointing to successful pilot projects around the world.[9]

1.2. Global warming and the transportation sector

It seems to be difficult to deal with climate policy in the transportation sector. CO_2 emissions from this sector are raising rapidly, both from land (road and rail), marine and air transport. People spend on average 1.1 hours per day travelling in urban and rural areas. This does not hold for individuals, but is roughly valid when applied to large groups.[10] Policies to slow the increase in emissions are relatively ineffective in the short term, but it is sometimes suggested that such policies have been effective in the longer term.[11]

The majority of carbon dioxide emissions from the transportation sector come from fossil fuel combustion in cars, trucks, ships, trains and airplanes. According to the US Environment Protection Agency, about 90% of the fuels consumed in the transportation sector are petroleum based – mainly gasoline and diesel. Since carbon is the main component of fossil fuels, the best way for estimating emitted CO_2 is to calculate the carbon content of the fuel and the amount consumed.[12]

In 2001, European Conference of Ministers of Transport (ECMT) reported that no country had adequately addressed the contribution of vehicles to carbon dioxide emissions, the result being that the fraction of global CO_2 emissions arising from the transport sector was increasing. Europe had taken the lead with a voluntary commitment to reduce new car fuel consumption by 25% over the next decade, and Japan was closely following suit. In the US there had been substantial

[9] Theodoros I. Zachariadis, (2005), *Assessing policies towards sustainable transport in Europe: An integrated model*, Energy Policy 33 (2005) p.1509.
[10] Arie Bleijenberg, (2012), *The Attractiveness of Car Use*, in Th.I Zachariadis,., *Cars and Carbon*, Springer, Cyprus, p.22.
[11] J.C. Jansen, S.J.A. Bakker, (December 2006), *Social cost-benefit analysis of climate change mitigation options in a European context*, Energy Research Center of the Netherland, ECN-E--06-059, p.28.
[12] Winston Harrington, (2008), The Design of Effective Regulations of Transport, OECD/ITF, JTRC Discussion Paper 2008-2, p.10. Retrieved August 10, 2012 from: www.internationaltransportforum.org

focus on developing advanced vehicle technologies in the laboratory, but in reality new car fuel economy continued to decline.[13]

The transportation sector is one of the most important sectors for the development of energy consumption and environmental emissions. The nearly complete dependence of the sector on oil products generates two sorts of concerns: security of oil supply, given the rising needs of transportation, and worries about climate change combined with the longer standing problems of congestion, noise and urban pollution.[14]

Until about a decade ago, direct public health impacts were the focus of auto emissions policies, which were designed to reduce emissions of the so-called 'conventional' pollutants carbon monoxide (CO), volatile organic compounds (VOCs), oxides of nitrogen (NO_x), and lead – substances that either alone or upon reaction with other pollutants can cause respiratory disease, elevated cardiovascular disease risk, high blood pressure, photochemical smog formation, reduced visibility and acid deposition. Of these, the most serious (and fortunately the easiest to deal with) was lead, an additive that raised octane levels in gasoline. Today, gasoline is lead-free in most of the developed world and is being steadily phased out almost everywhere else.[15]

Before deploying new standards, vehicles in Iran used gasoline containing lead. In 2001, the government of Iran introduced unleaded gasoline to eliminate lead pollution and in 2005 it required all gasoline sold to be unleaded. There is no comprehensive monitoring data for lead levels in Tehran, though average concentrations in 2002 were estimated to be 0.67 $\mu g/m^3$ based on information provided by the Air Quality Control Company (AQCC) in Tehran. This average is much lower than in previous years.[16]

More recently, these local air quality concerns were joined by a newly emerging problem to which vehicles are the major contributor: global warming.

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13 European Conference of Ministers of Transport (ECMT), (2001), *Vehicle Emission Reductions*, OECD Publications Service, Paris, France, p.8. Retrieved September 25, 2010 from: http://internationaltransportforum.org/pub/pdf/01VehEmis.pdf

14 P. Capros, L. Mantzos, V. Papandreou, N. Tasios,(2008), E*uropean Energy and Transport: Trends to 2030 – Update 2007*. European Commission, Brussels, p.52.

15 Winston Harrington, op. cit., p.5.

16 Majid Shafie-Pour, Mojtaba Ardestani, (2007), *Environmental damage costs in Iran by the energy sector*, Energy Policy 35 (2007), p.4418.

According to the IPCC, implementing GHG mitigation policies in the transportation sector may well reduce urban congestion. Consequently, urban congestion reduction may constitute a significant ancillary benefit. In addition, reduction of traffic accidents (mortality and morbidity) may be a significant positive externality arising from GHG policies targeting the transport sector, especially those policies focusing on enhancing public transport.[17]

Fuel quality concern

Fuel sulfur content has an important bearing on all of these issues. Sulfur affects the performance and durability of many exhaust-treatment and on-board diagnostic systems in gasoline and diesel vehicles (both cars and trucks). Reducing fuel sulfur cuts emissions of nitrogen oxides, hydrocarbons, particulate matter and carbon monoxide from all vehicles. Emissions of ultra-fine particles and especially benzene are also particularly sensitive to fuel sulfur content.

For new vehicle models, sulfur-free fuels help ensure the latest European emissions standards can be met. For gasoline cars, sulfur-free fuels help ensure significant reductions in CO_2 emissions can be made without exceeding 2005 EURO4 NO_x emissions limits. For heavy-duty vehicles, sulfur-free diesel improves the prospects of meeting 2005 EURO4 particulate matter emissions standards and expected 2008 EURO5 NO_x emissions limits. For light trucks and large diesel passenger cars, sulfur-free diesel improves the prospects of meeting EURO4 particulate and NO_x emissions standards.[18]

In almost all the European countries, tax incentives or regulations play an important role in providing proper conditions for the refining industry to make the investments needed to produce sufficient quantities of sulfur-free fuels. Early decisions about providing incentives, or mandatory fuel sulfur limits, would help refiners to plan investments and plant outages for refurbishment in a fashion optimal for meeting intermediate standards already mandated.

[17] J.C. Jansen, S.J.A. Bakker, op. cit., p.40.
[18] ECMT, op. cit., p.9.

1.2.1. An introduction to global warming and carbon dioxide emissions

The imperatives of contemporary political economy – for firms to improve their competitiveness, for states to improve their position in a global economic hierarchy, and for consumers to improve their quality of life – all require continuous investment in a variety of new technologies.[19]

The system of multilateral regimes currently in place to govern politics between states in the interstate system is, of course, highly dependent on the extensive physical movement of diplomats, advisors, negotiators and lobbyists around the world, between their capital cities and the sites of negotiations. The irony of this virtually continual dialogue between officials from many countries about climate change, moving from site to site as different governments host meetings[20] whilst contributing significant amounts of CO_2 to the atmosphere, is lost on few commentators.

According to the IPCC, the share of total GHG emissions by transportation has risen considerably. In 2004, the transportation sector produced 6.3Gt of CO_2 emissions (23% of world energy-related CO_2 emissions) and its growth rate is the highest among end-user sectors. Road transport accounted for 74% of total transport CO_2 emissions in 2006. The share of non-OECD countries was 36% at that time and the IPCC predicts that this will increase rapidly to 46% by 2030 if current trends continue.[21]

The IEA estimated in 2009 that total light-duty vehicle ownership will double in the next few decades from the current level of around 1 billion vehicles. Two thirds of this growth is expected in non-OECD countries.[22]

1.2.2. CO_2 emissions according to fossil fuel consumption

Transportation sector energy and CO_2 trends are very strongly linked to rising population and incomes. Transportation continues to rely primarily on oil. Given these strong connections,

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[19] Matthew Paterson, (2007), *Automobile Politics*, Cambridge University Press, New York, US, pp.4-5

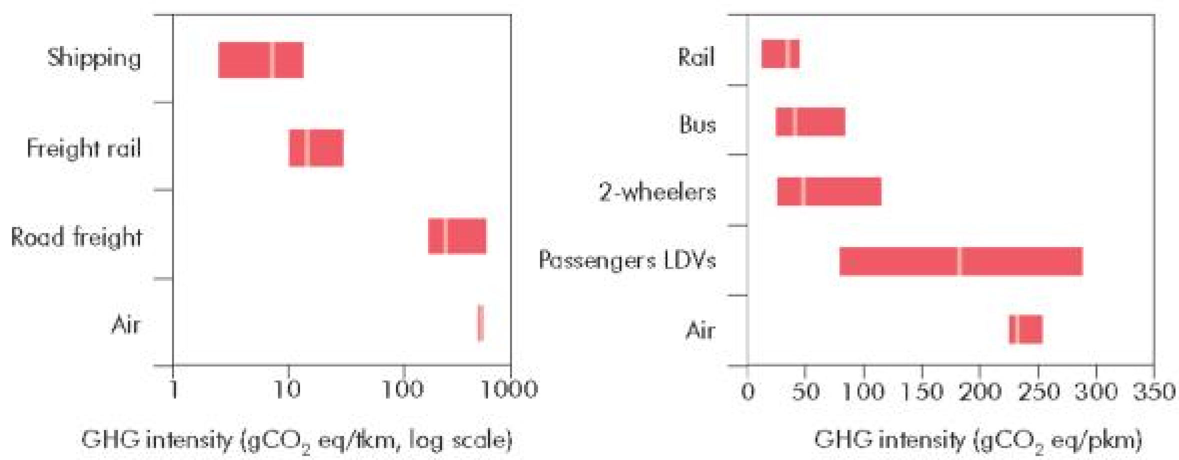
[20] For example, after the collapse of the formal negotiations in the Hague in November 2000, negotiators from OECD countries moved straight to Ottawa and then to Oslo for more meetings to try to resolve US–EU differences.

[21] Intergovernmental Panel on Climate Change (IPCC), (2007), Fourth Assessment Report, *Chapter 5: Transport and its infrastructure*, Cambridge, United Kingdom and New York, USA, p.325

[22] Intergovernmental Panel on Climate Change (IPCC), (2014), Fifth Assessment Report, *Chapter 8: Transport*, Cambridge, United Kingdom and New York, USA, p.605

decoupling transport growth from income growth and shifting away from oil will be a slow and difficult process.[23]

Road transportation consumes much more energy for economic production than other modes. Distributing consumers and numerous vehicles has raised CO_2 intensity for both freight and passenger purposes (Figure 1.3). Improving energy efficiency for road transportation needs more complicated policies for the key players – from automakers to drivers.



Note: The clear line indicates world average, the bar representing MoMo regions' discrepancy.

Figure 1.3 GHG efficiency of different modes, freight and passenger, 2005

Source: IEA 2009, Transport, Energy and CO_2

1.2.3. Economic issues of CO_2 emissions in the transportation sector

Negative externalities associated with transportation – which include air pollution, GHG emissions, accidents, noise and congestion – are costs generated by private users and imposed on society as a whole. In addition, road use may involve road construction, land purchase and parking facility costs, which are not charged directly to users but are paid for through general taxation.

Theoretically, cost-benefit analysis can be used not only to help decision-making, but also to ensure more efficient pricing by monetizing all relevant externalities and assessing the

[23] Arie Bleijenberg, op. cit., p.44

distributive effects. For example, De Borger et al. (1997) argue that internalizing external costs in the price of transport services is the appropriate way to take account of diverse objectives such as congestion, air pollution, noise damage and accident costs. However, they also noted that there are certain barriers to the internalisation of external costs, e.g. the evaluation of social costs, pricing of technologies, the heterogeneity of transport demand, determining optimal prices, estimation of transport equilibrium, etc. [24]

Browne and Ryan analysed the externalities of car transport in Beijing, China, and found that the social costs associated with motorised transportation were equivalent to about 7.5–15% of the city's GDP. Congestion and air pollution costs along with climate change costs are the most uncertain parameters.

In 1999, Johansson examined the total costs involved in the use of different fuels – including petrol, diesel, natural gas, biogas and methanol – in cars and heavy trucks. He considered the costs – including fuel costs, capital costs and total externalities – and found that no alternative fuel could compete with petrol and diesel in rural traffic when the economic valuation of CO_2 was taken to be equivalent to the prevailing tax of $200/ton carbon. However, in cities with a natural gas network, natural gas had the lowest cost for both cars and heavy trucks, while methanol from natural gas and biogas from waste products was also able to compete with diesel in urban traffic.

In another study, based on the PRIMES model, average costs of CO_2 reduction in 2010, compared to 1998 emissions, were estimated for a number of sectors, and the transport sector was again judged to be the most effective in terms of mitigating GHG emissions, e.g. industry (€73/ton), services (€26/ton), transport (€105/ton), power (€25/ton) and households (€142/ton).[25]

1.2.4. CO_2 emissions trends in the world transportation sector

Global demand for transport appears unlikely to decrease in the foreseeable future. The World Energy Outlook projects that transport fuel demand will grow by about 40% by 2035. To limit emissions from this sector, policy makers should first and foremost consider measures to encourage or require improved vehicle efficiency. Recommended policies are those that

[24] David Browne, Lisa Ryan, (2011), *Comparative analysis of evaluation techniques for transport policies*, Environmental Impact Assessment Review 31 (2011), p.226

[25] David Browne, Lisa Ryan, op. cit., p.228.

encourage public transportation and lower emissions from modes of transportation. These policies emphasize new low-carbon fuels, including electricity (e.g. electric and plug-in hybrid vehicles), hydrogen (e.g. through the introduction of fuel-cell vehicles) and biofuels (e.g. as a blend in gasoline and diesel fuel). The International Energy Agency advises using emissions pricing or fuel excise policies to avoid a rebound in transportation fuel demand.[26]

Bleijenberg reports that global transport energy grew between 2 and 2.5% between 1971 and 2006, accompanying economic growth around the world. The road transport sector (including passenger and freight) used the most energy and grew the most during this period.

The IPCC reported that GHG emissions from transportation have increased as a faster rate than any other energy end-use sector, from 2.8 to 7.0 Gt CO_2-eq in 2010. According to the IPCC, around 80% of this increase has come from vehicles (Figure 1.4).

[26] International Energy Agency (IEA), (2011), *CO_2 Emission from Fuel Combustion: Highlights*, Paris, France, p.10. Retrieved July 10, 2012, from: www.iea.org/co2highlights/co2highlights.pdf

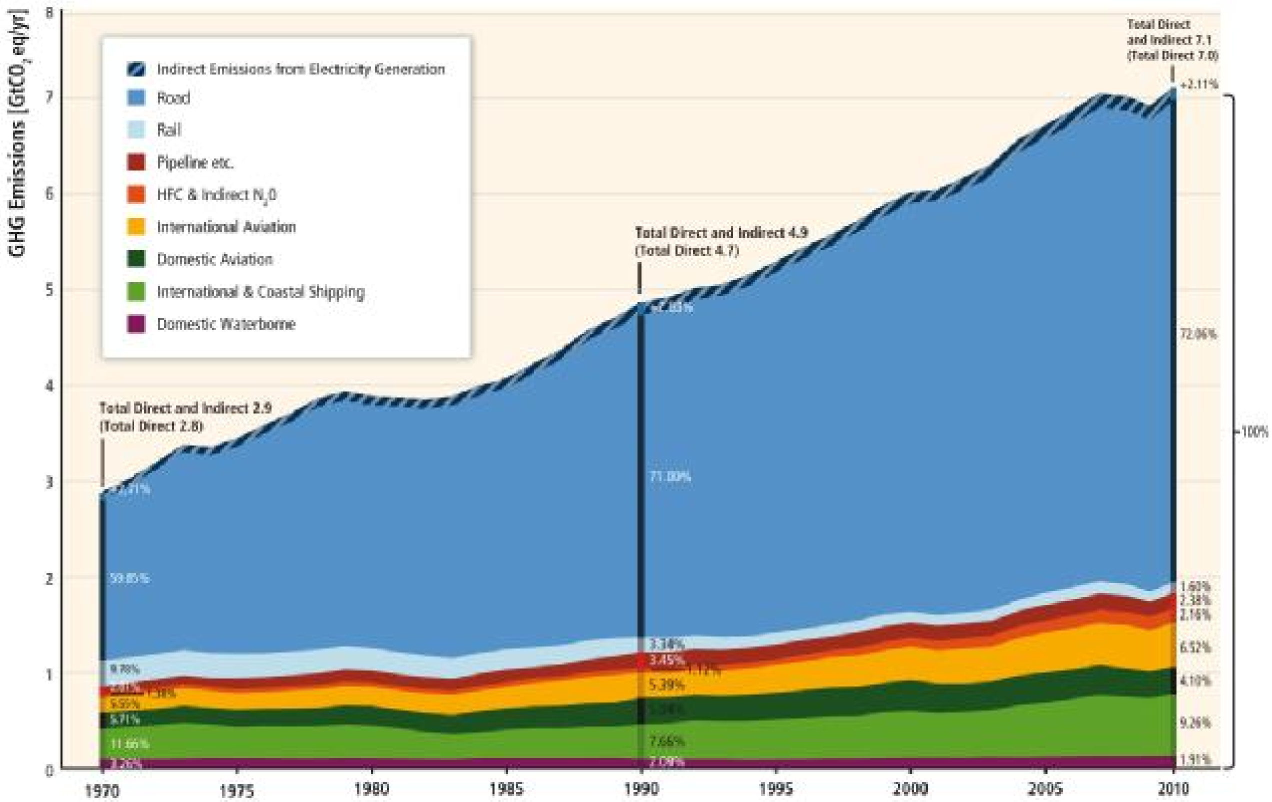


Figure 1.4 Direct GHG emissions of transportation by mode (1970 – 2010)

Within the transportation sector, light-duty vehicles (LDVs) consume about half of the travel-related energy used worldwide and perhaps two thirds of the energy used within national borders (i.e. excluding international shipping and air travel). According to Bleijenberg, OECD countries rely on 4-wheel LDVs far more than non-OECD countries.

The total worldwide stock of passenger LDVs has grown steadily, reaching over 800 million worldwide in 2008. Bleijenberg reports that the stock of LDVs grew by about 70%, or about 3% per year, from 1990 to 2008. Fleets are dominated by gasoline vehicles in most countries. In the same period, world population grew by 25% from 5.2 to 6.6 billion.[27]

[27] Arie Bleijenberg, op. cit., p.45

1.3. Description of Iran's transportation sector

1.3.1. Iran's petroleum production

With 137 thousand million barrels of crude oil and 29.6 trillion cubic meters of natural gas, Iran held the fourth-largest hydrocarbon reserves in the world at the end of 2010 (Figure 1.5). The country's oil and gas industry, with a history lasting more than a century, has played a significant role in developing the national and international economy.

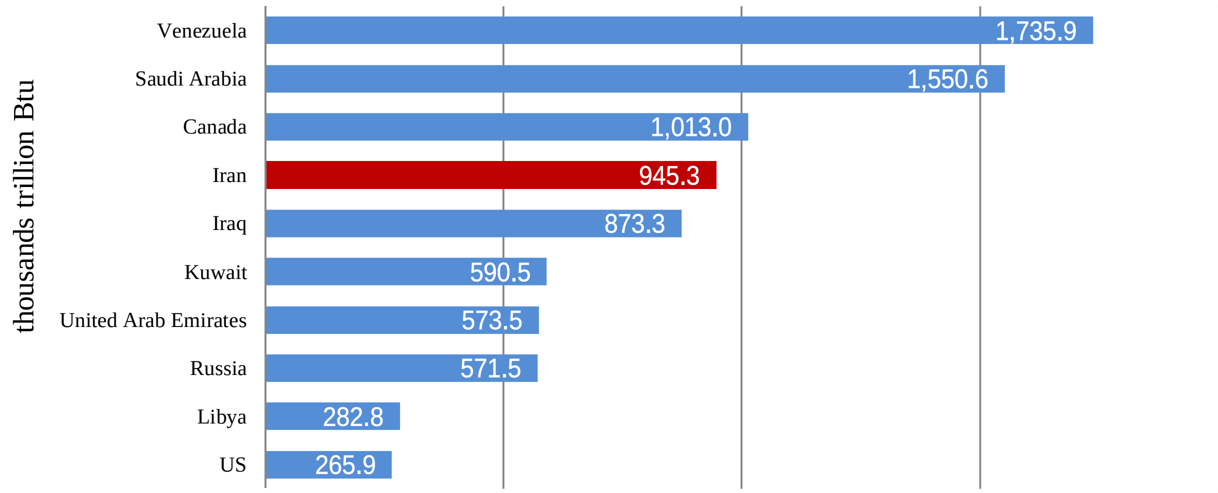


Figure 1.5. Top ten countries in hydrocarbon (oil and gas) reserves in 2010 (thousand trillion Btu equivalent)

Source: BP Statistical Review of World Energy, June 2014

Iran produced 205.8 million tons of crude oil in 2010 and maintains its fourth place as an oil producer, ranking after Saudi Arabia (525.8 million tons), the Russian Federation (511.4 million tons) and the United States (352.3 million tons).[28]

International sanctions and the lack of foreign investment and technology transfer have affected the Iranian energy sector. Iran's crude oil production fell in 2012, but it remained the second-largest OPEC producer on average during the year.[29]

[28] British Petroleum (BP), (June 2012), *BP Statistical Review of World Energy*, http://www.bp.com/statisticalreview

[29] US Energy Information Administration (EIA), *Country Analysis Brief Overview: Iran*. Retrieved May 4, 2013 from: www.eia.gov/countries/country-data.cfm?fips=IR

Over the past few years, Iran has expected its domestic refining capacity to meet growing domestic demand, and particularly for gasoline to meet the increasingly growth of local consumption.

Iran is the third-largest natural gas producer in the world, due in part to the development of the giant South Pars field. The US Energy Information Administration has forecas that, despite replaced delays in field development and the effects of sanctions, Iran's natural gas production is expected to increase in the coming years.

It should be added that BP presented Iran as the largest proven natural gas reserve (18.2% of the world reserves), ahead of the Russian Federation (16.8%) and Qatar (13.3%).[30]

1.3.2. Iran's oil consumption

Iran consumed over 92 million tons of crude oil in 2013, putting it eleventh in the world, after the US, China, Japan, India, the Russian Federation, Saudi Arabia, Brazil, Germany, South Korea and Canada, and ahead of Mexico, France, the UK and Italy (Figure 1.6).

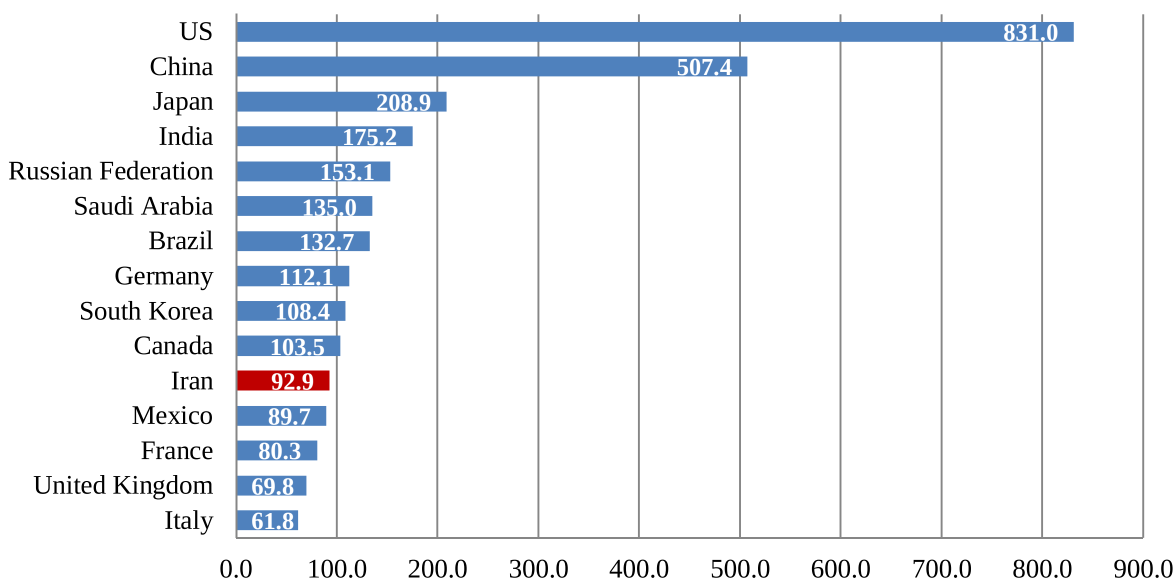


Figure 1.6 Top 15 oil consumer countries in 2013 (million tons)

Source: BP Statistical Review of World Energy, June 2014

[30] British Petroleum (BP), (June 2014), *BP Statistical Review of World Energy*, p.20 Retrieved December 31, 2014 from: www.bp.com/statisticalreview

Iran's Ministry of Energy (MOE) reports that consumption of the main petroleum products (liquefied gas, gasoline, kerosene, diesel and fuel oil) in Iran grew 0.8% annually between 2005 and 2011. The most growth was shown by diesel, with 4.1% during the period. The MOE also reports that diesel and gasoline consumption grew respectively by 43.5 and 26.1% in 2011, compared to 2010.[31]

1.3.3. A glance at the history of development planning in Iran

The Iranian government established its Planning Commission in 1946 to organize strategic spatial planning in the country and preparing development plans in Iran started in 1947.[32] This commission was reformed into the Planning and Budget Organization Commission to centralize national planning activities. Iran experienced five 'National Construction Plans' before the Islamic Revolution of February 11, 1979. The last plan was conducted from 1973–1977. The objectives of the plan were enhancing the level of knowledge, culture, health and welfare in the whole society, continuing economic growth, developing employment, and improving the bureaucratic system and environmental protection.

1.3.4. Five-Year Development Plans in Iran: An overview

After the end of the war with Iraq in August 1988, the Iranian government had to start mitigation plans to renovate the national economy (Table 1.2). Hence, the First Five-Year Development Plan (FYDP) was designed for the 1990–1994 period. In the First FYDP, the government considered the following objectives:

- Unification of exchange rates (from six to one);
- Reconstructing economic capacities that were damaged during the eight-year war with Iraq; and
- Encouraging economic activities after downturn.

During the subsequent FYDPs, enhancing economic infrastructural capabilities (e.g. national roads network, refineries, power plants, communications, water resource management and so forth) was the main objective of the government.[33]

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[31] Iranian Ministry of Energy (MOE), (2013*), Iran Energy Balance 2011*, p.79

[32] Iran Economics, (July, 2004). *60 Years Planning in Iran*. Retrieved March 26, 2012, from: http://www.iraneconomics.net/fa/articles.asp?id=379

[33] Andisheh Group. (October 2004). *Iranian Auto Industry: Problems and Issues, Challenges and Strategies*, Studies & Strategic Planning Center of Iran Khodro Co., Tehran, p.21.

Table 1.2 Iran’s Five-Year Development Plan time periods	
First FYDP	1990 - 1994
Second FYDP	1995 – 1999
Third FYDP	2000 – 2004
Fourth FYDP	2005 – 2009
Fifth FYDP	2011 - 2015

Source: Iranian Deputy President of Strategic Planning and Control

The Third FYDP took an approach called ‘Developing a Competitive Economy’, which aimed at liberalizing the economic system, social security enhancement, private sector encouragement, and decentralizing and reducing state governance. [34]

The Fourth FYDP was designed with a long-term perspective. This plan included a global approach for improving internal structures. Indeed, the planners’ objective was a ‘sustainable economic growth based on knowledge and a global approach.’

The Fifth FYDP is the first Iranian national development plan that was designed by executive institutions (e.g. the Ministry of Science, Research and Technology was responsible for preparing development documents for higher education, research and technology in Iran for the period 2011–2015) in a decentralized approach.[35]

The average annual growth rate of Iran’s GDP fluctuated significantly during the First FYDP.[36] However, the average GDP growth rate in 1990–2009 (the first four Five-Year Development Plans) was 4.9% (Figures 1.7 and 1.8).[37]

[34] Iran Economics, op. cit.,.
[35] Institute of Research and Planning for High Education, (2012), *The Fifth Development Plan.* Retrieved April 1,2012, from: www.irphe.ir/fa/Plan5/contactus.aspx
[36] World Bank (2012), Databank. Retrieved April 26, 2012, from: http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
[37] World Bank, op. cit.

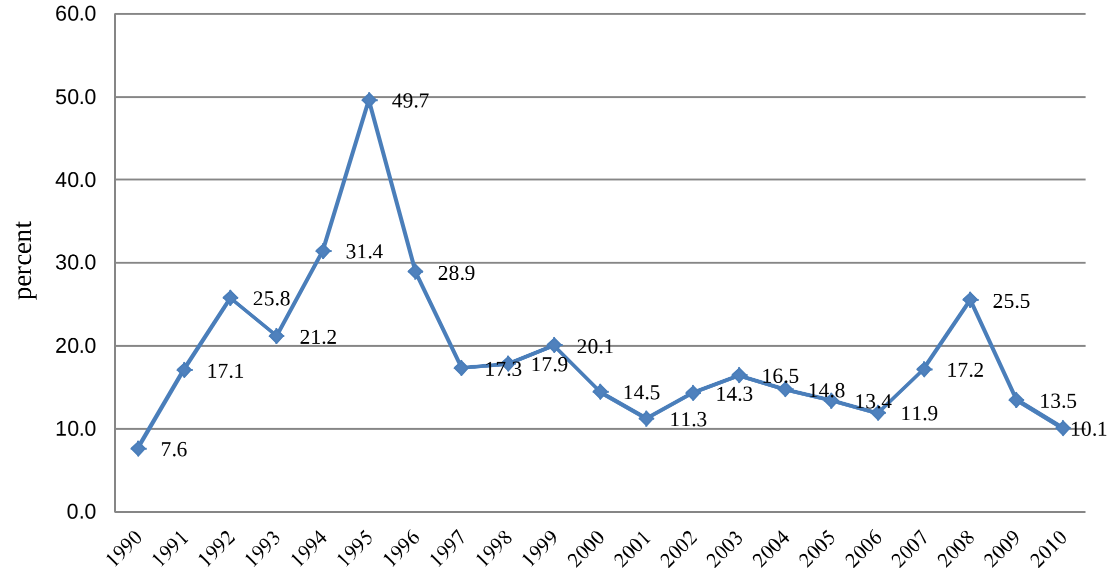

Figure 1.7. Iran's inflation, consumer prices (annual%)

Source: World Bank 2012

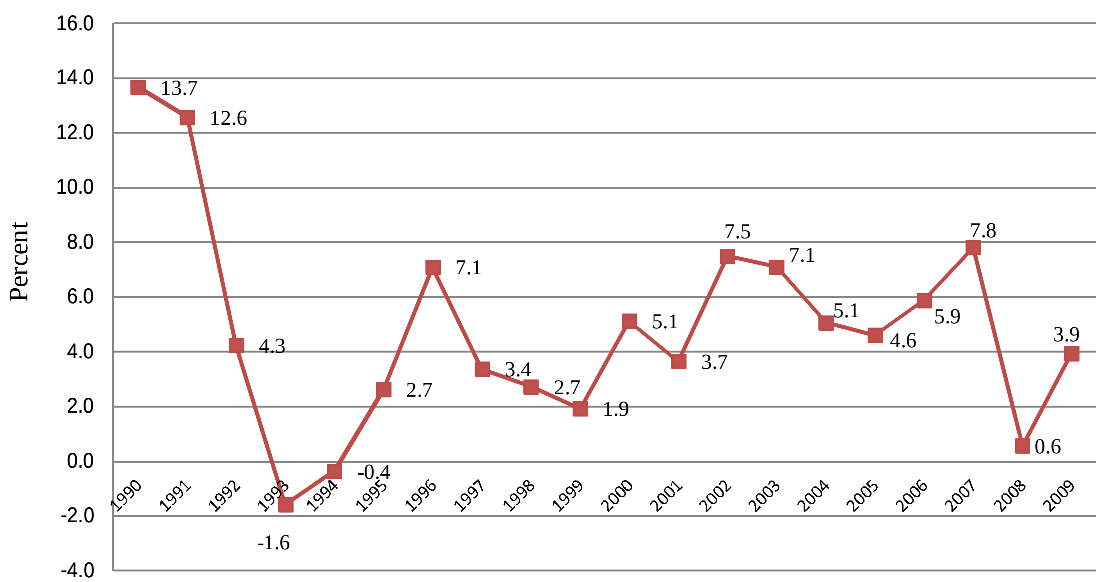

Figure 1.8 Iran's GDP growth (1990-2009) (% annual)

Source: World Bank 2012

The Iranian government has especially focused on the industry sector during the Five-Year Development Plans. According to the official statistics, the share of the industry and mining sectors in the national value added rose from 18% in the First FYDP to 26% in the Fourth FYDP. According to the Figure 1.9, in this trend, the oil and gas sector's share decreased from 17% to 10%. In other words, the industry and mining sector has taken the share of the oil and gas sector, rather than of others.[38] It should be added that the value-added growth rate of the industry sector fluctuated from 1991–2007, but the annual average growth is estimated 8.07%.

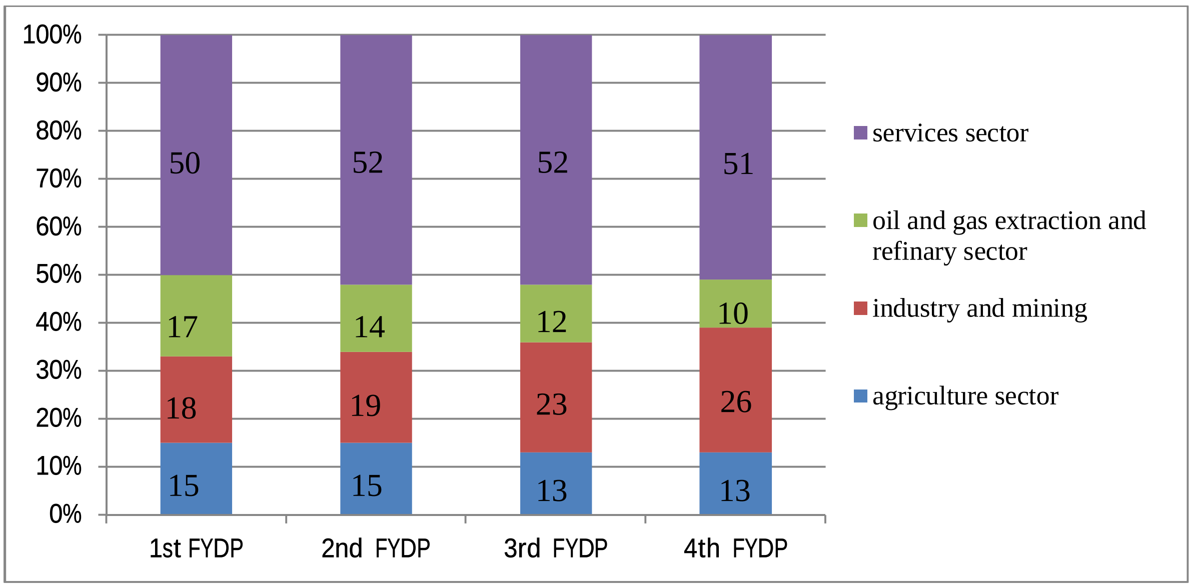

Figure 1.9 Shares of sectors in value-added in Iran's GDP

Source: Central Bank of Iran, National Accounts, 2010

According to the World Bank, Iran's gross domestic product (GDP) per capita in current prices has almost quadrupled since the end of the war with Iraq in 1988 and 2012 (Table 1.3). The economic indicators show this trend more clearly. For example, Iran's crude steel production grew from 1 million tons in 1988 to over 19 million tons in 2011. More capacity is under construction, and an annual crude oil production of 45 million tons is also planned from 2014.[39] The production of cement doubled within a decade from 20 million tons in 1998 to nearly 45

[38] Central Bank of the Islamic Republic of Iran (January 2010), *Iran National Accounts: Due to SNA1993 System. Retrieved* April 26,2012, from: http://www.cbi.ir/page/4460.aspx

[39] World Steel Association, (2012), *Steel Statistical Yearbook*, (1980-2011) Retrieved January 8, 2012 from: http://www.worldsteel.org/statistics/statistics-archive.html

million tons in 2008 and 61 million tons in 2010 (making Iran the world's fifth-largest producer).[40] Today in Iran, 631 dams are already in operation, 143 are under construction and 547 are in planning.[41] According to the International Organization of Motor Vehicle Manufacturers, Iran's auto industry produced more than 1.6 million vehicles and was ranked thirteenth worldwide in 2011. It should be noted that the Iranian auto industry produced nearly 25,000 vehicles in 1988.

These data show that the industrialization level in Iran has grown since the end of the war with Iraq and during the FYDPs. It is often argued that business and government in Iran are extremely dependent on energy. The fact that a considerable share of oil produced in Iran and nearly all of its natural gas are consumed within the country suggests that demand for fossil energy sources is expected to increase.[42]

Table 1.3 Iran's GDP per capita in current prices (USD)

1998	**2000**	**2002**	**2004**	**2006**	**2008**	**2010**	**2012**
1611	1537	1719	2354	2737	3140	5675	6578

Source: World Bank 2014

1.3.5. Iran's automotive industry

Following huge investments in Iran's automotive industry, the sector started to grow in the fifth FYDP. The statistics show that Iran's vehicle production in 2011 reached 1,648,505 units (3.1% growth from 2010).[43] Two main Iranian companies –. Iran Khodro Industrial Group (IKCO) and SAIPA Automotive Manufacturing Group – are the largest local automakers (with more than 95% of Iran's car production).

[40] Iran Cement Portal. Retrieved April 11, 2013 from: http://www.irancement.com
[41] Iran Water Resource Management Co., 2012. Retrieved January 25, 2012 from: http://daminfo.wrm.ir/home-fa.html
[42] Behrooz Abdolvand, David Ramin Jalilvand, Fardin Eskafi, (2012), *Iran versus USA: Geburtswehen einer neuen Weltordnung*, *Eine geopolitische Analyse*, WeltTrends Papiere 21, Universitätsverlag Potsdam, p.12.
[43] The International Organization of Motor Vehicle Manufacturers (OICA), (2012*). WORLD MOTOR VEHICLE PRODUCTION BY COUNTRY AND TYPE. 2010-2011 provisional figures.* Retrieved May 13, 2012, from: http://oica.net/wp-content/uploads/total-2011.pdf

All the produced/imported passenger vehicles in Iran consume gasoline or dual fuel gasoline/CNG. This means that there are no diesel or other fuel options for the vehicles in the country.

The history of Iran's vehicle industry can be divided to four periods of time:

1. Birth of the industry (1959-1978)

Iran's automotive industry started with assembling Jeeps in 1959. After this first experience, some companies started to assemble new cars under license from well-known global brands like GM and Talbot (UK). Some features of this period include:

- assembling cars under license from well-known automakers
- non-real technology transfer
- no innovation in products
- no plan to produce important complicated parts (e.g. engine)

Iran's automotive industry in this era was based on mass production, assembling foreign brands in order to supply the internal market. In this period, Iran's society was beginning to modernize, and introducing vehicles accelerated this trend.

2. Stagnation, endeavor to survive (1979-1990)

Because of economic crises raised by the Islamic Revolution and the war with Iraq, the Iranian government tried to protect the industry in this period. Hence, the number of vehicles produced fell considerably, to much less than the established capacity. Nationalizing private companies was one of the outcomes of this period. In summary, the main features of this period include:

- no plan, no strategy
- sharp decrease in production
- quality drop
- nationalizing private automakers

3. Growth and maturity (1990-2005)

After the war with Iraq and the deployment of the first Five Year Development Plan (1989–1993), the industry started to recover. Developing foreign relations and absorbing foreign direct investment (FDI) helped the industry to develop. During this period, two FYDPs were deployed and some new products were manufactured in Iranian factories.

Manufacturing many vehicle parts inside the country, considering quality and competitiveness were the turning points of this period. The following activities differentiate this period from the previous ones:

- Developing long-term and strategic plans for Iranian automakers
- Establishing research and development (R&D) departments in the automotive industry
- Development in supply chain management (establishing SAPCO and Sazeh Gostar Co.)
- Development in marketing management
- Continual improvement of quality in the new vehicles
- Cost reduction with mass production
- Developing joint venture contracts with foreign partners

In this period, Iran's automotive industry aimed to raise production standards to the world industry level.

4. Early senescence (2006 – present)

Iran's automotive industry has witnessed growth in recent years primarily on the back of the Iran Khodro Company's aggressive production and expansion plans. Large government subsidies and trade restrictions have reduced competition in the industry and facilitated strong domestic growth, although those measures have also hidden financial and operating weaknesses.[44]

After manufacturing 1 million vehicles in 2006, Iran's vehicle industry was considered a new global producer. But, the industry faced new concerns: limitation of the internal market and

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[44] Business Monitor International (BMI), (2012), *Iran Autos Report Q2 2012*, Business Monitor International, London, p.5

change in customers' tendency to buy new models and more modern cars. The challenges of the industry in this era include:

- Keeping and improving quality of products at a proper level
- Reducing costs and optimizing final prices
- Manufacturing competently with new technologies
- Competition with new models of imported cars
- Manufacturing new models to introduce for internal and external markets

Business Monitor International believes that by saturating the Iranian local vehicle market, the industry has to rely on expanding its ties with the foreign markets through joint venture cooperation. For example, IKCO has been expanding its ties with Turkey through joint ventures (JVs) as part of a broader effort by the Turkish and Iranian governments to increase bilateral trade.[45] These co-operations empower the industry to meet Western emissions standards and improve quality issues. However, limiting the purchasing power of the market can restrict the industry.

BMI forecast the annual economic growth at an average of 2.28% in 2011-2016. Consequently, they expected stable vehicle production and strong sales for the next five years. BMI also forecast that production will remain roughly at 1.6 million vehicles over their forecast period.[46]

According to the International Organization of Motor Vehicle Manufacturers (OICA), Iran's vehicle industry produced more than 1,648 vehicles in 2011 and was ranked thirteenth globally (Figures 1.10 and 1.11).[47] In this ranking, Iran, with 2% of total global vehicle production, is above the Thailand, the United Kingdom, the Czech Republic, Turkey, Indonesia, Poland, Argentina and Italy (OICA 2012). According to these records, Iran is the largest Automaker in the Middle East and the fifth in Asia, after China, Japan, South Korea and India (Figure 1.10).

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[45] Business Monitor International (BMI), (2012), *Iran Business Forecast Report Q4 2011*, Business Monitor International, London, p.19

[46] Business Monitor International (BMI), (2012), *Iran Autos Report Q2 2012*, Business Monitor International, London, p.5

[47] The International Organization of Motor Vehicle Manufacturers (OICA), (2012), *2011 PRODUCTION STATISTICS*, Paris, France. Retrieved July 10, 2012 from: http://oica.net/category/production-statistics/

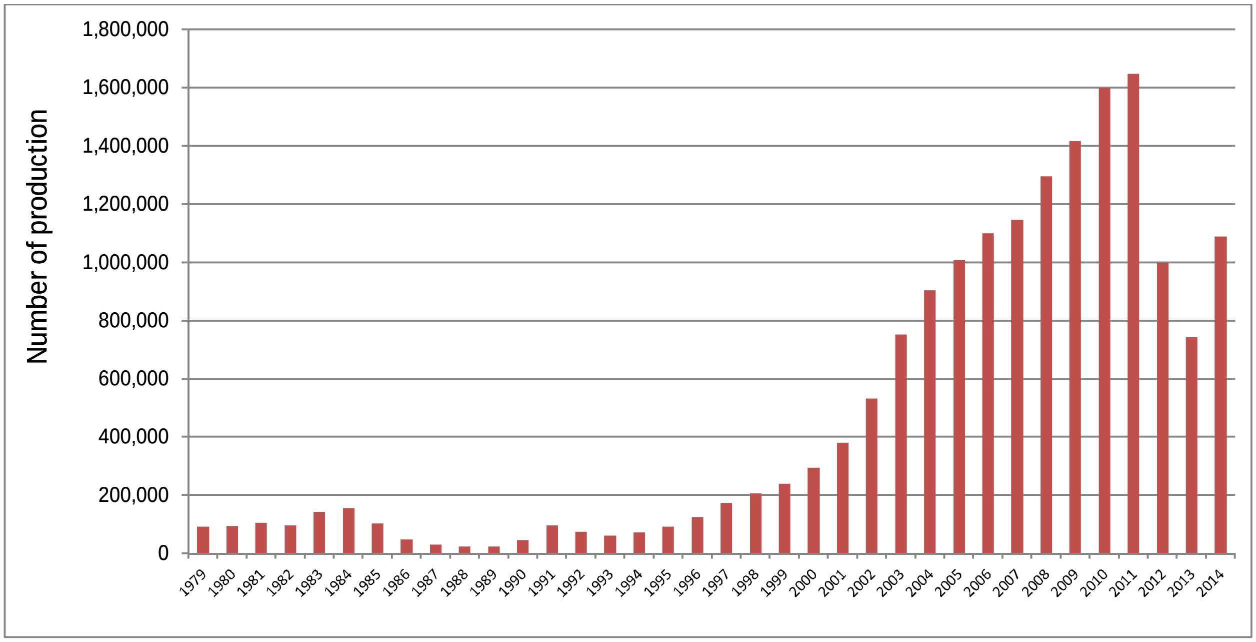

Figure 1.10 Iranian car production trend (1968-2013)

Sources: Iran Ministry of Industry, Mine and Trade, (2010)

The International Organization of Motor Vehicle Manufacturers (OICA), 2015

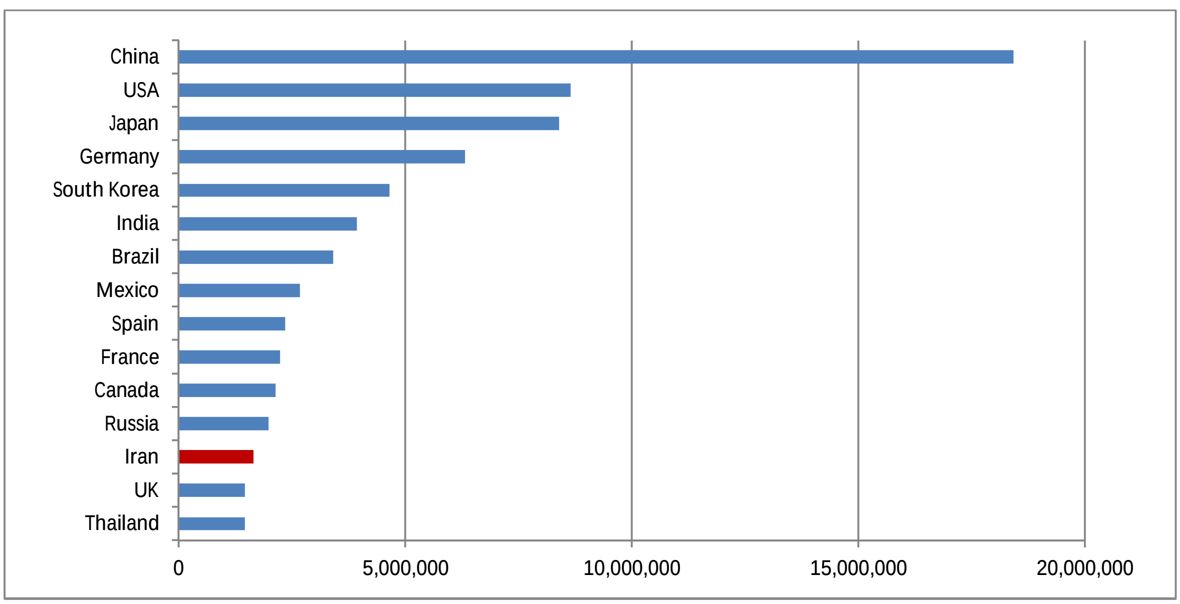

Figure 1.11 Global top 15 vehicle production ranking (2011)

Source: The International Organization of Motor Vehicle Manufacturers (OICA), 2012

Owing to the financial problems arising from economic sanctions – such as funds shortages, especially in supply chain – Iran's vehicle production decreased sharply in 2012 (-40% in comparison with 2011) and 2013 (-25.6% in comparison with 2012). Hence, the local market has been faced with increasing the prices of new products since early of 2013.[48] Iranian automakers renovated their capacity and produced over 1.09 million of vehicles in 2014. Although the financial sanctions have restricted Iranian automakers, the industry has adjusted to the new situation. Using local sources for supplying inputs and finding other foreign partners has helped local automakers to continue producing and to cope with sanctions.[49]

1.3.6. Employment in Iran's automotive industry

According to the WTO, Iran's automotive industry produced 16% of total value added in the country's industrial sector in 2010: 3.7 billion USD.[50] In fact, the industry has had a significant role in employment growth in the country. Table 1.4 shows the direct employees that work in the main Iranian automakers (i.e. Iran Khodro, SAIPA, Pars Khodro, SAIPA Diesel, Zamyad and Iran Khodro Diesel). According to the table, the number jobholders in Iran's automotive industry has grown more than 140% in this period.[51]

Table 1.4 Direct employees in the main Iranian automakers

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
22,862	27,783	34,111	38,188	40,774	41,065	45,363	45,729	45,333	47,867	53,179	55,022

Source: IFCO 2012

[48] Iran's automakers produced 1,000,089 and 743,680 vehicles in 2012 and 2013 respectively.
[49] Fardin Eskafi, (2013), *Iran's Automotive Industry: Coping with Sanctions*, Caspian Energy and Environment Bulletin, No.3, 2013, Iran's Internal Market, Berlin Center for Caspian Region Studies, Berlin, Germany, pp.21-26.
[50] Jahan-e-San'at, (February 16, 2012), *'Sahm-e 16% Sanat-e Khodro-ye Iran dar Arzesh-e Afzoode-ye Melli'* (*16% Share of Iran's automotive industry in the national value added)*, NO.2177, Tehran, Iran, p.7. Retrieved April 15, 2013 from: http://archive.jahanesanat.com/pdf/1390/11/27/07.pdf
[51] Iranian Fuel Conservation Company (IFCO) (2012), *Transportation Energy Data Book 2011*, Tehran, Iran. Retrieved April 15, 2013 from: www.ifco.ir

The automotive industry is the driver of development in Iran. Some reports say that this industry involves 50 types of sub-industries directly (such as spare parts in the supply chain) and more than 60 types indirectly (such as transportation, car services, etc.). It should be noted that, based on this point of view, 700,000 jobs directly and 2.4 million jobs indirectly depend on the automotive industry (i.e. more than 10% of the 24 million actively employed in the country).[52] These statistics show the important role of automotive industry in Iran's development plans.

[52] Shargh Newspaper, (January 9, 2013), Number 1644, p.4 Retrieved April 15, 2013 from: http://www.sharghdaily.ir

1.4. Problem definition and main research question

Climate change is a global concern of all developed and developing countries. It is in the interest of each country or region to lobby even more for national adoption of policies to reduce its effects, since every region benefits from reduced climate damage.[53] This research will describe the problem from the perspective of Iran's transportation sector.

1.4.1. Iran's status in carbon dioxide emissions

Thanks to BP, Iran is the world's fifth-largest oil-producing country after Saudi Arabia, the Russian Federation, the United States and China.[54] It is not surprising that oil and gas account for the largest fraction of Iranian carbon dioxide emissions. Natural gas and petroleum products have had the largest share in Iran's final energy consumption, nearly 90% in 2012 (Figure 1.12). Oil and gas resources have played a significant role in supplying energy for Iran's Five-Year Development Plans.

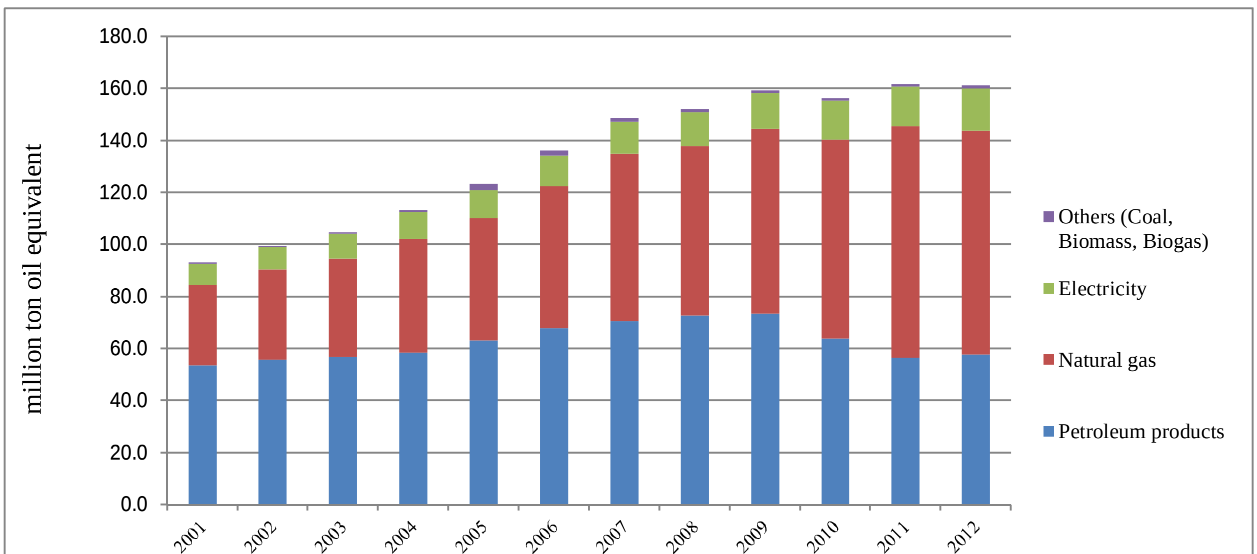

Figure 1.12 Iran's final energy consumption (million tons of crude oil equivalent)

Source: Iran Energy Balance 2012, 2013

[53] Stef Proost, (2008), *Full Account of the Costs and Benefits of Reducing CO_2 Emissions in Transport*, OECD/ITF, JTRC Discussion Paper 2008-3, p.17. Retrieved August 10, 2012 from: www.internationaltransportforum.org

[54] British Petroleum (BP), (June 2014), BP Statistical Review of World Energy, p.10. Retrieved 31 December, 2014 from: http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf

Iran experienced an industrialization era after the end of the war with Iraq in 1988. In the process, total primary consumption grew significantly from 2.7 quadrillion Btu in 1988 to more than 9.1 quadrillion Btu in 2010 (over 3.3 times).[55] Thus, increasing CO_2 emissions from fossil fuels is the main environmental outcome of energy consumption for all economic sectors of the country. According to statistics, CO_2 emissions per GDP, using purchasing power parities,[56] in Iran have increased significantly from 0.41 to 0.51 kilograms CO_2/USD, using 2005 prices from 1990 to 2012 (IEA 2014).[57] This means that for producing each USD in Iran's economy – in comparison with the world and the most rapidly growing economies – the country has consumed much more energy and so has emitted more carbon dioxide (Tables 1.5 and 1.6).

Table 1.5 CO_2 emissions per GDP using purchasing power parities in kilograms CO_2 / US dollar, using 2005 prices, in Iran, and selected regions and countries

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**%Change 90-12**
World	0.54	0.49	0.45	0.43	0.40	0.39	0.38	-27.9%
EU-28	0.42	0.37	0.32	0.30	0.26	0.25	0.25	-40.9%
US	0.59	0.55	0.49	0.44	0.40	0.38	0.36	-39.7%
China	1.38	1.07	0.79	0.81	0.65	0.65	0.62	-55.2%
Iran	0.41	0.49	0.50	0.51	0.49	0.49	0.51	23.3

Source: IEA 2014

Table 1.6 Iran's GDP using purchasing power parities in billion 2005 USD

1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**%Change 1990-2012**
430.0	515.3	628.3	824.7	1042.4	1073.7	1053.3	141.6%

Source: IEA 2014

[55] US Energy Information Administration (EIA), (2013), *Country Analysis Brief Overview: Iran*. Retrieved April 22, 2013 from: www.eia.gov/countries/country-data.cfm?fips=IR
[56] Purchasing power parities are the rates of currency conversion that equalize the purchasing power of different currencies. A given sum of money, when converted into different currencies at the PPP.rates, buys the same basket of goods and services in all countries. In other words, PPPs are rates of currency conversion that eliminate the differences in price levels between different countries (IEA 2012: 37).
[57] International Energy Agency (IEA), (2014), *CO_2 Emissions from Fuel Combustion: Highlights*, OECD/IEA, Paris, France, pp.81-83.

As is evident from Figure 1.13, the total CO_2 emissions from different Iran economy sectors in 2012 was about 556.9 million tons, with the energy sector (refineries and power plants) contributing over 34% of the total emissions, and the transportation, household, commercial, public and agriculture sectors contributing about 23.5%, 22.9% and 2.3% respectively.[58]

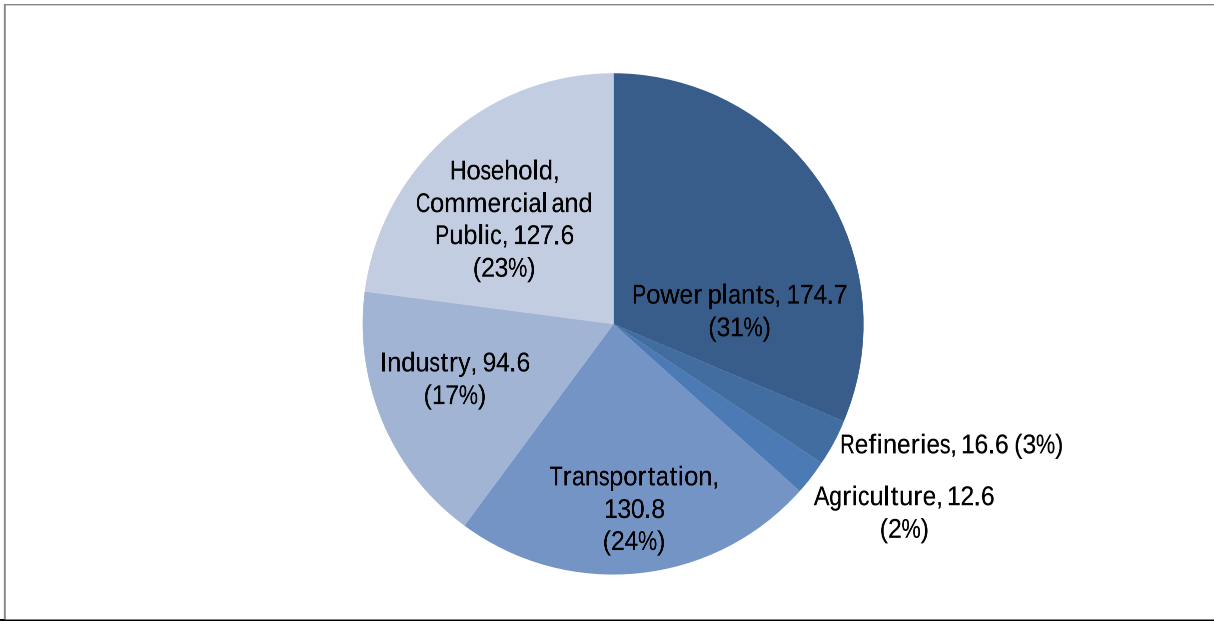

Figure 1.13 Iran's carbon dioxide emissions by sector in 2009 (million tons of carbon dioxide)

Source: Iran Energy Balance 2012, 2013

Along with Iran's growing economy, total carbon dioxide emissions have grown continually from 1988. This is because of growth in industrialization, development of natural gas end-users (especially household and power generation) and huge development in road transportation (e.g. number of vehicles) on the one hand, and a lack of energy efficiency improvement in the economy sectors on the other (Figure 1.14). Statistics show that, along with almost stable CO_2 emissions per capita in the European Union from 1990 to 2009, gradual growth in Iran meant it exceeded the EU in 2008 (Figure 1.15).

[58] Iranian Ministry of Energy (MOE), (2013), *Iran Energy Balance 2011*, Tehran, Iran, p.251.

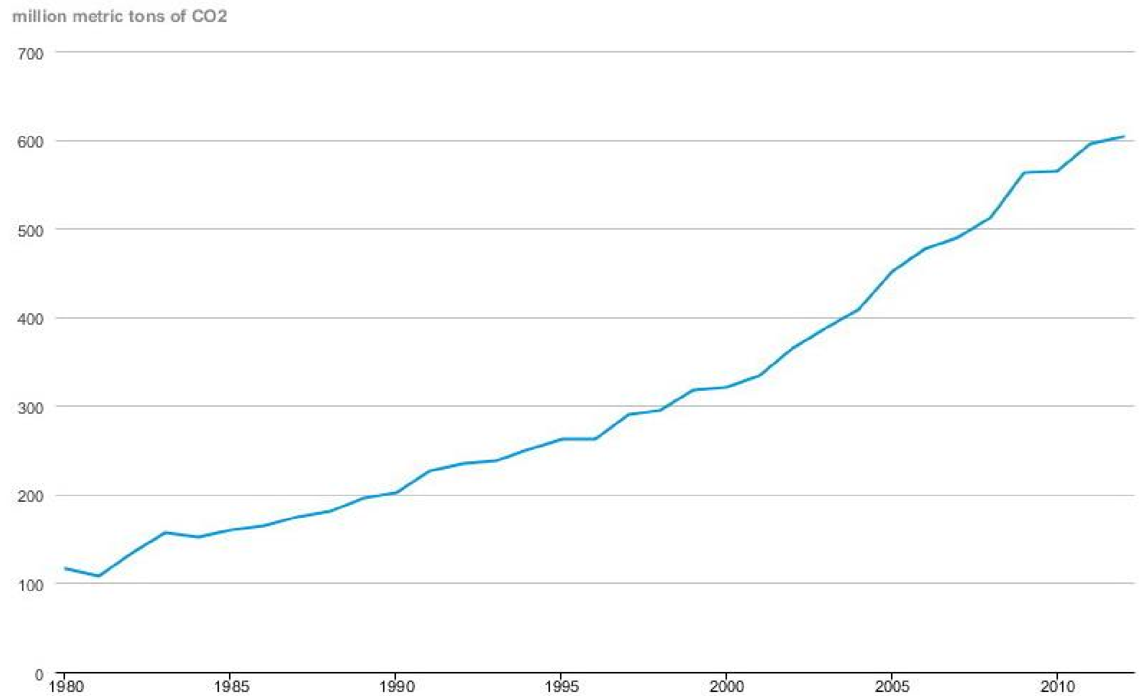

Figure 1.14 Iranian CO_2 emissions trend (1980-2012) (Million metric tons of CO_2)

Source: US Energy Information Administration, 2014

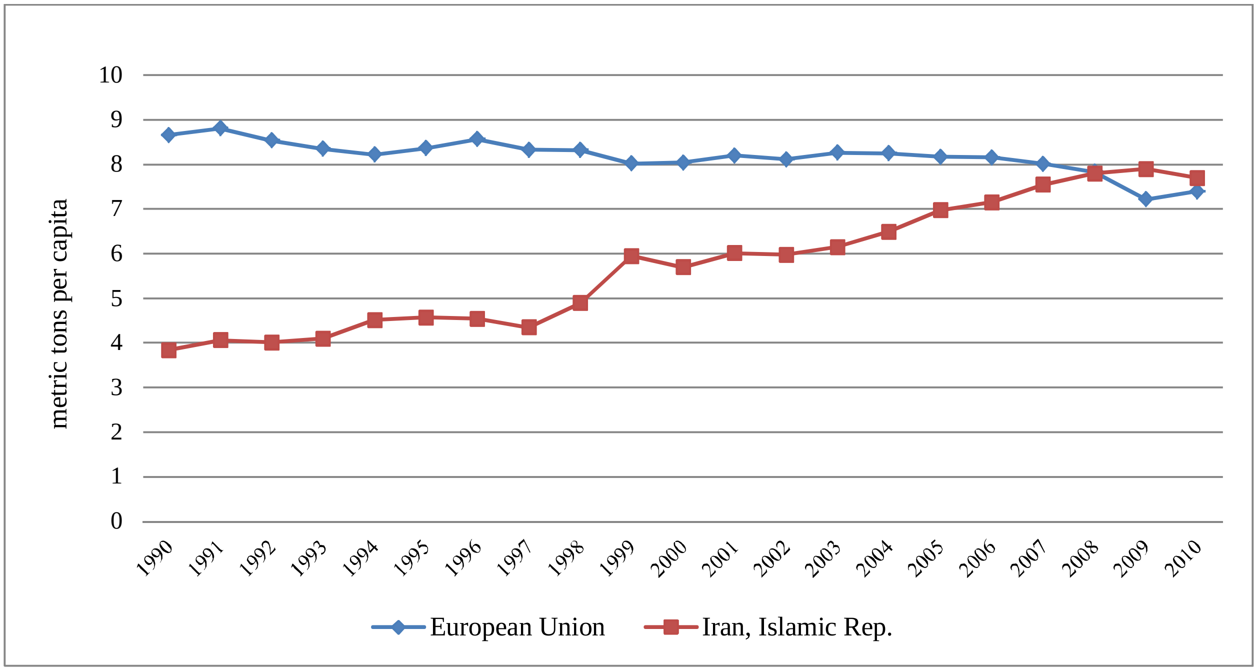

Figure 1.15 Iran and EU CO_2 emission per capita trends (1990-2010) (Metric tons of CO_2 per capita)

Source: World Bank, 2013

According to the IEA, Iran was among the top ten CO_2-emitting countries in 2012 (Figure 1.16).[59] Nearly two thirds of global CO_2 emissions for 2012 originated from these countries, with the shares of China (26%) and the United States (16%) far surpassing all the others.[60]

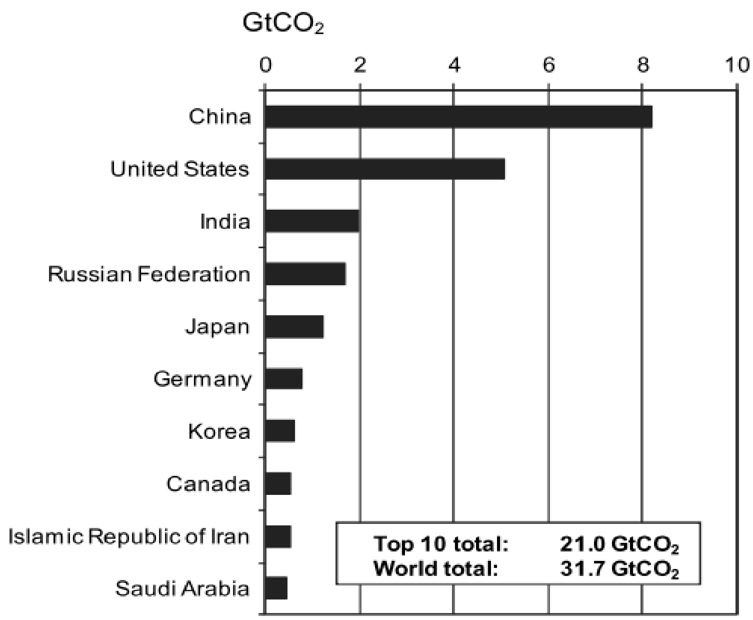

Figure 1.16 Top 10 emitting countries in 2012 (Gt CO2)

Source: IEA 2014

1.4.2. Energy intensity in Iran

Iran's economy is highly energy-intensive[61]. The energy intensity value in Iran is higher than most industrial economies and also higher than more densely populated developing countries such as China and India. The main reason for this concern is low energy prices, which have led to over-consumption of energy and low efficiency. Meanwhile, the presence of energy-intensive industry such as metal and petrochemical plants is also a contributing factor. Iran's energy intensity has grown increasingly since 1980 (Figure 1.17). Sabetghadam argues that the growth

[59] The IEA reported Iranian CO_2 emissions in 2010 were equal to 509 million tons.
[60] International Energy Agency (IEA), (2014), *CO_2 Emission from Fuel Combustion: Highlights*, OECD/IEA, Paris, France, p.10.
[61] Energy intensity is an indicator to show the energy efficiency of a country by calculating units of consumed energy per units of produced GDP. Thus, high energy intensities indicate a high price or cost of converting energy into GDP, and vice versa.

of this indicator may be partly explained by welfare improvement (hence household consumption), but mismanagement is undoubtedly the main cause.[62]

Figure 1.17 Iranian total primary energy intensity trend (1980-2011) (Btu per 2005 USD)

Source: US Energy Information Administration, 2014

Figure 1.18 depicts the energy intensity status of some regions in terms of final energy consumption intensity based on purchasing power parity in 2012. Iran's energy consumption for producing goods and services weak and the country is ranked among the regions with high energy intensity. According to the information of Figure 1.18, energy intensity in Iran is much more than oil producers such as Saudi Arabia and Venezuela. In 2012, producing each million UD dollars of the world value added has consumed more than 115 tons of crude oil equivalents, and for Iran more that 50% of the world level.

[62] Morteza Sabetghadam, (2006), *Energy and Sustainable Development in Iran*, Institute for International Energy Studies (IIES), A report prepared by HELIO International, Paris, France, p.32. Retrieved April 24, 2013 from: www.helio-international.org/reports/pdfs/Iran-EN.pdf

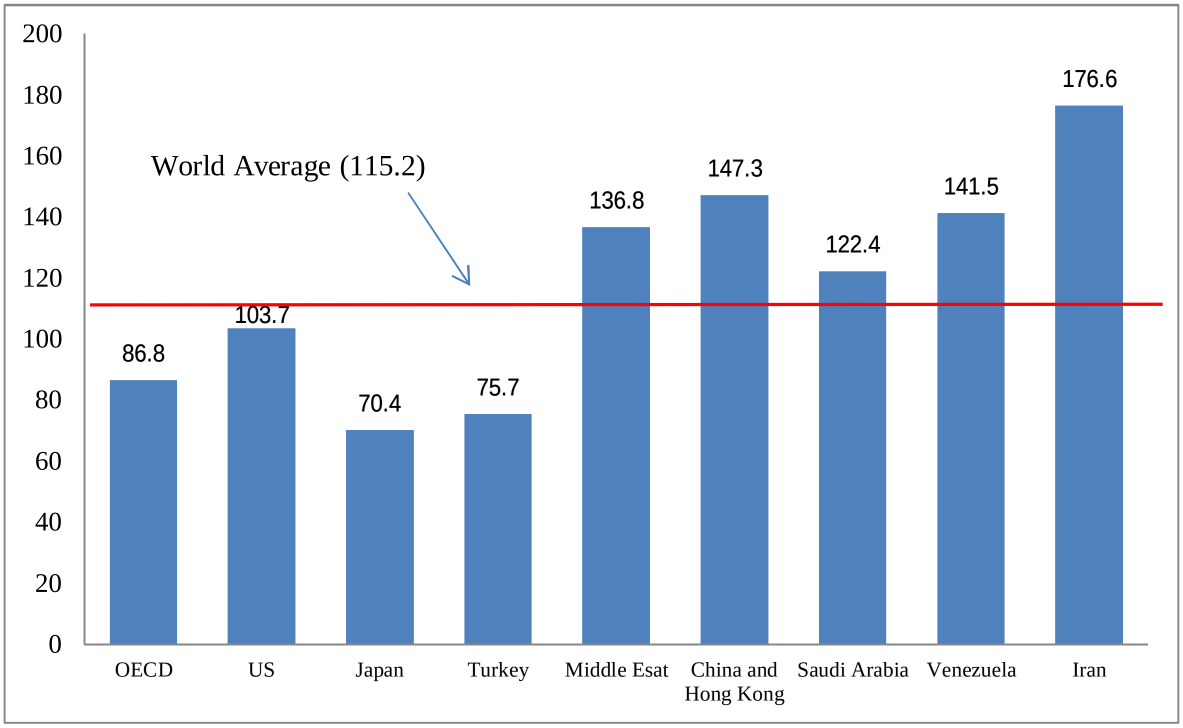

Figure 1.18 Final energy consumption intensity based on purchasing power parity in 2011 (toe/million USD)

Source: Iran Energy Balance 2012, 2013 in: IEA, International Energy Agency, Online Data Services

The growing trend of energy intensity leads to increasing environmental pollution and greenhouse gas emissions. Carbon intensity is an indicator to illustrate the amount of carbon dioxide emitted for producing goods and services. According to the US Energy Information Administration, the carbon intensity measure for Iran grew sharply from 2007 to 2011 in comparison with some neighbor countries. However the measure decreased for many regions and countries in the same period (Table 1.7).[63]

[63] US Energy Information Administration, 2013, *International Energy Statistics*, Retrieved April 25, 2013 from: www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=91&pid=46&aid=31

Table 1.7 Carbon intensity using market exchange rates (Metric Tons of Carbon Dioxide per thousand year 2005 USD)

	2007	**2008**	**2009**	**2010**	**2011**	Change% 07-11
World	0.59933	0.6015	0.61455	0.61647	0.61209	2.1
Europe	0.2941	0.28903	0.28021	0.27895	0.27229	-7.4
Middle East	1.18505	1.20277	1.27254	1.26445	1.3051	10.1
United States	0.45632	0.44405	0.42603	0.4315	0.4123	-9.6
China	2.17806	2.09988	2.17836	2.08278	1.93722	-11.1
Germany	0.2789	0.27552	0.27232	0.27006	0.25935	-7.0
Venezuela	0.87256	0.87829	0.88205	0.99076	0.9455	8.4
Saudi Arabia	1.18332	1.21899	1.26417	1.29993	1.43916	21.6
Iran	2.08577	2.19763	2.47088	2.42185	2.47036	18.4

Source: US EIA, 2013

1.4.3. Energy consumption and greenhouse gas emissions in Iran's transportation sector

Many diverse factors have an impact on levels of energy use and CO_2 emissions, such as travel patterns, income level, car ownership rate and average fuel economy.[64]

Economic growth during Iran's Five-Year Development Plans has brought growing domestic income (Table 1.8).[65] The number of passenger cars in Iran (both produced by local automakers and imported vehicles) grew from nearly 3 to more than 9.4 million during the Fourth FYDP from 2005 to 2009 (218% growth).[66] Owing to this trend, since the mid-2000s and after dramatic growth in car production in Iran, the motorization rate of passenger cars (number of passenger cars per 1,000 inhabitants) increased from 39 in 1977 to 115 in 2009. It should be noted that Iran's population grew in this period from 61 million in 1997 to 73.6 million in 2009.

[64] International Energy Agency (IEA) (2008), *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis*, Paris, France: OECD/IEA, p.60. Retrieved June 25, 2010 from: http://www.iea.org/papers/2008/indicators_2008.pdf

[65] World Bank, (2013), *Iran data profile.* Retrieved April 13, 2013 from: http://data.worldbank.org/country/iran-islamic-republic

[66] Iranian Fuel Conservation Company (IFCO) (2010), *Transportation Energy Data Book 2009*, Tehran, Iran. Retrieved April 27, 2012 from: www.ifco.ir

Table 1.8 Iran’s gross domestic income (constant 2005 USD)

2000	2002	2004	2006	2008	2010	2011	2012	2013
101.3	117.2	138.0	158.7	186.7	n/a	209.8	218.9	228.6

Source: World Bank 2013

The motorization rate of passenger cars in Iran is growing significantly. Mazraati simulates vehicle ownership in Iran with a logistic model based on data of the time period 1970-2005. He estimates 3.5% annual economic growth and 1.1% population growth by 2020 in comparison with 2005, and also considers a total 25% improvement in car fuel efficiency for the simulated time span. He finally forecasts that the motorization rate of cars (passenger and commercial cars) in 2020 will hit 210 to 260 cars per 1,000 inhabitants. Mazraati concludes that supplying proper fuel for this huge car fleet is a challenge for policy makers and he suggests that ‘energy subsidies removing’ can be counted as an appropriate alternative policy to control fuel consumption in Iran’s transportation sector.[67]

The growth of Iran’s car fleet, in parallel with economic growth, has raised fuel consumption in the transportation sector from 172 million barrel of crude oil equivalent in 1999 to near 300 million barrels of crude oil equivalent in 2012 (near 75% growth in 13 years) (Figure 1.19).[68] Because of improper growth of public transport in Iran, the proportion of private transportation has grown increasingly. Thus, the share of the transportation sector in fuel consumption grew from 47.6% in 1999 to 60% in 2009.[69] Mazraati forecasts that Iran’s total car fleet will consume 266 million liters of fuel (both gasoline and diesel) per day in 2025 if it hits over 211 vehicles per 1,000 inhabitants.

Among the EU-27 Member States, the highest motorization rates in 2009 belonged to Luxembourg and Italy, with 672 and 606 passenger cars per 1,000 inhabitants respectively. In 2009, seven more Member States (Cyprus, Malta, Austria, Finland Slovenia, Germany and Lithuania) had rates over 500 (i.e. at least one car per two inhabitants).[70]

[67] Mohammad Mazraati, (2006), *Modeling for oil demand in the Iranian transportation sector: Logistic model of number of vehicles*, Quarterly Energy Economics Review, No.8, Spring.
[68] National Iranian Oil Refining and Distribution Company (NIORDC), (2013), *Statistical Data Book*, Tehran
[69] IFCO (2010), op. cit.
[70] European Union, (2011), *Energy, transport and environment indicators*, Eurostat pocketbooks, Luxemburg, p.90.

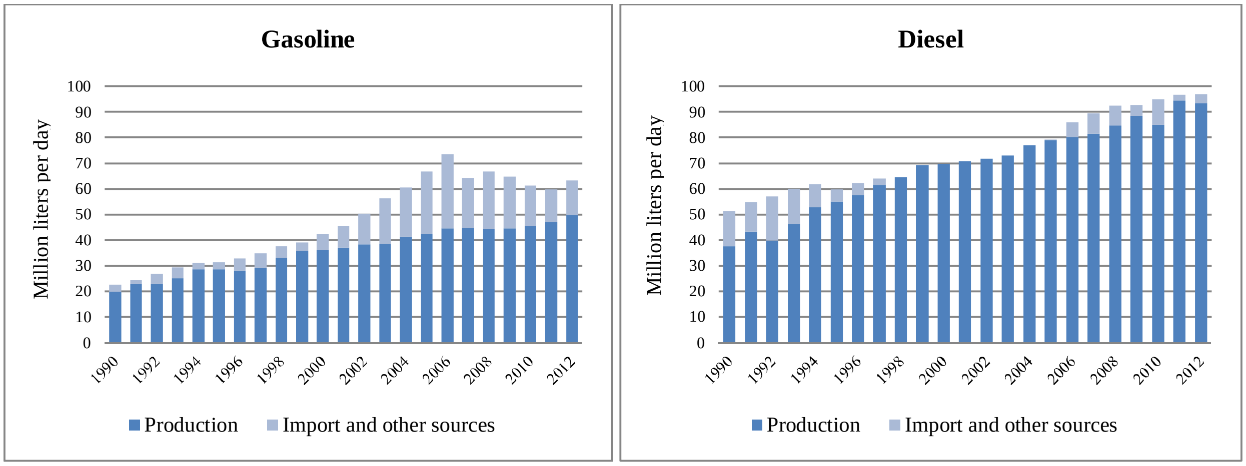

Figure 1.19 Gasoline and diesel consumption in the Iranian transportation sector (million liters per day)

Source: NIORDC 2013

1.4.4. Energy Subsidies in Iran

Iran is one of the most subsidized countries in the world and the most costly subsidy is the hidden/indirect subsidy allocated to energy carriers. According to the IEA, Iran paid 81 billion USD for energy subsidies in 2010, which ranked as the highest of any country (Figure 1.20).[71] If we calculate opportunity costs of energy products sales in the domestic and international markets, then the estimate may vary significantly. It is argued that investing this money into the productive sectors, rather than distributing via direct/indirect subsidies, would be adequate for tackling the country's critical economic problems.

The World Bank report argued that the huge proportion of total energy subsidies in Iran not only distorts consumer choice and obscures state accounts, but is the cause of significant environmental damage.[72]

[71] International Energy Agency, (2011), *World Energy Outlook*, OECD/IEA, Paris, France, p.515.
[72] World Bank, (2004), *Islamic Republic of Iran Energy-Environment Review Policy Note*, World Bank Report No.29062-IR.

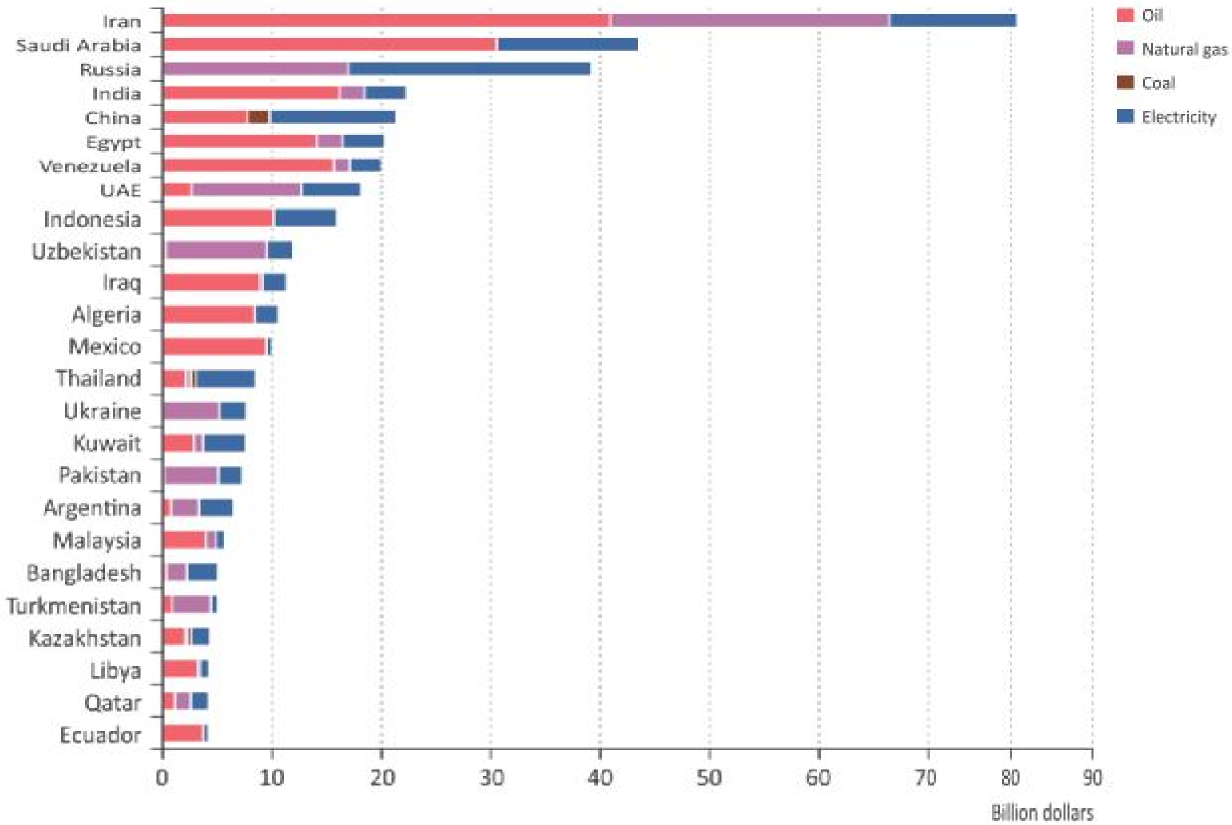

Figure 1.20 Economic cost of fossil fuel consumption subsidies by fuel for top twenty-five economies, 2010

Source: IEA 2011:515

Along with increasing total final energy consumption in Iran, the subsidies allocated to different sectors of the economy have increased since 1988. The Iranian government paid over 442,044 billion Iranian Rails (IR.R) in subsidies to the country's economy in 2009 (Table 1.9).

Table 1.9 Paid subsidies for energy carriers in different economic sectors of Iran (2009)

	Household	**Industry**	**Agriculture**	**Transportation**	**Commercial**	**Public**	**Total**
Billion IR.R	111,478.6	78,817.9	34071.2	177,623.2	16,119.9	23,922.2	442,033
Share(%)	25.2	17.8	7.7	40.2	3.6	5.4	100

Source: Iran Energy Balance 2009, 2010

The transportation sector received 212,894 billion IR.R in 2011, the largest consumer of governmental subsidies in the energy sector (over 40%). The household and industry sectors are the next most subsidized sectors, with 25.2% and 17.8% respectively. The commercial sector had the lowest share in 2009.[73]

Regarding energy carriers, diesel fuel received 27.3% of total subsidies in 2009. Electricity and gasoline are the next most subsidized carriers, with 26.2% and 18.2 respectively.

The Iranian government has had to pay subsidies increasingly in recent years coinciding with the growth of motorization in the country. Gasoline and diesel fuel subsidies have grown over 300% and 400% respectively (Figure 1.21).

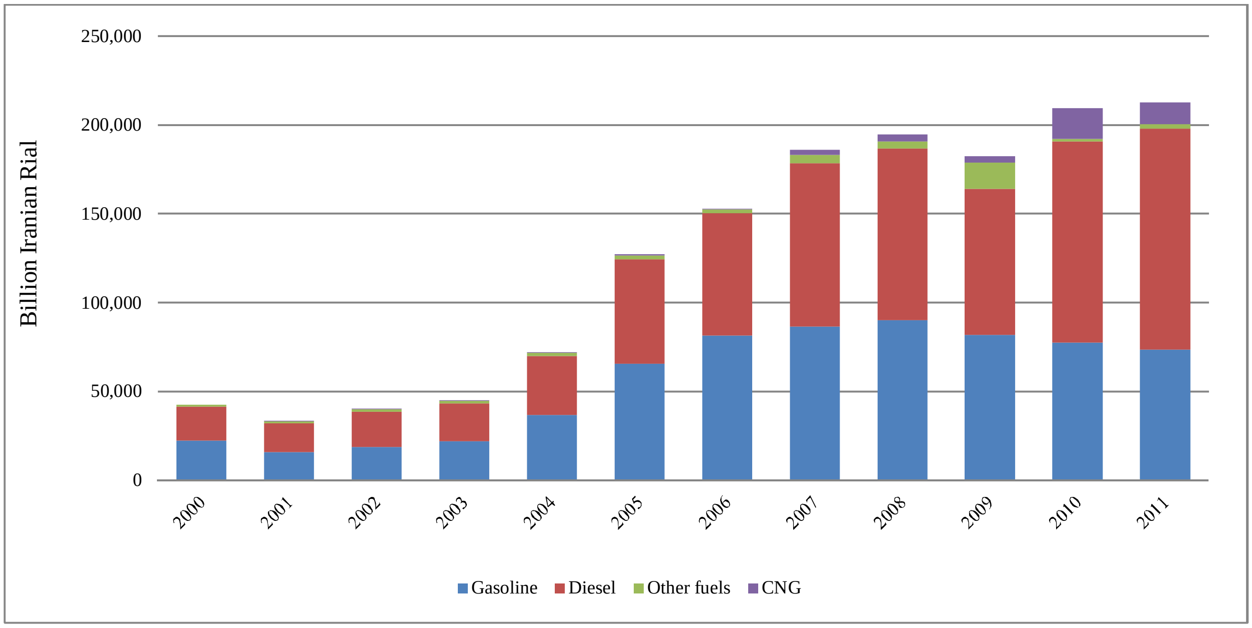

Figure 1.21 Paid subsidies for fuels in the Iranian transportation sector (2000-2011)

Source: Iran Transportation Data Book 2011, 2013

Iran’s Ministry of Power reported that the share of energy in household expenses for the lowest income-level families is more than for the highest ones. Gasoline subsidies for the highest income-level family in whole the country are 22 times more than for a family with the lowest income level.

[73] Iranian Ministry of Energy (MOE), (2011), Iran Energy Balance 2010, Tehran, Iran.

The government pays subsidies to empower consumers against rising prices and to preserve the cost of living. However, in the long term, energy subsidies have many diverse economic and political consequences:[74]

- Increasing energy consumption and higher energy waste
- Weakening incentives for innovation and using efficient technologies
- Degrading the environment by lowering air quality, especially in urban areas
- Placing a heavy burden on the government budget
- Cross-border smuggling of oil products to neighboring countries

The IEA expected that Iran's subsidy status regarding energy will fall significantly in the coming years if the sweeping energy pricing reforms that commenced in late 2010 are implemented successfully and prove durable.[75]

1.4.5. Environmental degradation and air pollution in Iran

Environmental degradation and air pollution are the first outcomes of energy consumption and fossil fuel combustion. For the time being, air pollution is one of the most significant challenges facing Iranian big cities, especially its capital city, Tehran. Air quality in Tehran is monitored by the Air Quality Control Company (AQCC) related to the municipality of Tehran.

Tehran AQCC monitors the air quality index (AQI) according to both national and US EPA ambient air quality standards. AQI is a combination of the main pollutants that are emitted from fossil fuel combustion: carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate material less than 10 microns in diameter (PM_{10}), particulates material less than 2.5 microns in diameter ($PM_{2.5}$), ozone (O_3), lead (Pb) and benzene.[76] The company reports that Tehran experienced just three purely clean days during the Iranian year 1390 (21 March 2011 to 20 March 2012) (Tehran Air Quality Control, 2012) (Table 1.10).

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[74] Mahammad Hassan Panjeshahi, (2012), 'Scenario Analysis for Energy Conservation and CO_2 Reduction in Iran,' paper presented in the 17th REFORM Group Meeting, Salzburg – Austria, August 27-31, 2012. Retrieved April 26, 2013 from: http://www.polsoz.fu-berlin.de/polwiss/forschung/systeme/ffu/veranstaltungen_ab_2012/12_salzburg.html

[75] IEA 2011, op. cit., p.514.

[76] Carbon dioxide (CO_2) is not an air pollutant alone. But, policy makers have focused on CO_2 emissions reduction because of its greenhouse gas effect and also because of the huge amount of emissions to the atmosphere from fossil fuel combustion. In case of any fuel consumption reduction or fuel efficiency improvement approaches, CO_2 emissions reduction and consequently air quality improvement are expected.

Table 1.10 Tehran air quality index status in number of days, based on different pollutants (1381-1390)[77]

	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390
Purely clean	8	11	20	23	36	22	13	41	14	3
Healthy	187	191	257	253	254	328	292	282	246	144
Unhealthy	169	161	88	89	75	15	59	40	104	215
Very unhealthy	1	2	0	0	0	0	1	1	1	3
Dangerous	0	0	0	0	0	0	0	1	0	0

Source: Tehran Air Quality Control, 2012

The problem is compounded by topographical conditions (mountains to the north and east), climatological factors (sunshine, frequent temperature inversions) that trap pollutants over the city and geographical factors (the high altitude of Tehran that makes fuel combustion less efficient).[78]

If the AQI of Tehran is reported very unhealthy or dangerous, the authority decides whether schools are closed, some industrial activities are stopped, and the elderly and the sick are advised to stay indoors.

The Iranian Ministry of Energy (MOE) calculated the amounts of air pollutants and greenhouse gas emissions from different economic sources in 2002 (Figure 1.22). According to these data, the transportation sector – emitting 48% of total nitrogen oxides (NO_x), 97% of total carbon monoxide (CO), 51% of total nitrous oxide (N_2O), 80% of total methane (CH_4) and 76% of total solid particulate materials (SPM) – was the most significant source of air pollutants and greenhouse gas emissions in 2012.[79] It should be mentioned that power plant and transportation sectors were the largest emitters of CO_2 and SO_2 in 2012 (58% and 79% respectively).

[77] The Iranian year begins within a day of 21 March and ends within a day of 20 March of the next Gregorian calendar.
[78] Majid Shafie-Pour, Mojtaba Ardestani, op. cit., 4413.
[79] Iranian Ministry of Energy (MOE), (2012), *Iran Energy Balance 2013,* Tehran, Iran, p.252

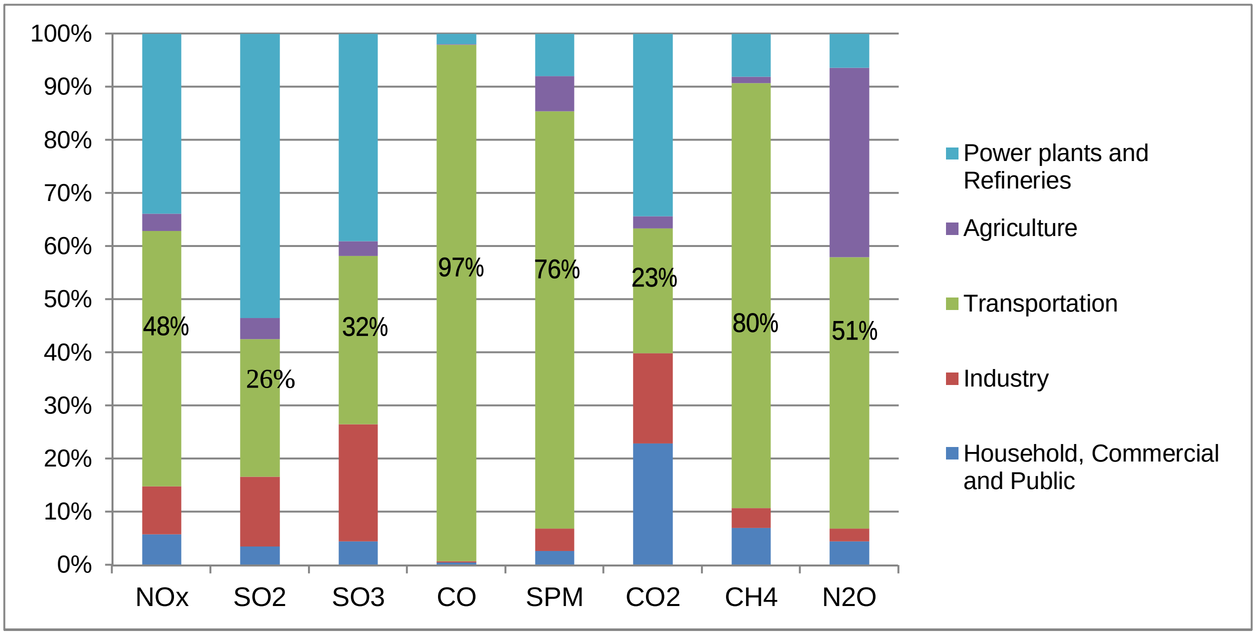

Figure 1.22 Air pollution and greenhouse gas emissions from fossil fuel consumption in Iran (2012)

Source: Iran Energy Balance 2012, 2013

The MOE reported that diesel, fuel oil and gasoline produced the most pollution in 2012. 42% of total NO_x, 34% of total SO_2, 51% of total SO_3, 76% of total SPM and 66% of total N_2O belonged to diesel combustion; 61% of total SO_2, 47% of total sulfur trioxide (SO_3) belonged to fuel oil combustion; and 95% of total CO and 17% of total NO_x belonged to gasoline combustion.

Natural gas is a cleaner fuel in comparison with those mentioned above and causes the least pollution. However, it is responsible for 53% of total CO_2 emissions in the Iranian energy sector.

Road transportation is responsible for a significant proportion of air pollution and greenhouse gas emissions in comparison to other modes (i.e. rail, air and maritime) in 2010. 92% of NO_x, 90% of SO_2, 99% of CO and 95% of CO_2 emissions in the whole sector belong to roads.[80]

1.4.6. Social costs of fuel consumption in Iran

The use of roads does not only contribute to economic growth, prosperity, recreation and so forth. It has some negative side effects such as noise, emission of pollutants and environmental damage. These side effects are labeled ‘external effects’ or ‘externalities’ and the costs

[80] Iranian Ministry of Energy (MOE), (2012), *Iran Energy Balance 2013,* Tehran, Iran, p.255

associated with them (e.g. costs of congestion, accidents, air pollution, noise, and environmental damage) are called 'external costs.'[81] External costs are imposed on society by their producers in economic sectors (i.e. energy consumers) and society has to tolerate the negative consequences such as noise and pollution.

Social costs are the negative impacts of the pollutants or activities on agricultural crops, ecosystems, materials or human health, and often are not internalized in final prices. In other words, social costs or damage costs are the sum of money required to compensate for the damage of pollution and greenhouse gas emissions.

The MOE calculated the social costs of environmental damage from fossil energy carriers based on the methodology of the World Bank and Iran Department of Environment (Iran DOE). The MOE estimated the sum of social costs in Iran in 2012 to be about 102,650 billion IR.R based on 2002 constant prices (Table 1.11). It should be added that this value is about 5% of Iran's GDP in 2012.[82] It can be seen that the transportation sector is by far the largest contributor to environmental damage and social costs, and power generation is the second.

Table 1.11 Iranian social costs of energy consumption by sector and by pollutants in 2010 (billion IR.R using 2002 constant prices)

	NO_x	**SO_2**	**SO_3**	**CO**	**SPM**	**CO2**	**CH4**	**NO2**	**Total**
Final Energy Consumption									
Household, Com. & Pub.	515	785	n/a	68	362	10,210	7	n/a	**11,947**
Industry	807	2,958	n/a	22	593	7,588	3	n/a	**11,951**
Transportation	4,299	5,810	n/a	12,430	10,825	10,463	77	n/a	**43,905**
Agriculture	292	913	n/a	22	915	1,009	1	n/a	**3,153**
Consumption in Energy Sector									
Refinery	n/a	n/a	n/a	n/a	n/a	1,326	1	n/a	**1,326**
Power plant	3,021	12,025	n/a	243	1,099	13,973	7	n/a	**30,368**
Total	8,935	22,491	n/a	12,786	13,794	44,549	96	n/a	**105,998**

Source: Iran Energy Balance 2012, 2013

Dr. Massoumeh Ebtekar, the Vice President and Head of the Iranian Department of Environment, and a member of the City Council of Tehran since 2007, argued that air pollution

[81] Dieter Schmidtchen, Christian Koboldt, Jenny Helstroffer, Brigit Will, Georg Hass,and Stefan Witte, (2009), *Transport*, *Welfare and Externalities*, Edward Elgar Publishing Limited, UK.
[82] The Central Bank of Iran reported the GDP of the country in 2012 as 2,029,287 billion IR.R. in constant rates of 2004. Retrieved January 5, 2015 from: www.cbi.ir/simplelist/2054.aspx

in Tehran has imposed at least 9 billion USD of costs on the health of Iranian big city inhabitants, especially Tehran.[83] Many scholars and politicians believe that vehicles are responsible for over 60% of pollution in Tehran.

Karimzadegan et al. studied the health damage costs from air pollution in Tehran. They used direct medical cost (DMC), contingent valuation (CV) and value of statistical life (VOSL) approaches and the household production model of health. According to the study, Health damage costs were estimated at 16,224 USD per each unit increase of PM_{10}, 28,816 USD per each unit increase of CO, 1927 USD per each unit increase of NO_2 and 7,739 USD per each unit increase of SO_2.[84]

The Iranian government has followed a comprehensive plan for phasing out old and worn out vehicles, although about 13% of passenger cars, 23% of buses, 39% of minibuses 9% of pickups, and 58% of trucks were over 20 years old and still travelling on the roads.[85]

Article 62 of the Fourth FYDP committed the government to phase out all the old age vehicles between 2005 and 2009, removing 200, 300, 400, 500 and 600 thousand vehicles, respectively. But, practically, the objectives of the plan have not been met. Table 1.12 shows the number of light-duty and commercial vehicles that were phased out from 2005-2009 in Iran.

Table 1.12 Number of phased-out vehicles in Iran, 2005-2009

	Passenger cars	Buses	Minibuses	Pick-ups	Trucks	Total	Planned
2005	57,200	1,647	1,996	10,676	741	72,260	100,000
2006	126,596	1,307	2,631	5,694	409	136,637	200,000
2007	204,850	1,760	3,491	6,534	825	217,460	300,000
2008	145,540	1,361	2,657	6,904	686	157,148	400,000
2009	127,408	1,086	2,049	8,006	786	139,335	500,000

Source: IFCO 2010

83 Farsnews, (April 30, 2013), 'Aloodegi-ye Hava Moáadel-e 9 Miliyard Dolar Hazineh be Salamat-e Mardom Tahmil Kardeh Ast,' Retrieved May 1, 2013, from: www.farsnews.com/newstext.php?nn=13920210000378

84 H. Karimzadegan, M. Rahmatian, DD. Farhud, M. Yunesian, (2008), 'Economic Valuation of Air Pollution Health Impacts in the Tehran Area,' *Iranian Journal of Public Health*, Vol. 37, No.1, 2008, pp.20-30.

85 Iranian Fuel Conservation Company (IFCO) (2010), *Transportation Energy Data Book 2009*, Tehran, Iran, p.83

With the production of new vehicles by local automakers and also the increase in income levels of Iranian households, the number of new vehicles has increased. By phasing out the old vehicles, it is expected that the average age of the vehicles will continue to decrease. However, tackling air pollution needs more restrictive standards in the transportation sector. Figures 1.23 and 1.24 compare the average age of road vehicles in Iran and the EU.[86]

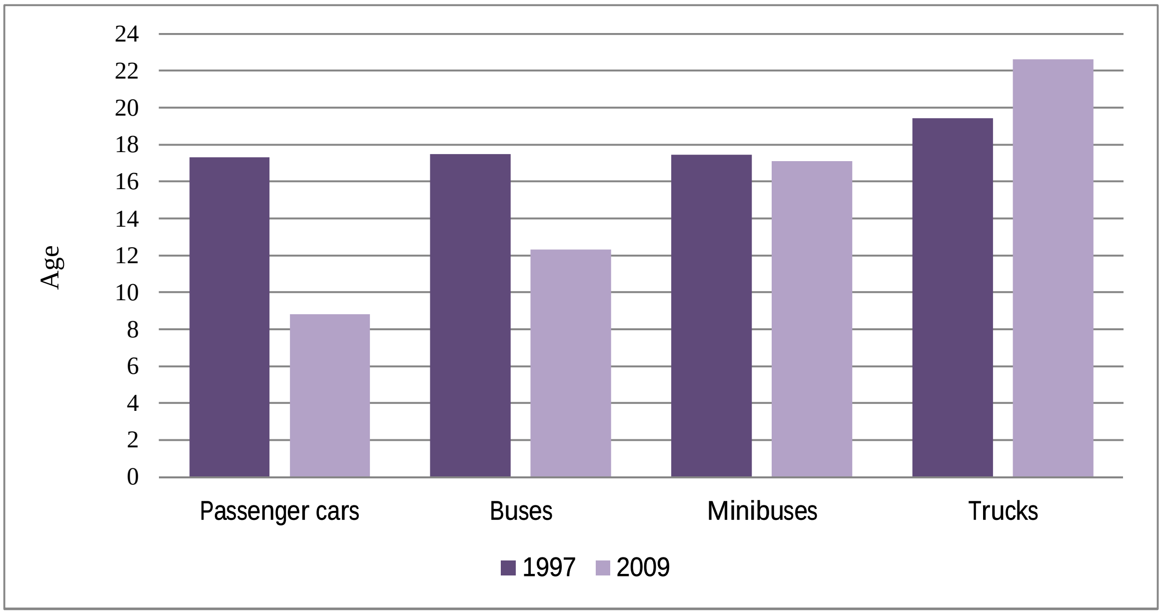

Figure 1.23. Average age of road vehicles in Iran in 1997 and 2009

Source: IFCO 2010

[86] European Environment Agency, (2013), *The Average age of road vehicles*, Last modified November 29, 2012 Retrieved May 1, 2013 from: http://www.eea.europa.eu/data-and-maps/figures/average-age-of-road-vehicles

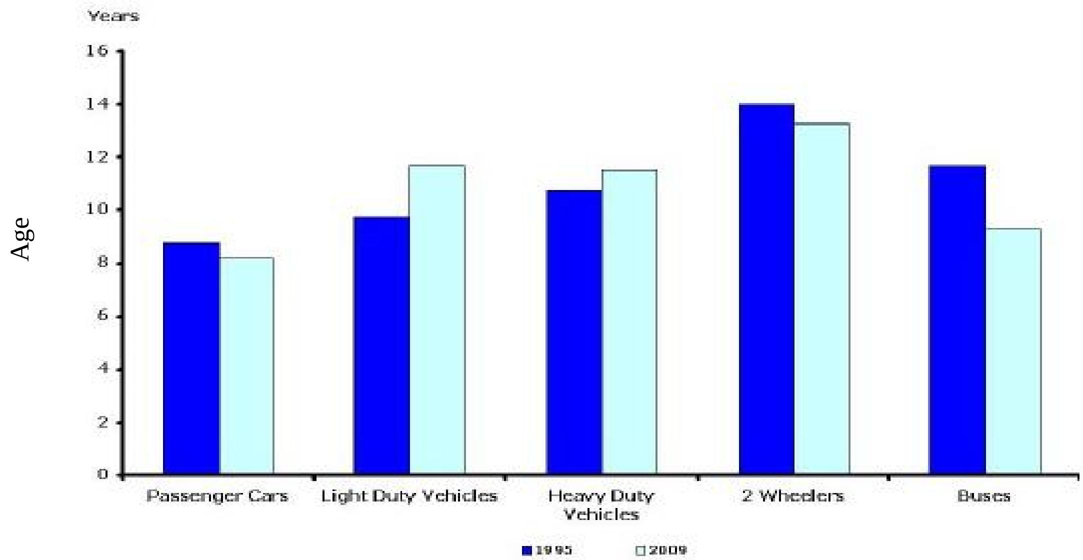

Figure 1.24 EU average age of road vehicles in 1995 and 2009

Source: European Environment Agency, 2012

1.4.7. Main research question

Global warming is the most important environmental issue facing global society. The transportation sector, as the main fossil energy consumer, is responsible for a significant proportion of carbon dioxide emissions, and policies to reduce emissions in this sector need more consideration:

- Mobility of emission sources
- Variety of vehicles' production technologies
- Expanded consumption market across the whole world

Iran's automotive industry has deployed European standards and the main Iranian automakers have had close relations with European companies. Hence, this research will try to benchmark carbon dioxide emissions reduction policies in the European Union.

According to what has been set out above, the main question of this research is:

How can the policies of the European Union's transportation sector be applied to Iran in order to reduce CO_2 emissions in the Iranian transportation sector?

I will attempt to answer the following sub-questions:

- What are the priorities of EU policy makers with regard to CO_2 emissions reduction in the transportation sector in comparison to their Iranian counterparts, and what are their instruments for deploying these strategies?
- Who are the players in each policy area and what are their roles therein?
- What are the policy instruments to reduce CO_2 emissions in Iran's transportation sector in comparison with EU?
- What are the methods and systems for policy monitoring and evaluation?
- What are the challenges for Iran's vehicle industry in reducing CO_2 emissions?
- What can be learnt from the successes and failures of the EU's automotive industry in reducing greenhouse gases?

Research objectives

1. The aim of this research is to illustrate and describe the factors that affect CO_2 emissions in the transportation sector in both Iran and the European Union (EU).
2. In addition, the research tries to compare the facts and features in both the EU and Iran, and to investigate the roots of developed policies and strategies to reduce carbon dioxide in the transportation sector.
3. Finally, the study aims to analyze the reasons for failures and successes in deploying related policies, and to suggest more appropriate policies to meet the expected objectives in CO_2 emission reduction in Iran's transport sector.

1.5. Methodology

'Comparison' is a fundamental method in scientific research. In comparative social science, the researcher normally investigates the similarities and differences between macro social cases. Ragin argued that the comparative method is traditionally qualitative and tends to be case-oriented, as opposed to variable-oriented.[87]

If we define carbon dioxide in the transportation sector as a dependent variable, the effective policies of this variable should be focused on three main pivots (independent variables):

- vehicle industry (vehicle supply side)
- consumers (demand side)
- fuel supply side

As Table 1.13 shows, independent variables in level II affect carbon dioxide emissions in more ways and, hence, policymakers should address players at each level with appropriate policies. In this study, because of the variety of variables in level II and the limitations of a research activity, I will focus on the vehicle industry.

Policymakers have given significant consideration to climate change during the last three decades.[88] In this respect, GHG emissions in the transportation sector, in contrast with other main sectors like energy and industry, have their own features. Thus, policy-making in this context involves more complicated considerations. Automotive industries are spread across countries and vehicle global markets are as vast as the road network. Because of the mobility of vehicles all around the world, the related policies have specific complications, in contrast with non-mobile sources.

In this research, as a *qualitative comparative analysis*, the complexities of different combinations of causal conditions that result in carbon dioxide emissions in the transportation sector will be studied. The European Union will be considered as a leading and developed pivot in the vehicle industry.

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[87] Charles C., Ragin, 1987, *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*, University of California Press, California, USA.

[88] United Nations Environment Program (UNEP) and World Weather Organization (WWO) established Intergovernmental Panel on Climate Change (IPCC) in 1988.

Table 1.13 Dependent and independent variables

Dependent variable	**Independent variables (level I)**	**Independent variables (level II)**	**Independent variables (level III)**	**Indicator/measure**	**Actors**
Carbon dioxide emissions in transportation sector	Vehicle industry (vehicle supply side)	Fuel consumption efficiency (distance traveled with determined consumed fuel)	- Fuel prices - National standards (for local market) - International standards (for export)	- vehicles' fuel economy - power engine technology - vehicle weight	Government; automakers
		Number of vehicles	-Demand side (local and international market)	- Number of vehicles per 1000 population - Number of hybrid vehicles in car fleet	Automakers
	Consumer (demand side)	Driving behavior	- Drivers' technical knowledge - Traffic management	- Vehicle miles of travel (VMT) - Shifting gears - Traffic management systems	Government; local authorities; consumers
		Vehicle maintenance	- Drivers' technical knowledge - Fuel and lubricant prices - Local regulations (annual checking of cars)	- Type of tire - Controlling tire air - Changing filters regularly, etc.	Consumers
		Vehicle age	- Households' financial situation - Local regulations (loans for buying new cars)	Average car fleet age	Government; consumers
		Financial systems	Local regulations (taxes and insurance costs)	Carbon tax (in EU); fuel subsidies reform plan (in Iran)	Government
		Demand management	- Local regulations - Local infrastructures	Tele-working; developing information and communication technology	Government
		Land use	- Land-use planning (urban and rural) - Transportation planning (for private and public)	- Vehicle miles of travel (VMT) - Population density - Transit trip capture rate	Government; local authorities
	Fuel supply side	Conventional fuels	- Technology used in refineries - Local regulations - Fuel prices	- Carbon content of the fossil fuels - Gasoline and gas-oil quality and quantity	Government; refineries; producers of alternative fuels; automakers
		Alternative fuels	- Technologies for fuel production - Engine technologies - Local regulations	- Carbon content of the alternative fuels - Varity of fuels available (gasoline, gas-oil, CNG, LPG, etc.)	

Iran was selected as the second case for the following reasons:

- According to the latest statistics, Iran is among the top ten GHG-emitting countries in the world
- Iran's vehicle industry, with more than 1.6 million products in 2011, is ranked thirteenth in the world
- Energy intensity is significant in Iran
- Iran is one of the most fuel-subsidized countries
- Fuel consumption in the transportation sector is increasingly high in the country
- More than 90% of the vehicles assembled in Iran are manufactured in two factories (Iran Khodro Co. and SAIPA Co.). Those companies have some joint venture contracts with well-known European companies (mostly Peugeot, Renault and Mercedes)
- Fuel consumption in the transportation sector is the main reason for air pollution in big cities, especially in Tehran

In this research, I look to identify causal approaches in improving policies for carbon dioxide emissions reduction in the Iranian and EU transportation sectors, comparing the cases. This study identifies the similarities and differences between CO_2 emissions reduction policies in both Iran and the EU, the framework being that of a comparative study. These cases will be investigated separately. Ragin mentioned three reasons for analyzing the causal complexities of the phenomena to be investigated in a comparative approach that we can note in this research:[89]

1- Rarely does an outcome of interest to social scientists have a single cause. For example, policy-making reasons and results for carbon dioxide emissions reduction in the Iranian and EU transportation sectors are not necessarily the same.

2- Causes rarely operate in isolation. For example, the combination of different causes and their different interactions in the time and location may give different results.

3- A specific cause may have opposite effects depending on context. For instance, raising fuel prices in each case of this study may result in paradoxical effects.

[89] Charles C., Ragin, op. cit., p.27.

According to these principles, a case-oriented comparative analysis would be the best methodology for this study.

In this research, I will investigate the visions and strategies of EU policies in terms of CO_2 emissions reduction in the transportation sector and compare these to Iran. At the same aim, I will seek a more appropriate pattern of strategies for Iran's transportation sector.

Comparative analysis is the methodology that will be used in the research. Therefore, the improvement potentials will be searched in policies of Iran transportation sector.

Comparative study is a rational approach for investigating experiments with different scopes. Within a comparative study, I can review the social, technical, financial and environmental considerations of policies in both domains and will investigate opportunities, threats, weaknesses and strengths (SWOT) for each, considering how to use financial and human resources more efficiently.

The primary review shows that EU Member States have made much progress in reducing CO_2 emissions after the Kyoto Protocol, and especially in the last 10 years. The lessons that can be learned from developed countries will guide developing countries in eliminating the most harmful environmental problems that human beings have faced with: global warming.

Research process design

As mentioned above, I will use comparative analysis to study two political entities, the Iranian and EU transportation sectors. This sector of the economy can be divided into four sections: air, water (maritime), rail and road.

I will focus on light duty vehicles transportation, and always refer specifically to this mode when I write 'transportation' in general. For data gathering and data analysis in Chapters 4 and 5, I focus on light-duty vehicles in both European Union and Iranian road fleets.

In this study, CO_2 emissions in the transportation sector are considered as the dependent variable. I define three categories of independent variables:

1. Vehicle industry, as producer and supplier of products (vehicles) that are the final consumers of fuels with the potential of emitting carbon dioxide (vehicle supply side). The main players of this first category are governments and vehicle manufacturers.

2. Consumers, as applicants for services from the transportation industry, whether passenger or commercial freight (demand side). The main players of the second category are governments and consumers.

3. Fuel supply side is the third category that has a significant role in emitting CO_2 in the sector. The players of this category are governments, refineries, producers of alternative fuels and automakers.

Fuel consumption

This refers to the amount of fuel (liters) used per distance (100 kilometers). This measure is used in Europe, China, Australia, New Zealand and South Africa. Iranian automakers and importing companies use this measure as well.[90 and 91]

Fuel economy

Some countries use the distance traveled per unit of fuel used to measure fuel efficiency. This measure is named fuel economy and is presented in miles per gallon (mpg) or kilometers per liter (km/lit). That is common in the US, UK, Japan, Korea, the Netherlands, Denmark, Latin America, India, Pakistan, Thailand and some parts of Africa. In the case of mpg, the gallon should be identified, since an imperial gallon is about 20% larger than the US gallon. Fuel economy and fuel consumption are reciprocal quantities, as shown in Figure 1.25.

[90] Institute of Standards and Industrial Research of Iran (ISIRI) (2009), Gasoline vehicles – Criteria for fuel consumption and energy labeling instruction, ISIRI Standard Number 4241-2, 1st Rev., Tehran, Iran. Retrieved May 16, 2012 from: www.isiri.org

[91] Institute of Standards and Industrial Research of Iran (ISIRI) (2007), Heavy duty and semi-heavy duty vehicles and construction, building, mining, and agriculture machinery diesel engines – Criteria for fuel consumption and energy labeling instruction, ISIRI Standard Number 8361, 1st Rev., Tehran, Iran Retrieved May 16, 2012 from: www.isiri.org

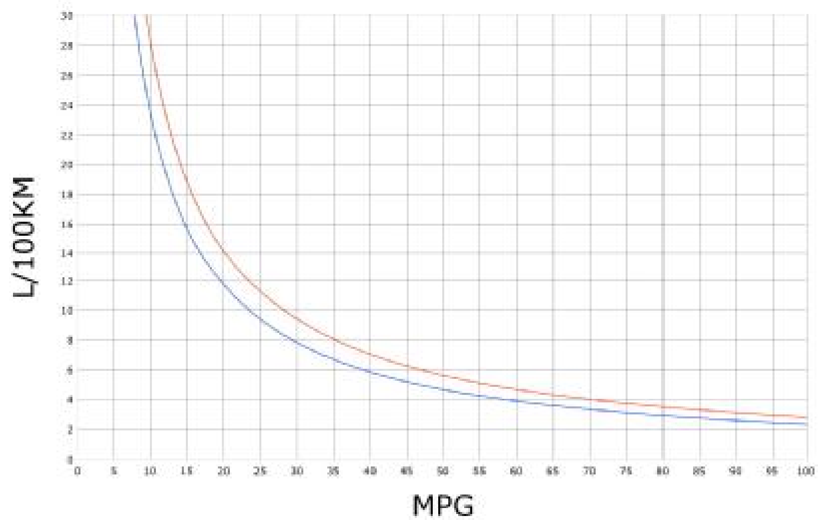

Figure 1.25. Relation between fuel consumption (lit/100 km) and fuel economy (mpg)

The fuel efficiency of each vehicle mainly depends on its engine technology. Research and development (R&D) sections of automakers compete to improve the efficiency of new vehicles and to introduce this to the public via the amount of CO_2 that a vehicle emits into the atmosphere over each kilometer traveled (grCO_2/km). Vehicle weight is another variable that affects the fuel efficiency of a vehicle. This measure depends on the materials used for producing the vehicle.

1.5.1. Variables of the research

A. Independent variables of the automotive industry

i. Fuel consumption efficiency

As illustrated above, fuel efficiency or fuel economy is among the main variables that affect CO_2 emissions in the transportation sector. It is also an indicator for evaluating the environmental performance of a vehicle in terms of CO_2 emissions.

ii. Number of vehicles

The number of vehicles is an independent variable that affects CO_2 emissions through fuel consumption in each country. In this study, I will investigate this variable by referring to the number of vehicles per 1,000 inhabitants (motorization rate).

B. Independent variables of consumers

There are five independent variables presented in the second category:

i. Driving behavior

That is a complex of factors that are directly related to a driver in terms of fuel consumption and also CO_2 emissions. There are some indicators for investigating this variable more precisely (e.g. gear shifting).

ii. Vehicle maintenance

Some technical factors should be considered by each owner during the use stage in the life cycle of a vehicle. These factors return to maintaining the optimum performance of the vehicle from a fuel-consumption point of view. Maintaining factors include regular tune-ups, tire type, controlling tire air, changing filters regularly, and so forth.

iii. Vehicle age

Maintenance costs of a vehicle usually increase and fuel efficiency usually decreases through aging. In addition, new cars will introduce more fuel-efficient technologies that encourage owners to change their old vehicle. The average age of passenger vehicles in the EU is 8 years, and for the Iranian passenger car fleet about 9 years.[92, 93]

iv. Financial systems

Financial systems can affect fuel consumption and CO_2 emissions. This depends on economic structures – the countries use different financial mechanisms (e.g. carbon taxing in EU and reforming fuel subsidies in Iran).

v. Demand management

Demand management, as an independent variable, is a combination of factors that reduces costs and time for doing jobs, and so reduces demand for transportation services and fuel consumption. Demand management can be considered as a social welfare indicator.

[92] International Energy Agency (IEA), (2012), *CO_2 Emission from Fuel Combustion: Highlights*, Paris, France

[93] Iranian Fuel Conservation Company (IFCO) (2011), *Transportation Energy Data Book 2010*, Tehran, Iran

Regulating rules in this context requires developing appropriate infrastructure. Some factors, such as distance working and developing information and communication technologies, are placed in this category.

C. Dependent variables for fuel supply

In addition to the vehicle industry (as supplier of vehicles) and consumers (as applicants), this study will not neglect the role of fuel suppliers in CO_2 emissions reduction. The effective factors in this group are:

i. The quality of conventional fuels (i.e. gasoline and diesel) in the EU and Iran, and

ii. The variety of fuels available in the transportation sector (gasoline, diesel, CNG, LPG, electricity and etc.)

The available technology for producing different kinds of fuels plays an important role in developing alternative fuels. On the other hand, final price is another factor that affects consumers' choices.

Business as Usual (BAU) scenario

I will investigate the current situation of CO_2 emissions in the Iran transportation sector and will develop a 25-year scenario with the information gathered – a Business as Usual (BAU) scenario. In this BAU scenario, I simulate the situation that Iran transportation sector will face in the next 25 years, assuming current trends and situations continue. In the next step, the results of this scenario will be compared with the current and future situation of the EU.

SWOT analysis

SWOT analysis is a strategic management and planning method for evaluating the opportunities, threats, weaknesses and strengths involved in a project. This method can be conducted for analyzing the current situation of a project (e.g. CO_2 emission in the transportation sector) and to identify internal and external factors that are favorable and unfavorable for achieving expected objectives.

Studying Iranian and EU policies, regulations and technical standards, according to three categories, makes clear the opportunities, threats, weaknesses and strengths of Iran's transportation sector in fuel consumption and carbon dioxide emissions. This information is the cornerstone of the SWOT analysis in this study. This SWOT analysis will be conducted in four steps:

1. Specifying the main concepts

In the first step, I will specify the opportunities, threats, weaknesses and strengths of Iran's transportation sector relating to CO_2 emissions. In this step, the priority and importance of the items will not be considered. It is clear that the information from previous stages in investigating the three categories of dependent variables is a good input here.

2. Classification

In this step, similar concepts are classified in a specified class. Each class should have two specificities: comprehensive and unique. Comprehensive means that the class should cover all the similar concepts and unique means that each concept should be placed in just one class.

3. Comparing classes in a mutual approach

In the third step, each class should be compared with all the classes mutually, with scores taken according to their priority. To obtain a better result, I use the comments and opinions of scholars in related fields.

4. Analyzing questionnaires and ranking strategies

In this step, I investigate the strategies used and rank them according to the circumstances facing Iran's transport sector.

This study will suggest appropriate strategies for Iranian policymakers dealing with CO_2 emissions in the transportation sector.

1.6. Theoretical approach

The normal life of billions of people on the Earth has a direct relation to energy consumption. Without energy, not only would the lights of urban areas be turned off, but food, agricultural and industrial production would also be cut and billions of jobs would be lost. After the industrial revolution, human life has depended on energy consumption completely, and economic growth is meaningless without energy.

In the last 250 years, world primary energy consumption has increased. The global economy needs energy to continue growing and accessibility to energy resources have faced political and economic challenges. In this regard, fossil energy resources have been the most accessible and have had the largest share in primary energy consumption. With growing world energy consumption, demand for fossil energy resources has grown (Table 1.14). The statistics show that world total primary energy consumption has risen 2.5% from 2001-2011 and the share of developing countries is much more than that of developed.[94]

Table 1.14 World total primary energy consumption in 2001 and 2011

Energy source (million tons of oil eq.)	2001	share%	2011	share%
Fossil	8192.1	87	10689.3	87
Nuclear	600.8	6	599.3	5
Hydroelectricity and renewables	641.2	7	986.3	8
Total	9434.1	100	12274.9	100

Source: BP Statistical Review of World Energy, June 2012

British Petroleum predicts that, given continual economic growth of countries like China, India, Brazil and Russia, the world primary energy consumption will increase by 40% over the next twenty years, with more than 90% for non-OECD countries.[95]

There is not any reliable alternative for fossil energy resources for all economies worldwide. Renewable energies and nuclear energy have not inclusively been used because of security and

[94] Primary energy consumption growth during 2001-2011 was for OECD -0.8%, European Union -3.1% and non-OECD 5.3% (BP 2012).

[95] BP, (19 January 2011), *Emerging Economies to Lead Energy Growth*. Retrieved February 25, 2013 form http://www.bp.com

technologic issues. Since carbon is the main element in the fossil energy content, carbon dioxide is an ordinary exhaust emitted from consuming these sources.

1.6.1. Carbon dioxide emissions and climate change

The US Environmental Protection Agency (EPA) has issued the results of various ice core studies that show concentrations of carbon dioxide in the atmosphere from hundreds of thousands of years ago through to 2011 (Figure 1.26).[96]

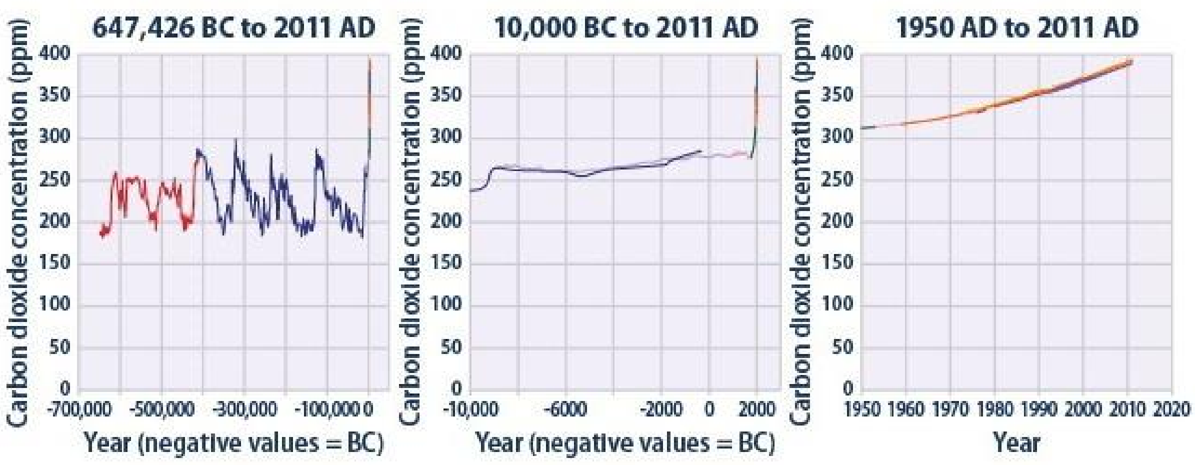

Figure 1.26 Global atmospheric concentration of carbon dioxide over time

Date source: Compilation of 12 underlying datasets. See www.epa.gov

According to the middle graph, CO_2 concentration rose dramatically after the industrial revolution. The US EPA estimates that, over the past 150 years, annual average CO_2 concentrations have increased steadily from approximately 270-290 ppm in pre-industrial times to 391 ppm in 2011 (40% increase) and the concentrations measured currently are the highest observed over the entire period of record. It should be noted that carbon dioxide accounts for nearly three quarters of total global greenhouse gas emissions.

The problem of human-induced climate change was hypothesized in the early 1890s by Swedish scientist Svante Arrhenius, who warned about the possibility of a so-called ‘enhanced’ greenhouse effect caused by excess carbon dioxide in the atmosphere.[97]

[96] US EPA, (2013), *Atmospheric Concentrations of Greenhouse Gases*. Retrieved April 3, 2013 from: http://www.epa.gov/climatechange/science/indicators/ghg/ghg-concentrations.html

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the climate system is indisputably warming. This is evident from observations of increases in global average air and ocean temperatures, the widespread melting of snow and ice, and a rising global average sea level.[98] Over the last 250 years or so, human activities such as the burning of fossil fuels, the removal of forests that would otherwise absorb carbon dioxide and their replacement with intensive livestock ranching have released a range of greenhouse gases (GHGs) into the atmosphere. As a result, the capacity of the atmosphere to absorb heat and emit it back to earth has been substantially increased.

The most alarming indicators for climate change are often based on scientific modeling that looks at future global warming scenarios, which suggests that the public and policymakers must trust scientists and their models. Otherwise, indicators are unlikely to raise the necessary alarm.

1.6.2. Environmental policy in national and international contexts

If we are living in a 'realist world,' a global approach to protect the environment faces numerous problems. For realists, the world is 'doomed to unsustainability and crisis.'[99] From a realist perspective, environmental problems are seen merely as a security issue, as environmental problems have the potential to become a major source of inter- and intra-state conflict.[100] The realist approach cannot really explain the more than 200 international agreements that have been reached so far.

The interdependence of a global ecology that does not know any political boundaries and the fragmented world of politics that consists of more than 190 sovereign nations is a clear

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[97] Sarah Pralle, (2009), *Agenda-setting and climate change*, Environmental politics, Vol. 18, No. 5, September 2009, pp.781-799

[98] Intergovernmental Panel on Climate Change (IPCC), (2007), *Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* . Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p.6. Retrieved July 10, 2010, from: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf

[99] Paterson, Matthew, (2006), *Theoretical Perspectives on International Environmental Politics*, in Betsil, M./Hochstetler, K./Stevis, D. (eds.): Palgrave Advances in International Environmental Politics, Basingstoke: Palgrave Macmillan, p.57.

[100] Robert Garner, (2011), *Environmental Politics: The Age of Climate Change,* 3rd Edition, Basingstoke: New York: Palgrave Macmillan.

dichotomy.[101] The political theory of realism does not offer any solutions to the problems raised by this dichotomy. The possibility must be taken into account that the current 'dominant form of political organization may be inadequate to manage the relationship between humankind and the natural environment on a lasting and sustainable basis.'[102]

Environmental policy is shaped to a great extent by a supranational structure of institutions and processes that was initiated by the United Nations Conference on the Human Environment in Stockholm (1972), followed by summits in Rio (1992) and Johannesburg (2002). These complex structures of international frameworks and protocols for sustainable development are a result of the realization that most critical environmental problems can only be solved internationally. In addition, environmental policy implementation is increasingly being shaped by agreements reached on international levels. In nation states, countries have different priorities when addressing international environmental policies.[103] It should be noted that nation states and national governments are still key players in international negotiations and are responsible for implementing national environmental policy programs.[104] It should not be forgotten that, despite the increasingly global nature of environmental policy, the nation state exercises a great deal of influence in policy-making. Many aspects of environmental policy are still not subject to international negotiations, and it remains up to national governments to implement what has been agreed upon internationally.[105, 106]

1.6.3. The political context of carbon dioxide emissions

Climate policies have been adopted by governments at the international (UN), national, provincial/state, municipal, and institutional (e.g. university) levels (Figure 1.27).

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[101] Andrew Hurrell, Benedict Kingsbury, (1992), *The International Politics of the Environment: An Introduction*, in: Hurrell, A., Kingsbury B., (eds.), The International Politics of the Environment: Actors, Interests and Institutions, Oxford, Clarendon Press, p.4.

[102] Andrew Hurrell, (1995), *International Political Theory and the Global Environment*, in: Booth, K., Smith, S., (eds.), International Relations Theory Today, Cambridge, Polity Press, p.130.

[103] According to Chasek et al. (2010: 53-55), nation states can take four different roles when negotiating an international treaty. A state can be a *'lead'* state that is highly committed to the treaty's objectives. In this case, this state would try to convince other nations to sign the treaty, too. Secondly, a state can play the role of a *'support'* state prepared to accept the contents of the treaty but unwilling to take a leadership role. Thirdly, nation states can be *'swing'* states, which means that they can be persuaded of the benefits of the treaty; and, fourth and finally, nation states can play the role of *'veto'* states. In this case they will try to block any agreement about a treaty.

[104] Robert Garner, op. cit., p.84.

[105] Martin Jänicke, (2005), *Trend Setters in Environmental Policy: The Character and Role of Pioneer Countries*, in Martin Jänicke, Klaus Jacob, (eds.), Environmental Governance in Global Perspective: New Approaches to Ecological and Political Modernism, Berlin: Freie Universität Berlin, 51-56.

[106] Robert Garner, op. cit., p.24.

However, most critically, policy implementation is often expressed as legislation, regulations, or the announcement of approved funding for various incentive schemes. Serious action on the climate change issue does not begin until this policy implementation commitment is put in place.[107]

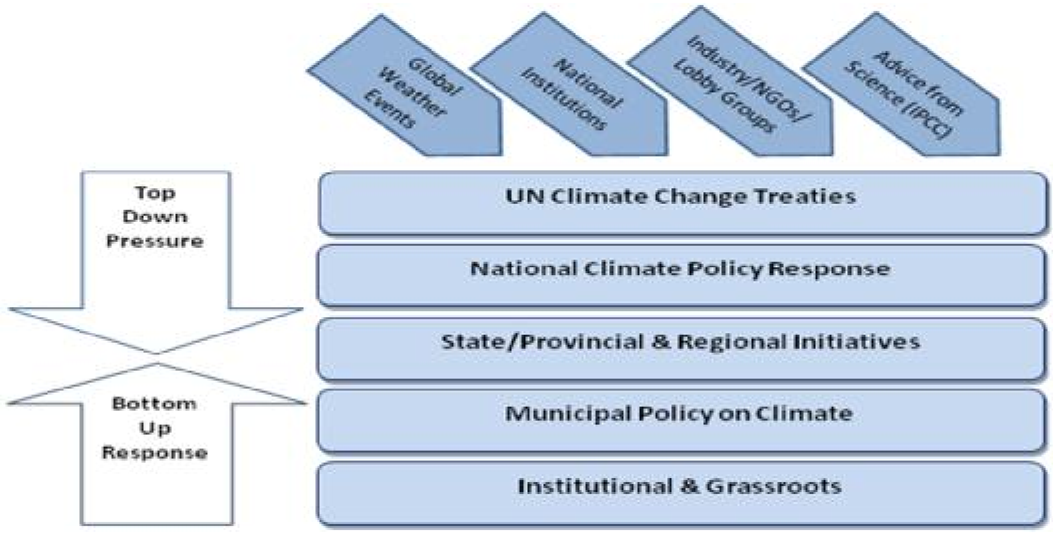


Figure 1.27 Levels of climate change policy

At the problem-identification sub-phase of agenda-setting, governing bodies need to be convinced that climate change represents a real threat or risk and that they should do something about it, or will be expected by the public, shareholders or stakeholders to do something about it (i.e. adopt a climate policy). Being convinced of the seriousness of the issue usually starts with the basic science of climate change, as periodically summarized by the Intergovernmental Panel on Climate Change since 1990.

1.6.3.1. Agenda-setting in climate change

The agenda itself is a portfolio of various topics and problems that will be the subject of the decision-making process and subsequently executed within a defined and institutionalized framework. Technically, agenda-setting is the beginning of the policy cycle.[108] Policy analysis scholars have defined the conceptual framework of the policy cycle in different stages, but

[107] Donald E. MacDonald, (2011), *Climate Change Policy 101*, Earth Common Journal, Vol. 1, No. 1, September 2011, pp.40-41
[108] Martin Jänicke, Philip Kunig, Michael Stitzel, (2003), *Umweltpolitik*. Bonn: Verlag J.H.W. p.55.

according to the same procedure. Donald MacDonald defines it in four main stages (agenda-setting, policy formation, policy implementation, and policy review) (figure 1.28).[109]

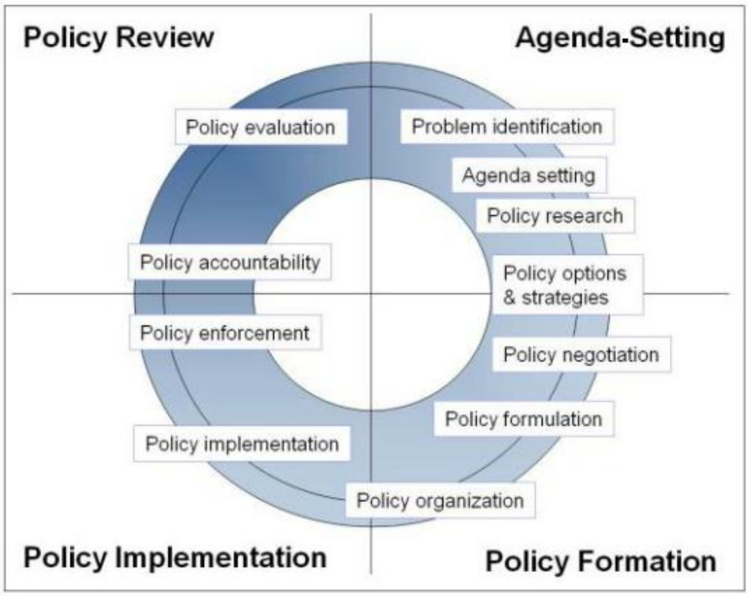


Figure 1.28 The Policy Cycle

The consequences of socio-economic development automatically lead to problems that the political system has to address.[110] Problems that matter to a vast amount of people and which are visible and undeniable have a good chance of entering the political arena. Another factor that makes it more likely for a topic to appear on the agenda is if the capability and capacity to solve the problem are available.[111] It should be noted that problems without attached solutions are less likely to rise high on governmental agendas and are unlikely to make it onto decision agendas at all.

[109] Donald M. MacDonald, op. cit., p.40.
[110] Martin Jänicke et al, op. cit., p.55
[111] Michael Howlett, M. Ramesh, Anthony Perl, (2009), *Studying Public Policy: Policy Cycles and Policy Subsystems*, 3rd Edition, Toronto, Oxford University Press, p.101.

Keeping climate change on the agenda

Keeping climate change at the forefront of government decision agendas will be critical in the coming years because climate change is a long-term problem and governments are unlikely to 'solve' the climate crisis with one policy enacted at one point in time.[112]

Agenda-setting scholars ask why some policy issues emerge on governmental agendas while others are relatively neglected.[113] Some of them note that public problems rise and fall on public and governmental agendas often independently of the objective state of a problem. Indeed, some problems are not defined as problems at all, but rather as conditions with which we choose to live. Problems without readily available and feasible solutions may fail to get on the decision agendas of governmental actors, even if they attract public and governmental attention. Other problems may rise up on the agenda only to fade as the public grows 'bored' and turns to other issues, becomes cynical about agenda-setting scholars' ability to solve the problem, or assumes that it has been solved by the government. Agenda-setting research examines the fates of different public policy issues as they receive more or less public and governmental consideration, and agenda-setting scholars attempt to explain these varying patterns of attention.[114]

The public agenda refers to the set of issues that are most salient for citizens and voters, the governmental agenda consists of the issues that are up for discussion in governmental institutions such as legislatures and executive agencies, and the decision agenda is the narrower set of issues about which governmental officials are poised to make a decision. Non-governmental institutions, such as the media, also have agendas, and these can affect the public and governmental agendas.

Finally, agenda-setting literature assumes that highly salient issues are more likely to move onto the decision agendas of governmental institutions. More effort and resources are expected to be directed to solve these problems than other, less-salient problems, although policy change is not guaranteed even when an issue is highly salient.

[112] Sarah Pralle, (2009), *Agenda-setting and climate change*, Environmental politics, Vol. 18, No. 5, September 2009, p.781.
[113] John Kingdon, (1995), *Agendas, alternatives, and public policies*. 2nd ed. New York: Longman.
[114] Sarah Pralle, op. cit., p.782.

Climate change can be considered 'on' the agenda of many democratic countries, but its position on these agendas varies across time and space. It may, for example, be high on a government's agenda after weather-related natural disasters, but then fade as politicians turn their attention to other issues. Keeping climate change at the forefront of governmental decision agendas will be critical in the coming years because climate change is a long-term problem, and ongoing scientific and technological advances will continue to shape (and reshape) our understanding of the problem and the feasibility of various solutions.[115] Thus, public opinion on climate change has expected agenda-setting scholars to introduce executive and tangible policies with short-term consequences. From this point of view, policies with financial instruments and economic impacts have been included.

John Kingdon envisions the rise and fall of issues on the agenda as a product of the interplay of three 'streams' or policy processes: problems, policies and politics. These streams operate largely independently of one another, as they tend to have their own rules, 'star' different players, and are subject to different internal dynamics.

The problem stream and climate change

According to Kingdon, problems come to the attention of policymakers via indicators, focusing events and feedback. Indicators can illuminate the scope and severity of a problem through the monitoring of natural (or social) processes, activities and events. Indicators arise through both routine monitoring and special studies.

Agenda-setting scholars have defined climate change as a global problem. For example, contemporary scientific and political interest in the phenomenon of global warming was sparked in part by US scientist Charles Keeling's decades-long monitoring of atmospheric carbon dioxide (CO_2) levels, which he began measuring in the late 1950s. His measurements produced what is known as the 'Keeling curve,' which shows an alarming trend of increasing carbon dioxide emissions over the last half-century. Before his study, scientists were not certain whether carbon dioxide would accumulate in the atmosphere or be absorbed by the ocean and vegetation.

[115] Sarah Pralle, op. cit., p.783.

Keeling's research indicated that CO_2 was in fact concentrating in the atmosphere and he provided important evidence suggesting that humans were contributing to the problem.[116]

Indeed, the debate over solutions, or what Kingdon calls the 'policy stream,' is a critical part of the agenda-setting process.

The policy stream and climate change

In addition to a problem stream, Kingdon envisions a policy stream in which solutions are generated by specialists and experts within policy communities and wait to be attached to the salient problems of the day. Kingdon argues that proposals must pass a threshold test of technical feasibility and congruence, with values to be selected. Moreover, solutions must be perceived as staying within budgetary limits.

For our purposes, the most important point that Kingdon and others make about solutions is the need to have one: problems that have no solutions attached to them are less likely to make it onto governmental and decision agendas. The public is also less likely to worry about problems when they feel there is nothing to be done about them.[117] For climate change to rise and stay high on agendas, the public and policymakers must be convinced not only that we *should* do something to combat climate change, but that we *can*.

Politics and climate change

Political opportunities depend on some factors that affect agendas. Kingdon assumes three key political factors to complete his agenda-setting model: the national mood, organized political forces, and administrative or legislative turnover.[118] The balance of interest group support and opposition to a policy may shape policymakers' agendas and selection of alternatives.[119]

Windows of opportunity

The likelihood of any issue rising to prominence on the agenda is significantly increased when the problem, policy and politics streams join together. Regardless of whether a window opens

[116] Sarah Pralle, op. cit., p.784.
[117] Sarah Pralle, op. cit., p.786.
[118] John Kingdon, op. cit., p.146.
[119] John Kingdon, op. cit., p.150.

predictably or randomly, policy entrepreneurs must be ready to seize the moment, for the windows rarely stay open for very long.[120]

According to Kingdon, the agenda is affected more by problems and political streams, and the alternatives are affected more by the policy stream. Basically, a window opens because of change in the political stream (e.g. a change of administration, a shift in the seats in parliament, or a shift in national mood); or it opens because a new problem captures the attention of governmental officials and those close to them.[121]

Once the window of opportunity opens, it does not stay open long. The window closes for a variety of reasons. First, participants may feel they have addressed the problem through decisions or actions. Even if they have not, the fact that some action has been taken brings down the curtain on the subject for the time being. Second, participants may fail to get action. If they fail, they are unwilling to invest further time, energy, political capital, or other resources in the endeavor. Third, the events that promoted the window to open may pass from the scene. Fourth, if a change in personnel opens a window, the personnel may change again. And finally, the window sometimes closes because there is no available alternative.[122] Thus, policy entrepreneurs seize the opportunity when a policy window opens, attaching solutions to problems, overcoming constraints by redrafting proposals, and taking advantage of politically propitious events.[123]

1.6.3.2. Policy formation

Policy formation during the past two decades has been driven ‘top-down’ internationally by the UNFCCC. Broad agreement is generally reached on an international framework, protocol or accord in which countries agree to both common and increasingly individual policies they will undertake. Current examples include the Framework Convention on Climate Change (1992), the Kyoto Protocol (1997), and the still incomplete Copenhagen Accord (2010). These international agreements should lead to national policy developments for serious action to meet international commitments. MacDonald describes this policy cycle in a sine wave form, with wax and wane over time (Figure 1.29). In this concept, public interest in climate change is defined as a ‘submarine issue.’ Since policymakers on the international level reach a specific treaty regarding

[120] Sarah Pralle, op. cit., p.787.
[121] John Kingdon, op. cit., p.168.
[122] John Kingdon, op. cit., p.169.
[123] John Kingdon, op. cit., p.166.

climate change, the policy (according to a top-down approach) enters the local/national level. Thus, policymakers focus to meet their international commitments and implement the local related policies effectively. The national government announces climate policies to the public through the media and explains the national situation in international climate movements. Climate policy entrepreneurs, government policymakers and the public need reliable information to measure the impact of new policies on the national and international economy. Important metrics for assessing the potential impact of a proposed GHG reduction target on different national economic levels include: overall changes in GDP, economic impact on key industrial sectors (e.g. automotive industry), and impact on key commodities important to consumers/voters (e.g. price of fuel for transportation, energy carriers for households, etc.). This analysis is then usually discussed internally at the political level.[124]

Because world economies (from the most developed to less developed and developing countries) are tightly linked with economic growth, economic assessment has been a key part of policy formation. Thus, policy entrepreneurs consider the potential impact of the economy on a country's Gross Domestic Product (GDP).

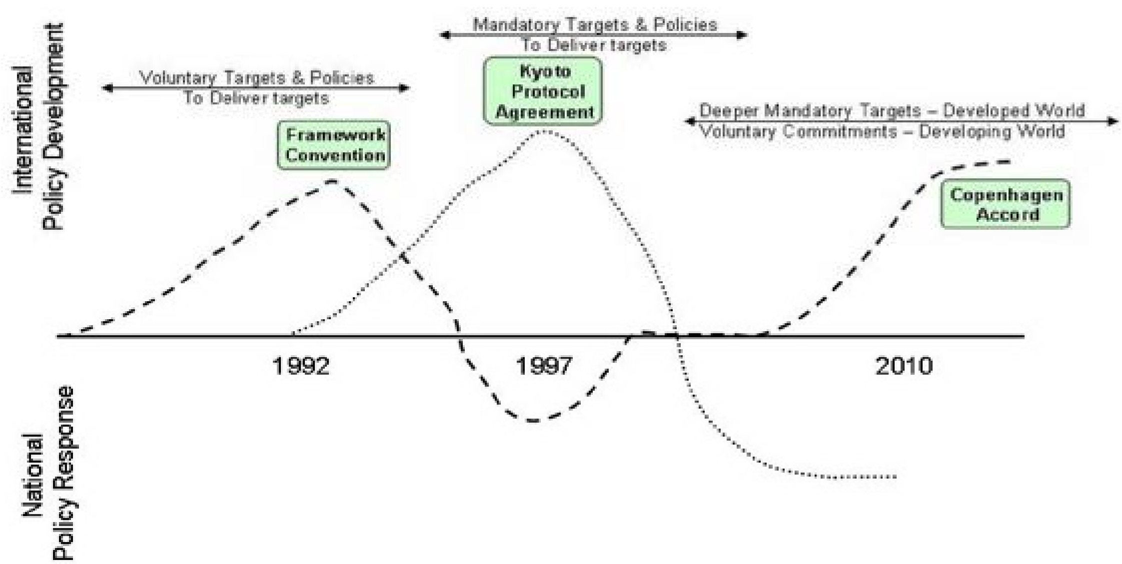


Figure 1.29 International and national climate policy cycles

[124] Donald M. MacDonald, op. cit., pp.42-43.

Advocacy coalition groups[125] respond to climate policies from their specific points of view. Industry tends to argue about profitability, while non-governmental institutions tend to argue for more stringent carbon dioxide reduction targets. Theodore Panayotou has discussed the regulatory and community pressure on firms in developed and developing countries. He argues that studies of firm behavior in developed countries tend to find regulatory pressure to be the most potent driver of environmentally preferred technologies, while studies of firm behavior in developing countries tend to find community pressures as the most important determinant of firms' environmental behavior.[126]

Anthony Leiserowitz conducted a survey and summarized international public opinion, perception and understanding of global climate change. According to his investigation, a majority of the public in affluent democracies believes that global warming is a 'somewhat serious' to 'very serious' problem, and these numbers have been increasing in recent years. It is interesting to note that many developing countries (e.g. Venezuela and India) viewed this global risk as more serious than most developed countries (e.g. the USA). In his conclusion, many respondents also consider global warming a threat to their own country's vital interests, however, individuals in developing countries appear to be more convinced that climate change is a direct threat to them and their families than do individuals in developed countries.[127]

Large proportions of citizens around the world appear to believe that global warming represents a critical threat in the next 10 years. However, respondents in developed countries are less convinced than people in developing countries that global warming will directly affect them, their families and their communities. In other words, citizens in affluent democracies tend to think that the impacts of global warming will be geographically distant, affecting people in other

[125] According to three sets of strategies in Kingdon's stream model (problems, policies and politics), the actors pursuing these strategies would comprise a range of groups and individuals, including environmental advocacy groups, scientists, journalists, agency personnel, legislators, cabinet members, and perhaps even leaders in renewable energy technologies. Together they constitute the 'climate change advocacy coalition' (Pralle 2009: 788).

[126] Theodore Panayotou, (2000), Globalization and Environment , Background paper for the Human Development Report 1999 United Nations Development Program (UNDP), Center for International Development at Harvard University, p.8.

[127] Anthony Leiserowitz, (2007), *International Public Opinion, Perception, and Understanding of Global Climate Change, In: United Nations Development Program,* Human Development Report 2007/2008. Fighting climate change: human solidarity in a divided world. UN, p.35.

countries but not necessarily themselves. This is likely to decrease the salience of the issue for people in affluent democracies.[128]

One conclusion we can reasonably draw from this data is that there is a significant amount of latent public concern about global warming. Policy entrepreneurs within the climate change advocacy coalition might be able to tap into this latent concern and thereby raise the salience of the problem with the public and policymakers. The key question is how to do it, and this question unfortunately elicits no clear and easy answers. More research is needed to uncover the best strategies for communicating to the public and policymakers in ways that would increase the salience of the issue.[129]

The more general lesson is that the public must be made aware of the specific impacts of global warming, whether these are close to home or more distant. Wood and Vedlitz (2007) found that, when survey respondents were presented with clear evidence of the effects of global warming, such as rising sea levels, melting glaciers and polar ice caps, and increasingly severe storms, they altered their assessment of the severity of the problem.[130]

1.6.3.3. Policy implementation

In climate change policy implementation, a climate strategy is deployed to reduce foreseen GHG emissions. This is the point where a government must pass a law or regulations or make a firm budget commitment to some program or research effort.[131]

Since carbon dioxide from fossil fuel combustion is the largest greenhouse gas (GHG) emissions source, it is obvious why GHG emissions reduction policies have been focused, directly or indirectly, on reducing consumption of these resources.

The world community adopted a protocol in Kyoto at the third conference of the UNFCCC on 11 December 1997 in order to control and reduce emissions of GHGs. The Kyoto Protocol is the most important and comprehensive international document for addressing GHGs that commits developed countries to reduce these gases between 2008 and 2012. This protocol developed financial mechanisms for encouraging developing countries to reduce their GHGs as well. On 8

[128] Anthony Leiserowitz, op. cit.
[129] Sarah Pralle, op. cit., p.789.
[130] Sarah Pralle, op. cit., p.791.
[131] Sarah Pralle, op. cit., p.787.

December 2012, the ‘Doha Amendment of the Kyoto Protocol’ was adopted and the members extended the commitments from 2012 to 2020.

Policy-making and goal-setting for CO_2 emissions reduction on the national level is not limited to the Kyoto Protocol. Many developing countries with considerable total annual CO_2 emissions and without any official international commitment have developed specific targets and projects.

It should be mentioned, however, that the Kyoto Protocol has encouraged developing countries to reduce their GHGs emissions, but the goal of reducing emissions is primarily economically, not ethically, motivated. It is obvious that in CO_2 emissions reduction decision-making in many countries, even developed ones, the economic and energy security factors are more considerable than environmental security factors. However, any policy instrument for reducing CO_2 emissions can limit carbon dioxide concentration in atmosphere.

1.6.3.4. Policy review

This last stage of the climate change policy cycle is perhaps the most crucial. This stage assesses whether or not a policy that has been developed and implemented is actually achieving the anticipated outcomes it was designed around.[132]

On 8 December 2012, at the eighth session of the Conference of the Parties to the Kyoto Protocol (CMP), held in Doha, Qatar, the Parties adopted, in accordance with Articles 20 and 21 of the Protocol, an Amendment to the Kyoto Protocol, Decision 1/CMP.8.

1.6.4. Discussion and summary

Unlike reductions in regional air pollutants, which bring immediate health and ecosystem benefits, achieving GHG reductions in one area of the globe is generally insufficient to bring about global benefits.[133]

To date, most policy reviews at the international UN level, coupled with the periodic IPCC scientific assessments, have concluded that the existing policies are insufficient. The global community, made up of individual countries, inevitably needs to return to Phase 1 or 2 of the

[132] Donald M. MacDonald, op. cit., p.45.
[133] Donald M. MacDonald, op. cit., p.46.

policy cycle (Agenda-Setting and Policy Development) and start again about every 5-10 years. This trend is likely to continue for decades to come.

The Subsidy Reform Plan in Iran is a market mechanism to reduce CO_2 emissions in terms of fossil fuel consumption.

A key challenge in climate policy politics will be to keep the issue high on public, governmental, and decision agendas, as it must weather any economic storms or other developments that might weaken the commitment of the public and policymakers to solving it. Decades ago, Downs (1972) predicted that attention to environmental issues would gradually decline after an initial period of enthusiasm and high salience.[134]

Firms may resist implementing CO_2 emissions regulations and standards to avoid losing competitiveness. However, some financial mechanisms (e.g. removing and paying subsidies for fossil and alternative fuels respectively, carbon tax, etc.) can justify investment in related fields. Thus, increasing the costs of consuming fossil energy and CO_2 emissions can increase total costs and final prices of goods and services. This issue can affect negatively both competitiveness on the supply side and dissatisfaction, because of higher prices, on the demand side.

As the costs and difficulty of solving a problem become more evident, the public tends to lose interest. If the public believes that large sacrifices are required, then attention to a problem may wane. According to Guber, in the environmental policy area, the most important 'real world' events affecting the place of environmental issues on the agenda are economic events. Put simply, economic problems often move environmental problems and solutions down the list of priorities.[135] There are many indicators that prove climate change threatens the world economy, but policy entrepreneurs have a difficult task in keeping climate change on top of the list of environmental problems.

In addition to emphasizing local impacts, climate change policy entrepreneurs should make it clear to the public and policymakers that global warming may lead to higher death rates from

[134] Sarah Pralle, op. cit., p.787.
[135] Sarah Pralle, op. cit., p.788.

heat waves and higher disease rates, and that greenhouse gases add to air pollution and its associated health problems.[136]

If global warming is framed in part as an energy issue, then it becomes possible for climate change advocates to speak about jobs and other economic opportunities associated with the transition to clean energy.[137]

Steinmeier and Gabriel reported that the global market volume for green technologies currently stands at 1,400 billion Euro, and that this will more than double to 3,300 billion Euro by 2020 (including green services). In Germany alone, the market volume will rise from 220 billion to over 500 billion Euro. This shows the enormous potential that these technologies hold.

They concluded that 2.3 million people are currently employed worldwide in the renewables sector, and this figure is set to triple or quadruple over the coming years. In Germany, there are already 280,000 jobs in the renewables sector alone.

Perhaps the best strategy for keeping climate change on the governmental and decision agendas is to design climate change policy in ways that encourage future administrations to pay attention to the problem and discourage future efforts to overturn or ignore it.[138]

Climate change science has no shortage of indicators. We have data confirming a rise in global temperatures, and scientists are accumulating evidence to show that climate change is affecting sea level, precipitation, polar ice cap coverage, migratory patterns of animals, species habitats, the intensity of hurricanes, and other natural processes.

[136] Sarah Pralle, op. cit., p.7892.
[137] Sarah Pralle, op. cit., p.795.
[138] Sarah Pralle, op. cit., p.795.

2. Carbon dioxide emissions in in the European Union transportation sector

This chapter will give a holistic view of CO_2 emissions in the EU's transportation sector. I will try to describe the status quo of the issue in the EU and the EU's strategies for meeting international commitments in the Kyoto Protocol framework.

The first voluntary standard for fuel efficiency in the EU was introduced to the automotive industry in the late 1990s. Thereafter, policy makers needed to restrict fuel efficiency standards further to reduce both CO_2 emissions and oil dependence. Thus, mandatory regulations have developed.

None of the voluntary and mandatory regulations determine any specific technologies to reduce emissions. However, automakers have deployed different strategies to meet the regulations.

Since fossil fuels contain over 95% of the energy carriers in the EU's transportation sector, the European Commission has deployed specific policy instruments for the fuel supply sector. Increasing the share of diesel in the energy mix, blending biofuels with conventional diesel or gasoline, enhancing hybrid vehicles and using financial policies can be mentioned here.

2.1. CO_2 emissions worldwide and in the EU: History and trends

2.1.1. A perspective on CO_2 emissions worldwide

Global primary energy demand by industry is projected to rise by 40% by 2030 from 2007 levels. This would put global energy-related CO_2 emissions at 40.2 gigatons (Gt) in 2030, with an annual growth rate of 1.5%.[139] This estimate puts the world on track for a long-term concentration of greenhouse gases in the atmosphere and results in an unsustainable living environment.

EEA reports that total GHG emissions from international transport reached 285 million tons CO_2-equivalents in 2010.[140] Among the main energy consumers (power generation, industry, transportation and household sectors), transportation sector greenhouse gas emissions increased

[139] International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps*, Paris, OECD, p.9. Retrieved June 14, 2012, from: www.iea.org
[140] European Environment Agency (EEA), (2012). *Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012*, Copenhagen, p.13. Retrieved June 11, 2012, from: http://www.eea.europa.eu

by 28% over the period 1990–2007. This compares with a reduction of 11% in the non-transport sectors. Transportation will account for 97% of the increase in world primary oil use between 2007 and 2030. The significant impact of fossil fuel consumption – i.e. energy security and the environmental impact of greenhouse gases and other gaseous pollutants – has encouraged all countries to reduce consuming fossil fuels in the transportation sector as a high-priority strategy.

Preliminary projections by the International Council on Clean Transportation (ICCT) of worldwide sales and total global population of all on-road vehicles in a business-as-usual scenario based on historic trends illustrate the magnitude of the challenge facing transportation and environmental policymakers over the coming decades (Figure 2.1).[141]

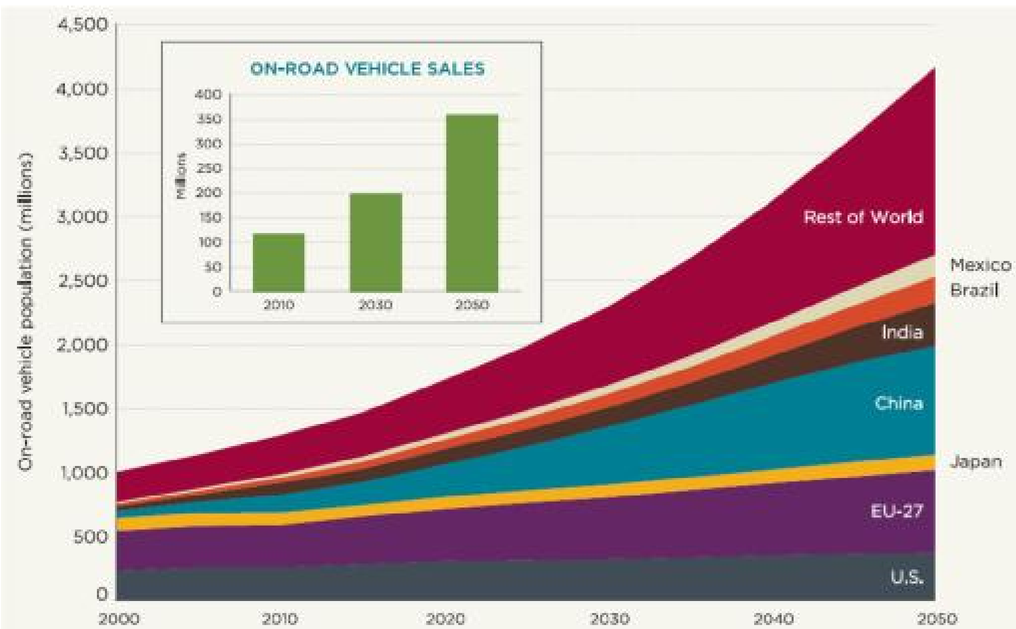


Figure 2.1. Projection for the global on-road vehicle population

Source: ICCT 2011, A Ten-Year Retrospective

According to projections, it is expected that fossil fuel consumption for the road transportation sector to increase globally by 2030. Kodjak et al. concluded that, following the current trends, CO_2 emissions from road transport are expected to grow by more than 2% per year between 2010

[141] International Council on Clean Transportation (ICCT), (2011), *A Ten-Year Retrospective*, Retrieved July 23, 2013 from: www.theicct.org

and 2030.[142] This is mostly because of a dramatic increase in the number of vehicles on the roads in developing economies.

Policymakers have called reducing energy consumption so far the ‘global energy crisis.’ The Corporate Average Fuel Economy (CAFÉ) regulations have been known as the first fuel economy standards for reducing fuel consumption by improving the average fuel economy of cars and light trucks sold in the US after the Arab Oil Embargo in 1973. The first CAFÉ was enacted by the US Congress in 1975. The National Highway Traffic Safety Administration (NHTSA) has recently issued final rule for CAFÉ standards for model years 2017 and beyond.

Society in the US has experienced the outcomes of developing these standards in the national economy. Between 1975 and 2005, US fuel economy standards saved 3 million barrels of oil per day and cut petroleum imports and CO_2 emissions by about a quarter, a net saving of about $30 per ton of CO_2.[143]

The IEA estimated that there is a potential for cost-effective technical improvement in new vehicle fuel economy of 50% by 2030. This would result in a reduction of close to 500,000 tons of oil equivalent (toe) fuel use and almost 1 Gt of annual reduction in CO_2 emissions. The IEA also estimated that if its energy efficiency policy recommendations for transport are implemented globally without delay, there could be a saving of around 1.4 Gt of CO_2 per year across the transport sector by 2030.[144]

Geurs et al. concluded that to limit the increase in mean global temperature to 2°C, greenhouse gas emissions in high-income countries need to be 80–95% less in 2050 than in 1990.[145]

Deploying emissions reduction policies in the transportation sector is much more difficult because of mobile sources, technology levels differences, spreading users, and the different behaviors of drivers. Owing to these specifications, studies expect less emissions reduction potential for transportation. The UNEP estimated the total emission reduction potential in 2020

[142] Drew Kodjak, Francisco Posada Sanchez, Laura Segafredo, (2012), *Policies that work: How vehicle standards and fuel fees can cut CO_2 emissions and boost the economy*, International Council on Clean Transportation (ICCT) and Climate Works Foundation, San Francisco, US.
[143] Drew Kodjak et al., op. cit., p.12.
[144] IEA, (Sep., 2010), op. cit., p.9.
[145] Karst Geurs, Hans Nijland, Bas van Ruijven, (2011), *Getting into the Right Lane for Low-Carbon Transport in the EU*, Published in Rothengatter, W. et al., Transport Moving to Climate Intelligence, Springer, New York, p.53.

to be in the range of 17±3GtCO_2-eq. Among the sectors, transportation's share is low (1.7-2.5 GtCO_2-eq) in comparison to the power sector, manufacturing industry, buildings, forestry and agriculture. The results of another study from IPCC brought similar results (Table 2.1).[146]

Table 2.1. Estimates of sectorial greenhouse gas emissions reduction potentials, 2020 and 2030

	Emissions reduction potential in 2020 (GtCO_2eq per year) (UNEP estimation)	Emissions reduction potential in 2030 (GtCO_2eq per year) (IPCC estimation)
Power sector	2.2 – 3.9	2.4 – 4.7
Manufacturing industry	1.5 – 4.6	2.5 – 5.5
Transportation	1.7 – 2.5	1.6 – 2.5
Buildings	1.4 – 2.9	5.4 – 6.7
Forestry	1.3 – 4.2	1.3 – 4.2
Agriculture	1.1 – 4.3	2.3 – 6.4
Waste	Around 0.8	0.4 – 1.0
Total (central estimate)	17 ± 3	23 ± 3
Total (full range)	10 – 23	16 – 31

Source: UNEP 2013

2.1.2. CO_2 emissions in the EU: History and trends

The European Commission reported that about 11% of GHGs emitted worldwide each year come from the European Union.[147] The EU's share in global emissions is falling as Europe reduces its own emissions and as those from other parts of the world, especially the major merging economies such as China, India and Brazil, continue to grow. Table 2.2 shows the emissions of EU members from 1990 to 2011.

Table 2.2. CO_2 emissions in the EU-27 without LULUCF[148]

Total CO_2 emissions (in Gg CO_2 equivalent)			Changes in emissions from 1990 (%)	Average annual growth rates from 1990 (%)
1990	**2000**	**2011**		
4,406,963	4,111,651	3,743,430	-15.1	-0.8

Source: United Nations, Climate Change Secretariat, Summary of GHG Emissions for EU-27, 2012

[146] United Nations Environment Programme (UNEP), (2013), *The Emissions Gap Report 2013*, United Nations Environment Programme, Nairobi. Retrieved February 11, 2014 from: www.unep.org/emissionsgapreport2013/

[147] European Commission, (July 2013), *EU greenhouse emissions and targets*, Retrieved August 3, 2013 from: www.ec.europa.eu/clima/policies/g-gas/index_en.htm

[148] land use, land-use change and forestry

Owing to measures taken by the European Member States, the EU has been successful in cutting greenhouse gas emissions under its international commitments (Table 2.3). The significant point is that, by reducing emissions since 1990, the EU has continued economic growth nearly in parallel.[149]

The overall EU GHG emissions-reducing trend is dominated by the two largest emitters, Germany and the United Kingdom, accounting for about one third of total EU-27 GHG emissions. These two Member States have achieved total GHG emission reductions of 483 million tons CO_2-equivalents in 2010, compared to 1990.[150]

The main reasons for the favorable trend in Germany were increasing efficiency in power and heating plants and the economic restructuring of the five new *Länder* after German reunification. The reduction of GHG emissions in the United Kingdom was primarily the result of liberalizing energy markets and the subsequent fuel switches from oil and coal to gas in electricity production and N_2O emissions-reduction measures in the production of adipic acid.

France and Italy were the third and fourth largest emitters in 2010, respectively accounting for 11.1% and 10.6% of total EU-27 emissions. France's emissions were 6.6% below 1990 levels in 2010. In France, large reductions were achieved in N_2O emissions from adipic acid production, but CO_2 emissions from road transport and HFC emissions from the consumption of halocarbons increased considerably between 1990 and 2010. Italy's GHG emissions were 3.5% below 1990 levels in 2010. Emissions increased since 1990 primarily from road transport, electricity and heat production and petroleum refining, but the country's total GHG emissions have decreased significantly (7.2%) since 2008.

Poland and Spain are the fifth and sixth largest emitters in the EU-27, accounting for 8.5% and 7.5% of total EU-27 GHG emissions in 2010. Poland decreased GHG emissions by 12.4% between 1990 and 2010 (and by 28.9% since the base year, which in Poland's case is 1988). The main factors for decreasing emissions in Poland — as for other new Member States — were the

[149] According to Eurostat, the GDP growth of the EU-27 in 2009 fell to -4.5% because of economic recession. At the same year, final energy consumption experienced -5.36% growth as well.

[150] European Environment Agency (EEA), (2012). *Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012*, Copenhagen; p.11-12 Retrieved June 11, 2012, from: http://www.eea.europa.eu

decline of energy-inefficient heavy industry and the overall restructuring of the economy in the late 1980s and early 1990s. The notable exception was transport (especially road transport), where emissions increased. Spain increased emissions by almost 26% between 1990 and 2010. This was largely due to emission increases from road transport, electricity and heat production, and manufacturing industries.

Table 2.3. Overview of EU-27 and EU-15 GHGs source categories in the period 1990– 2010 (million tons CO_2-equivalents)

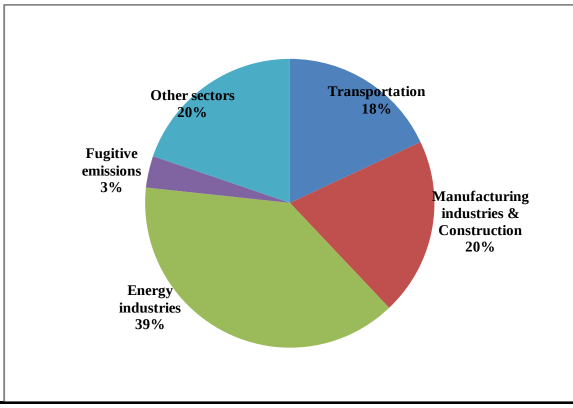
Source category	EU-15	EU-27
	Million tons of CO2-equivalent	
Road transportation (CO_2 form 1A3b)	108.3	159.3
Consumption of halocarbons (HFC from 2F)	70.9	82.3
Cement production (CO_2 from 2A1)		-22.2
Production of halocarbons (HFC from 2E)	-25.8	-25.8
Nitric acid production (N_2O from 2B2)	-26.1	-36.5
Enteric fermentation (CH_4 from 4A)		-41.8
Households and services (CO_2 from 1A4)	-28.5	-77.8
Agricultural soil (N_2O from 4D)	-40.1	-70.9
Iron and steel production (CO_2 from 1A2a + 2C1)	-42.9	-92.2
1B fugitive emissions from fuels (CH_4)	-49.6	-73.4
Manufacture of solid fuels (CO_2 from 1A1c)	-51.4	-53.6
Adipic acid production	-57.3	-58.3
Solid waste disposal on land (CH_4 from 6A)	-59.9	-55.7
Public electricity and heat production (CO_2 from 1A1a)	-61.1	-208.7
Manufacturing industries (excl. iron and steel) (energy-related CO_2 from 1A2 excl. 1A2a)	-114.2	-207.9
Total	**-451.7**	**-862.3**

Source: European Environmental Agency (2012)

The energy sector has been the main carbon dioxide emitter of the EU-27 since 1990.[151] Despite total GHGs reductions in the EU in 1990-2010 period, there is a considerable growth in the transportation sector. According to the UNFCCC, greenhouse gas emissions of the transportation

[151] United Nations Framework Convention on Climate Change (UNFCCC), (2012), *Summary of GHG Emissions for EU-27*. Retrieved August 2, 2013 from: http://unfccc.int/files/ghg_data/ghg_data_unfccc/ghg_profiles/application/pdf/eu-27_ghg_profile.pdf

sector have increased to nearly a quarter of the energy sector emissions of the EU-27 in 2011 (Figure 2.2).



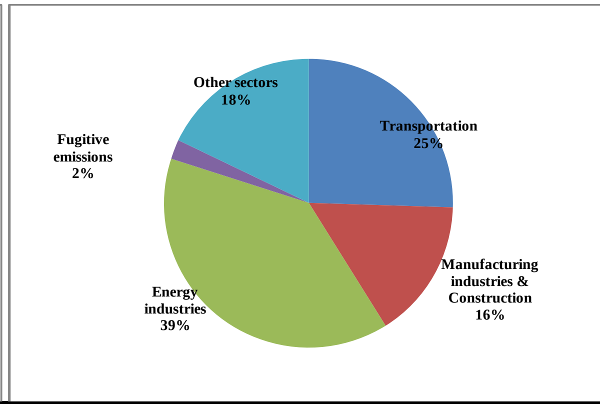


Figure 2.2. Breakdown of GHG emissions within the EU-27 energy sector in 1990 (left) and 2011 (right)

Source: UNFCCC 2012

2.1.3. Road transportation and carbon dioxide emissions in the EU

The European Commission reports that more than two thirds of transportation-related greenhouse gas emissions are from road transportation.[152] Final energy consumption of the sector in the EU-27 grew to 7.2% between 2000 and 2010 (Figure 2.3).[153]

Despite decreasing rates of specific fuel consumption of the average car (by liters/km) in the EU-27, 1990 to 2007 (-14.8%), the amount of CO_2 emissions has increased significantly because of huge amounts of energy consumption by the transportation sector.

[152] http://ec.europa.eu/clima/policies/transport/index_en.htm

[153] Eurostat, (August 2012), *Consumption of Energy*, Retrieved August 9, 2013 from: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Consumption_of_energy

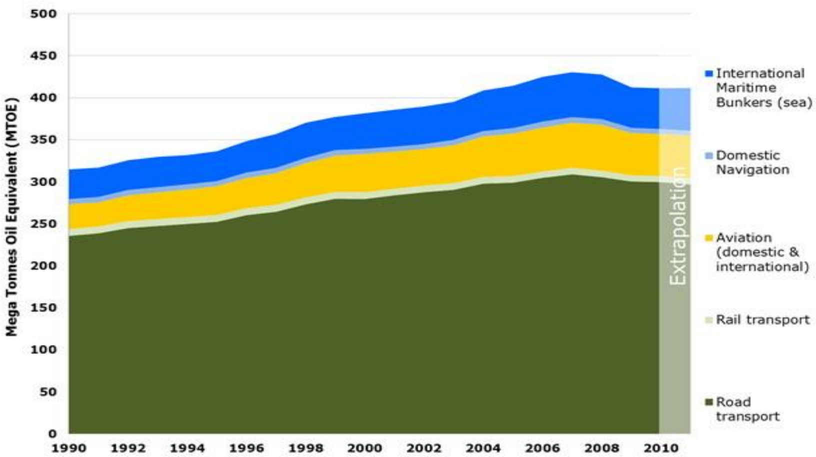


Figure 2.3. Final energy consumption by transport modes between 1990-2010 in EU-27 (Mega tons of oil equivalent)

Source: European Environment Agency (Jan, 2013)

Although many improvements in vehicle efficiency have been achieved in the period, fuel consumption and greenhouse gas emissions continue to grow. The growth in demand for energy for transportation is not confined to business, as it has been accompanied by an expansion in personal travel and freight transport.

Despite falls in the amount of energy consumed by transport in 2008 and 2009 (at least, in part, reflecting the impact of the economic recession), an analysis over a longer period of time shows that transportation was the fastest growing consumer of energy and producer of greenhouse gases.

2.1.4. The international approach of the EU to controlling carbon dioxide emissions

The Kyoto Protocol was adopted in Kyoto in December 1997 and entered into force in February 2005. While the UNFCCC only *encouraged* industrialized countries to stabilize GHG emissions, the Kyoto Protocol for the first time *committed* them to do so. Reduction targets were set for 37 industrialized countries, which agreed to reduce their greenhouse emissions by an average of 5% against the *base year* levels (1990) over the five-year period 2008-2012.

The EU regulated decision No 280/2004/EC for monitoring GHG emissions of the community and implementing the Kyoto Protocol. This decision has the following objectives:

1. To monitor all anthropogenic GHG emissions covered by the Kyoto Protocol in the Member States;

2. To evaluate progress towards meeting GHG reduction commitments under the UNFCCC and the Kyoto Protocol;

3. To implement UNFCCC and Kyoto Protocol obligations relating to national programs, greenhouse gas inventories, national systems and registries of the EU and its Member States, and relevant procedures under the Kyoto Protocol;

4. To ensure the timeliness, completeness, accuracy, consistency, comparability and transparency of reporting by the EU and its Member States to the UNFCCC secretariat.

The EU-15 took on a commitment under the Kyoto Protocol to reduce emissions by 8% during the first period. The EU-27 does not have a common target in the same way as the EU-15. EEA reports that the EU-27 decreased GHG emissions by 18.4% between 1990 and 2011 (-1024 million tons CO_2-eq) and it seems likely to hit the 2020 target (20% reduction by 2020 compared to its base year 1990) earlier than the proposed target (Figure 2.4).[154]

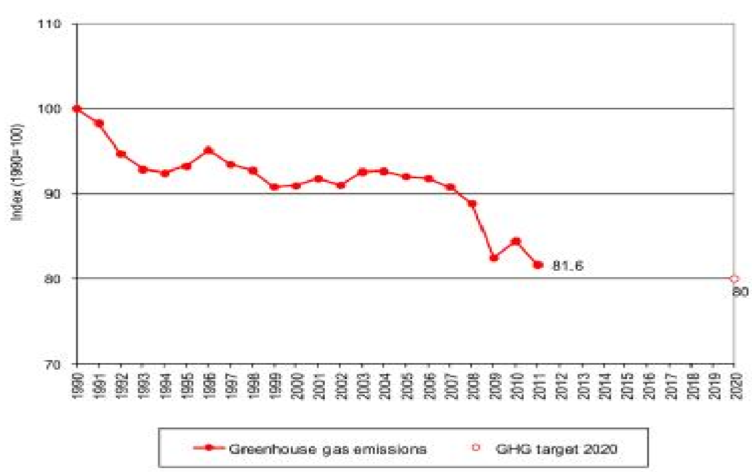


Figure 2.4. EU-27 GHG emissions 1990-2010 (excluding LULUCF)

Source: European Environmental Agency (2012)

[154] European Environment Agency (EEA), (2013). *Annual European Union greenhouse gas inventory 1990–2011 and inventory report 2013*, Copenhagen; pages iv and v. Retrieved February 9, 2013, from: http://www.eea.europa.eu

For the EU-15, GHG emissions in 2011 were 14.9% below 1990 levels. In other words, the EU-15 has met the Kyoto Protocol commitments of an 8% reduction by 2008-2012 compared to its 'base year.' It should be added that GHG emissions decreased 4.2% (near 160 million tons CO_2-eq) between 2010 and 2011 (Figure 2.5).

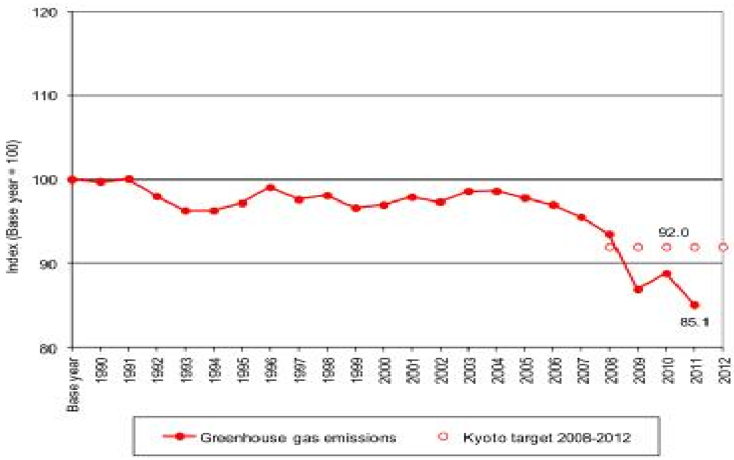


Figure 2.5 EU-15 GHG emissions 1990-2010 compared with the target for 2008–2012 (excluding LULUCF)

Source: European Environmental Agency (2012)

The EU adopted the Climate and Energy Package in April 2009. The Package sets out the objective of limiting the rise in global average temperature to no more than two degrees Celsius above pre-industrial levels. To achieve this goal the EU committed to a unilateral emissions reduction target of 20% by 2020 compared with 1990 levels and agreed to a reduction of 30%, provided that other major emitters agree to take on their fair share of a global reduction effort.

The transportation sector and international reduction strategies

The transportation sector was not explicitly mentioned in the Kyoto Protocol, and the implementation of the protocol, e.g., in the EU by the EU Emissions Trading Scheme (EU-ETS), focused on reductions by the largest GHG emitters in industry and energy conversion (some 10,000 plants), making up about 45% of total EU GHG emissions. In other words, the Kyoto Protocol focused on emissions on national territory only.[155]

[155] Wolfgang Schade, (2011), *Transport in the Past and Current Climate Policy Regime*, Published in Rothengatter, W. et al., Transport Moving to Climate Intelligence, Springer, New York, p.30.

Since the Kyoto Protocol only provided a reduction path until 2012, further agreements had to be developed for 2013 and beyond. This was the purpose of the Bali Action Plan agreed at the Conference of the Parties (COP13) in Bali, in which it was planned to set up two ad-hoc working groups. These were the working group on long-term cooperative action (AWG-LCA), which should develop a consistent long-term strategy for mitigation, adaptation, and financing, and the working group on further commitments for Annex I parties under the Kyoto Protocol (AWG-KP), which should establish further reduction targets for the Annex I countries by 2017 or 2020. Both working groups were to prepare an agreement to be adopted at the COP15 in Copenhagen in 2009. As we know now, this attempt failed and the outcome of COP15 was the so-called Copenhagen Accord that again did not specify any commitments for the transport sector.

However, the Bali Action Plan introduced the concept of Nationally Appropriate Mitigation Actions (NAMA), which could provide a way forward to take transport measures, in particular in developing countries, for reducing GHG emissions, as was proposed by several organizations after COP15.

The transportation sector was neglected completely in the first 15 years of climate policy. The 10% reduction target of the EU for 2020 compared to 2005 was the first that applied directly to the transportation sector.[156]

Shade discusses how passenger vehicle population and total vehicle miles of travel are the main reasons for oil demand growth in all regions of the world.

EU commitments in the Kyoto Protocol

Under the Kyoto Protocol, the 15 countries that were EU members before 2004 (EU-15) are committed to reducing their collective emissions to 8% below 1990 levels by the years 2008-2012. Emissions monitoring and projections show that the EU-15 is well on track to meet this target. Most Member States that have joined the EU since 2004 also have Kyoto reduction targets of 6% or 8%.[157]

[156] Wolfgang Schade, op. cit., p.35.
[157] http://ec.europa.eu

2.2. CO_2 emissions in the EU transportation sector: An overview

2.2.1. Current situation and emission trends

Most European countries deal with fossil energy consumption from two points of view: the environmental concerns of pollution and greenhouse gas emissions on one hand, and economic sustainability and improving energy security on the other.

Europe imports approximately €300 billion worth of oil annually; one third of this is consumed by cars.[158] Thus, controlling energy consumption and reducing greenhouse gas emissions have been a priority for European policymakers.

As mentioned before, total greenhouse gas emissions reduced in the EU in the 1990-2010 period, but some reports show a considerable growth for the transportation sector. The IEA predicts that, owing to current trends, global energy use in the sector will increase on average by 1.6% annually up to 2030, unless significant policy action is taken.[159]

According to the European Environment Agency, despite carbon-reduction programs in transportation, greenhouse gas emissions have increased significantly by over 17% over 20 years (from 1990 to 2010) in the sector. The emissions from this key source are due to fossil fuel consumption in road transport, which increased by 17% between 1990 and 2010.[160]

Over three quarters (76.5%) of the EU-15 emissions in 2010 belonged to five countries: Germany, France, the UK, Italy and Spain. Apart from Germany (-3%), all EU-15 member countries'[161] carbon dioxide emissions grew during the period (Table 2.4). For some members, such as Ireland and Luxemburg, the growth was over 100% during the period, which is because of growth in road transportation demand and growth in the number of vehicles. The Member States with the highest increases in absolute terms were Spain, Italy, France and Portugal. The

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[158] Transport & Environment (June 2012), *Car CO_2 standards*, p.3. Retrieved July 6, 2012, from: www.transportenvironment.org

[159] International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps*, Paris, OECD, p.43. *Retrieved* June 14, 2012, from: www.iea.org

[160] European Environment Agency (EEA), (27 May, 2012), *Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012*, Copenhagen, pp.193 – 194. Retrieved June 11, 2012, from: http://www.eea.europa.eu

[161] For EU-27 Member States, Bulgaria, Estonia and Lithuania had an improving performance trend as well.

countries with the lowest increase in relative terms were Finland, France, Sweden and the United Kingdom.

Table 2.4. Road Transportation: Contributions of EU-15 to CO_2 emissions

Member State	CO_2 emissions in Gg			Share in EU-15 emissions in 2010 (%)	Change 2009-2010 (%)	Change 1990-2010 (%)
	1990	2009	2010			
Austria	13,324	20,894	21,662	2.9	4	63
Belgium	19,270	25,914	23,222	3.1	-1	21
Denmark	9,282	12,160	12,108	1.6	0	30
Finland	10,806	11,278	11,810	1.6	5	9
France	112,787	122,270	123,829	16.6	1	10
Germany	150,358	144,134	145,438	19.5	1	-3
Greece	11,742	20.964	18,907	2.5	-10	61
Ireland	4,691	11,860	10,951	1.5	-8	133
Italy	93,387	109,906	108,678	14.5	-1	16
Luxemburg	2,574	5,823	6,202	0.8	7	141
Netherlands	25,470	33,344	33,757	4.5	1	33
Portugal	9,476	18,263	18,046	2.4	-1	90
Spain	50,442	86,114	82,943	11.1	-4	64
Sweden	17,310	18,752	18.962	2.5	1	10
United Kingdom	108,135	110,812	110,822	14.8	0	2
EU-15	**639,055**	**752,488**	**747,336**	**100**	**-0.7**	**17**

Source: European Environmental Agency (2012)

CO_2 emissions from road transportation had the highest increase in absolute terms of all energy-related emissions (Figure 2.6), while CO_2 emissions from manufacturing industries decreased substantially between 1990 and 2010. Increases in road transport occurred in most of the European Member States, whereas emission reductions from manufacturing industries mainly occurred in Germany after reunification.[162]

[162] European Environment Agency (EEA), (27 May, 2012). *Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012*, Copenhagen, p.116. Retrieved June 11, 2012, from: www.eea.europa.eu

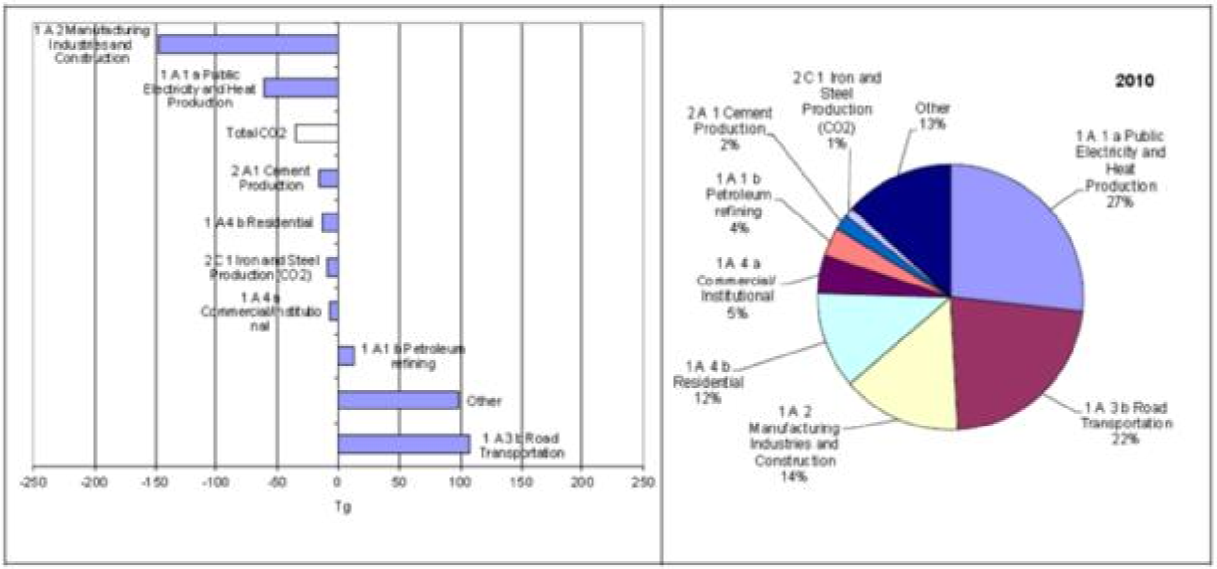

Figure 2.6. Absolute change of CO_2 emissions by large key source categories, 1990 to 2010, in CO_2 equivalents (Tg) for EU-15, and share of largest key source categories in 2010 for EU-15

Source: European Environmental Agency (2012)

Demand growth

As mentioned before, the main reasons for significant growth of CO_2 emissions in European Member States' road transportation during the last two decades are growth in road transportation demand and growth in number of vehicles. The number of cars sold directly relates to the economic growth of the geographic region. According to Eurostat, GDP in the EU-27 grew 40% between 1992 and 2007. Statistics show that European people have purchased more cars as their welfare has improved. The EEA reported that the motorization rate (number of passenger cars per thousand inhabitants) in EU-27 countries increased from 345 in 1990 to 473 in 2009 (over 37%) (Table 2.4).[163]

[163] European Environment Agency (EEA), (2011), *Laying the foundations for greener transport*, TERM 2011: transport indicators tracking progress towards environmental targets in Europe, EEA Report No 7/2011 , Copenhagen, Denmark.

According to the EEA, demand for transport grew by approximately one third between 1990 and 2009. This led to a 37% increase in greenhouse gases from transport in the same period.[164]

Table 2.5. Number of passenger cars per thousand inhabitants in EU-15 Member States and EU-27 totals

Member State	**1990**	**2009**	**Change (%)**
Austria	388	521	34
Belgium	387	479	24
Denmark	309	383	24
Finland	388	519	34
France	476	500	5
Germany	461	510	11
Greece	170	454	167
Ireland	228	432	89
Italy	483	605	25
Luxemburg	477	660	38
Netherlands	367	460	25
Portugal	185	419	126
Spain	309	478	55
Sweden	419	460	10
United Kingdom	361	470	30
EU-27	**345**	**473**	**37**

Source: EEA 2011

Tables 2.4 and 2.5 show that the performance of German policymakers was more successful than those in other Member States: despite growth in motorization rate, greenhouse gas emissions were reduced during the last two decades.

Vehicular expenses in the EU

Harrington discussed the expenses of owning and using a private car, which accounts for 18% of the expenditure of an American household. These costs in the Europe are higher than the US

[164] European Environment Agency (EEA), (11 Nov., 2011), *European transport sector must be ambitious to meet targets*, Retrieved June 10, 2012, from: http://www.eea.europa.eu/pressroom/newsreleases/european-transport-sector-must-be

because of higher prices of fuel and vehicles. However, the statistics show that the motorization rate is saturating in European Member States.[165]

Pollution emission in the sector

The responsible European institutions have reported many improvements in air quality since the EU introduced some binding and non-binding limits in the 1970s. Key legislation that set pollutant limits across Europe includes the 2008 directive on ambient air quality and cleaner air for Europe (2008/50/EC) and the 1996 framework directive on ambient air quality assessment and management (96/62/EC).[166] However, road transportation is the major cause and the main source of air pollution in European countries. Figure 2.7 shows the share of the different sectors in European greenhouse gas emissions and air pollution in 2008.[167]

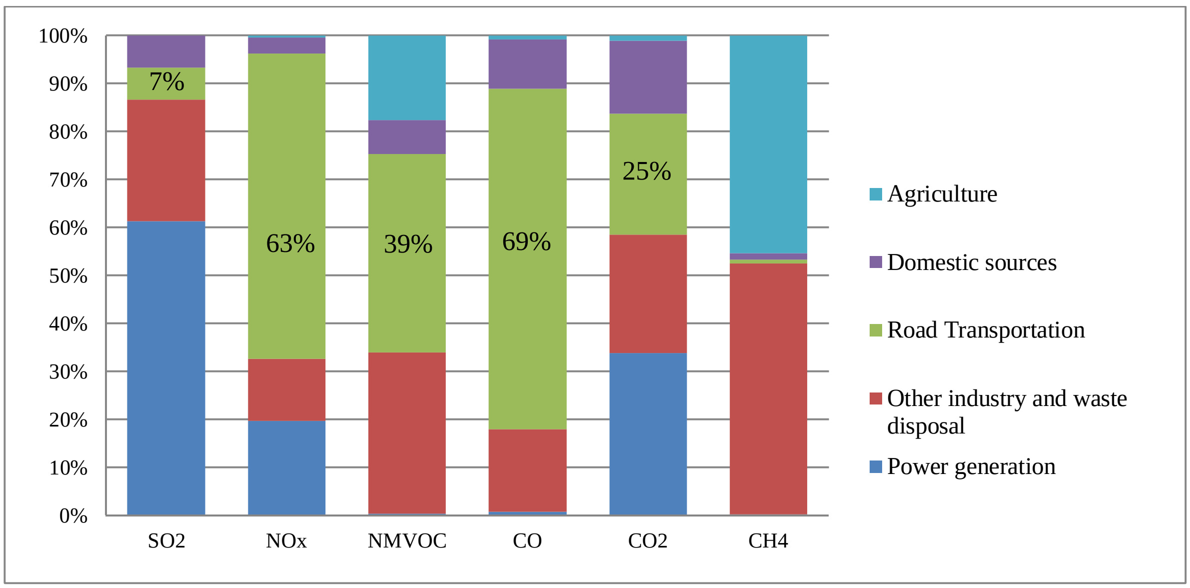

Figure 2.7 Greenhouse gas emissions and air pollution in Europe

Source: EEA 2008

It should be mentioned that carbon dioxide is not the only pollutant. However, regulations and technical procedures for reducing and controlling the other main pollutants – particulate matter of certain sizes ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides

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[165] Winston Harrington, (2008), *The Design of Effective Regulations of Transport*, OECD/ITF, JTRC Discussion Paper 2008-2, p.8.

[166] European Environment Agency (EEA), (Aug. 19, 2013), *Air legislation in Europe*, Retrieved August 24, 2013 from: www.eea.europa.eu

[167] European Environment Agency (EEA), (Dec. 19, 2008), *Sources of Air Pollution*, Retrieved August 24, 2013 from: www.eea.europa.eu

(NO_x), ozone (O_3), lead (Pb) and non-methane volatile organic compounds (NMVOC) – will lead to reduced CO_2 emissions directly or indirectly. For example, low-sulfur fuels are necessary to meet stricter emissions standards and in addition they help fuel efficiency in new engines. Improvement in pollution standards of new vehicles is a key challenge for reducing carbon in transportation.

Vehicle emissions have been regulated through a series of performance and fuel standards, including the 1998 directive relating to the quality of gasoline and diesel fuels (98/70/EC) and vehicle emissions standards, known as Euro standards.

The Euro 5 and 6 standards cover emissions from light vehicles including passenger cars, vans and commercial vehicles. The Euro 5 standard came into force on 1 January 2011 and requires all new vehicles covered by the legislation to emit fewer particulates and nitrogen oxides than specified in the limits. Euro 6, which entered into force in 2015, imposed stricter limits on nitrogen oxides emitted by diesel engines.

Owing to emissions limits for vehicles, transport-related emissions of particulate matter (30%), acidifying substances (34%) and ozone precursors (48%) have reduced across the 32 EEA member countries between 1990 and 2007.[168] The introduction of catalytic converters and reduced sulfur content in fuels has contributed substantially to the reduction of these pollutants, offsetting the pressure from increased road traffic (Figure 2.8).

[168] European Environment Agency (EEA), (2010), *Towards a resource-efficient transport system*, TERM 2009: indicators tracking transport and environment in the European Union, EEA Report No 2/2010, Copenhagen, Denmark, p.17.

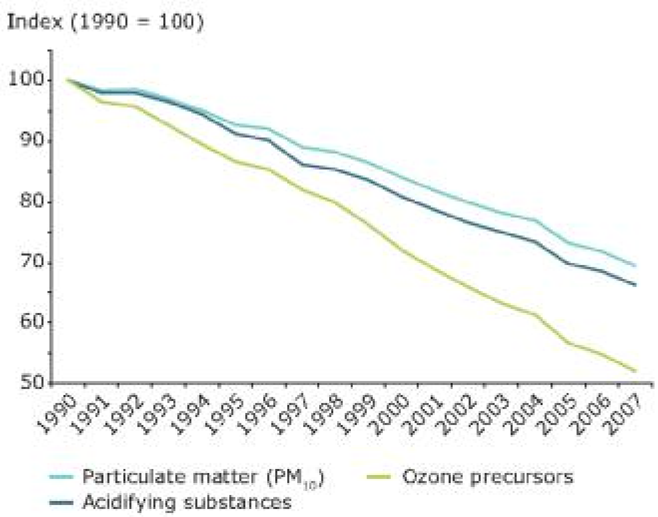

Figure 2.8. Transportation emissions of regulated air pollutants in EEA member countries

Life-cycle analysis of passenger cars from a greenhouse gas emissions point of view

The environmental compatibility of a vehicle is determined by the environmental burden caused by emissions and the consumption of resources throughout the vehicle's life cycle (Figure 2.9).

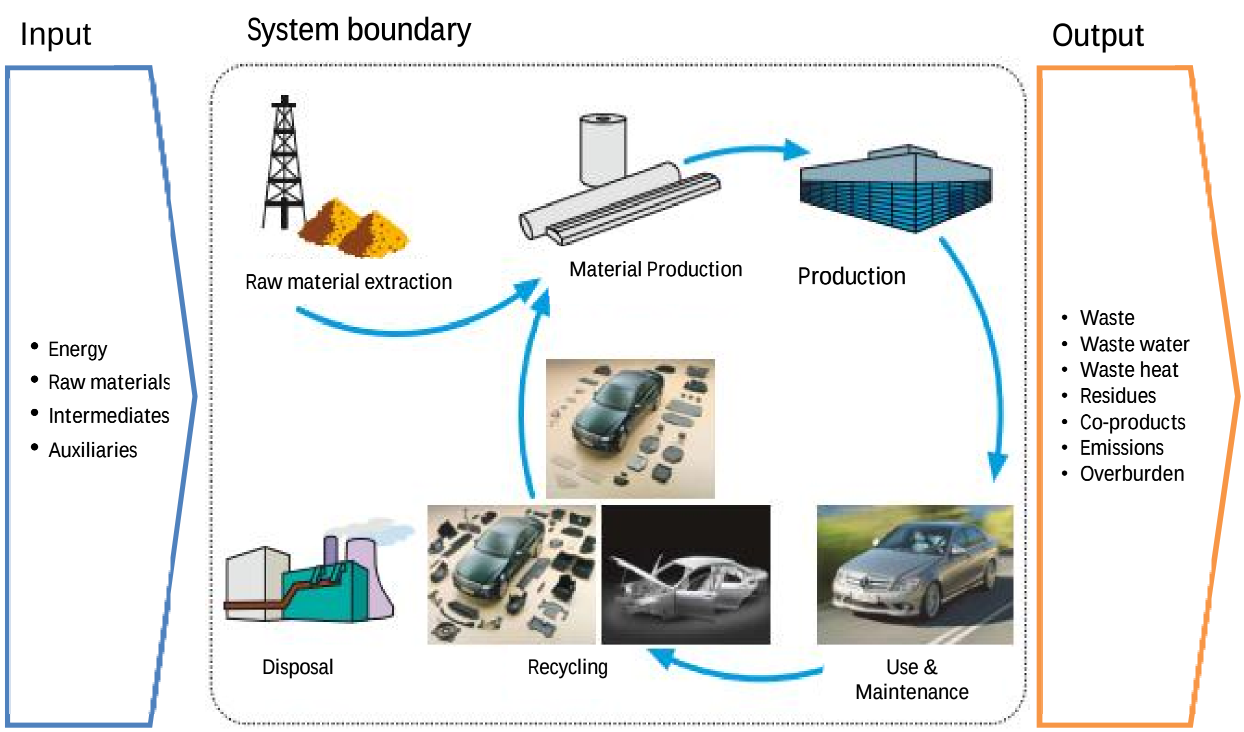

Figure 2.9. Overview of a passenger car's life cycle

Source: Mercedes Benz, August 2007

Mercedes Benz reported that the use phase accounts for the largest share of CO_2 emissions and primary energy consumption (over 83% for C-Class Saloon).[169] For a more complete assessment, the environmental impact of different fuels' life cycles should be added to the issue. The European Environment Agency conducted a full life-cycle analysis for passenger cars in 2008, based on 2005 data. According to the study's results, a total of 777 Mt CO_2-equivalent was attributable to passenger cars in the EU-25 in 2005.[170] Of this, 77% was from the combustion of fuels in vehicle operation (tank to wheel), 13% from the production and distribution of fuels (well to tank) , 8% from vehicles production, and finally 1% from disposal of used vehicles (end of life) (Figure 2.10).

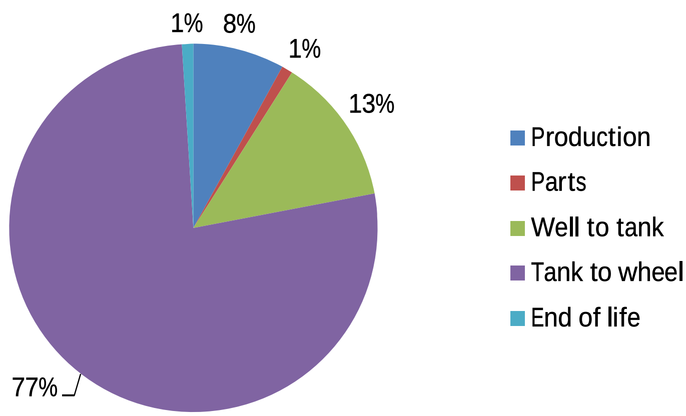

Figure 2.10. Life cycle analysis of greenhouse gas emissions from a passenger car in the EU

Source: EEA 2010

Offsetting carbon reduction by car market behavior

Capros et al. indicated the slow pace of energy efficiency of new cars in the decade 1990-2000.[171] The key point here is the factors that offset efficiency improvement:

[169] Mercedes Benz, (August 2007), Environmental Certificate C-Class Saloon, DaimlerChrysler AG, Mercedes Car Group, D-70546 Stuttgart, Germany.
[170] European Environment Agency (EEA), (2010), *Towards a resource-efficient transport system, TERM 2009: indicators tracking/ transport and environment in the European Union*, EEA Report No 2/2010, Copenhagen, Denmark, p.15.
[171] P. Capros, L. Mantzos, V. Papandreou, N. Tasios, (2008), *European Energy and Transport: Trends to 2030 – Update 2007*. European Commission, Brussels, p.53.

1. Growth in vehicle size

The average size and weight of registered cars have increased over the last 15 years in the EU.[172] The first reason for this is changing life styles and increasing demand for longer and heavier vehicles. For example, SUVs have become more popular in the EU. Secondly, enhancing the safety features and standards in new cars has resulted in higher weights and so tended to raise fuel consumption.

2. Growth in vehicles' engine capacity

The European car market has tended to produce and consume vehicles of higher engine capacity on average. The IEA reported that the number of cars with an engine capacity greater than two liters has more than doubled since 1990.

3. Growth in car usage (distance travelled by car)

For most European countries, improvements in the fuel efficiency of new cars have not been sufficient to offset the distance travelled by each car. The EEA reported that the majority of member countries (except for Bulgaria, Estonia, Lithuania and Germany) have shown an increase in transportation carbon dioxide emissions between 1990 and 2007 because of increased transportation movements.[173]

2.2.2. A perspective on CO_2 emissions in the EU's transportation sector

Global perspective

With the global population growing by around 40% by 2050, the number of vehicles in the world is expecting to increase from 700 million to 2 billion by that time. Owing to this growth, the global demand for energy will increase between two and three-fold.[174] The International Energy Agency (IEA) and the International Transport Forum (ITF) have developed a range of

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[172] International Energy Agency (IEA) (2008), *Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis,* Paris, France: OECD/IEA, p.63. Retrieved June 25, 2010 from: http://www.iea.org/papers/2008/indicators_2008.pdf

[173] European Environment Agency (EEA) (2010), Towards a resource-efficient transport system; TERM 2009: indicators tracking transport and environment in the European Union, Copenhagen, p.15. Retrieved July 25, 2012 from: http://www.eea.europa.eu/publications/towards-a-resource-efficient-transport-system

[174] Duncan Eggar, (2007), *Toward a Policy Agenda for Climate Change: Changing Technologies and Fuels and the Changing Value of Energy*, published in Sperling, D., and Cannon, J. S., Driving Climate Change: Cutting Carbon from Transportation, Academic Press is an imprint of Elsevier, p.29.

projections of possible 'business-as-usual' scenarios following these estimates[175] (Figure 2.11). Kodjak et al. projected that road emissions will grow more than 2% annually, reaching 8.4 Gt CO_2 in 2030. They stated the US, China and the EU are expected to remain the top three emitters, responsible for more than 60% of global road emissions.[176]

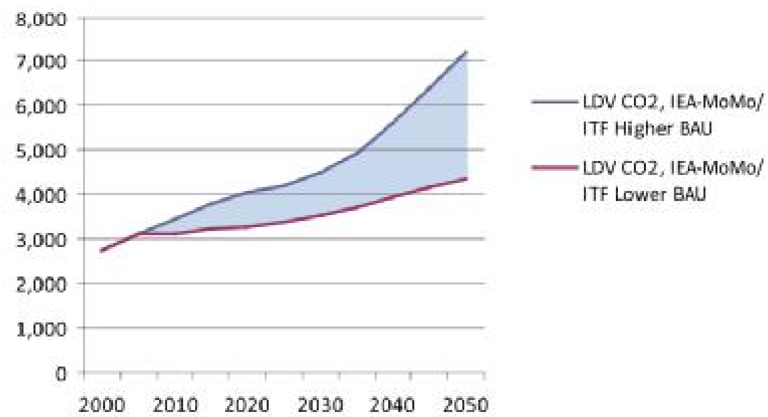

Figure 2.11. World CO_2 emissions from cars (Mt of CO_2 equivalent GHG, well-to-wheels)

Source: IEA and ITF

The FIA Foundation et al. project that non-road transportation will push the share of road transportation to less than 40% by 2050, but the rapid growth – by 80% – of new non-OECD countries will be a challenge owing to growth of fuel demand by then. [177]

These projections emphasize the strong likelihood of serious energy security and environmental global concerns in future. The EEA predicts that, owing to current trends, greenhouse gas emissions from the world transportation sector will continue to grow in contrast to other sectors such as industry, housing and energy production.[178]

Projection of energy consumption in EU transportation

Capros et al. studied energy consumption in European transportation. They projected a 0.8% annual increase from 2005 to 2030, which is lower than the rate of 1.76% growth experienced

[175] FIA, IEA, ITF and UNEP, (March 2009), 50by50 Report on making cars 50% more fuel efficient by 2050 worldwide, p.6.
[176] Drew Kodjak et al, op. cit., p.5.
[177] FIA et al, op. cit., p.6.
[178] European Environment Agency (EEA), (2010), Towards a resource-efficient transport system, TERM 2009: indicators tracking transport and environment in the European Union, EEA Report No 2/2010, Copenhagen, Denmark, p.14.

from 1990 to 2000. According to their study, diesel and gasoline were the most used fuels in transportation by over 95% in 2010. They projected that the rate will increase to over 88% in 2030, but the share of diesel will remain at near 60% and the alternative fuels market will double in the period from 6% to near 12% (Table 2.6 and Figure 2.12).[179]

Table 2.6 Trends of energy consumption in road transport

shares in %	1990	2005	2010	2020	2030
Gasoline	57.7	38.8	35.2	31.4	29.3
Diesel	41.1	58.8	58.9	58.9	58.9
LPG	1.2	1.5	1.8	2.0	2.1
Biofuels	0.0	1.1	3.9	7.4	9.4
Gas	0.1	0.2	0.2	0.3	0.3
Electricity	0.0	0.0	0.0	0.0	0.0

Source: European Commission (2008) (by Capros et al.)

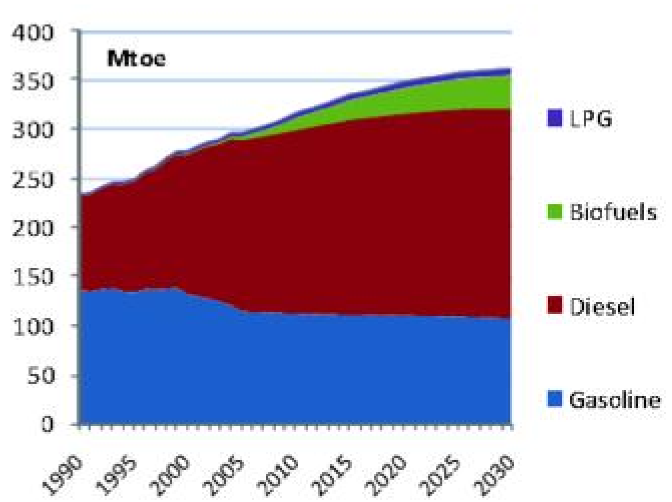

Figure 2.12. Energy consumption in road transport

Source: European Commission (2008) (by Capros et al.)

Continual increase owing to economic growth

Growth in transportation activities is also related to economic growth and market demand. Capros et al. showed transportation activity growth by estimating the relations of passenger-

[179] P. Capros et al, op. cit., p.54.

kilometer and ton-kilometer to economic growth and completion of internal market in the EU (Figures 2.13 and 2.14).

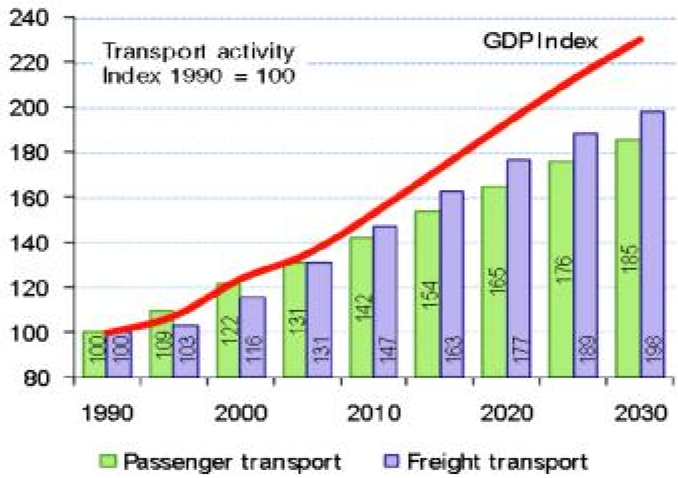

Figure 2.13. Transport activity growth 1990-2030

Source: European Commission (2008) (by Capros et al.)

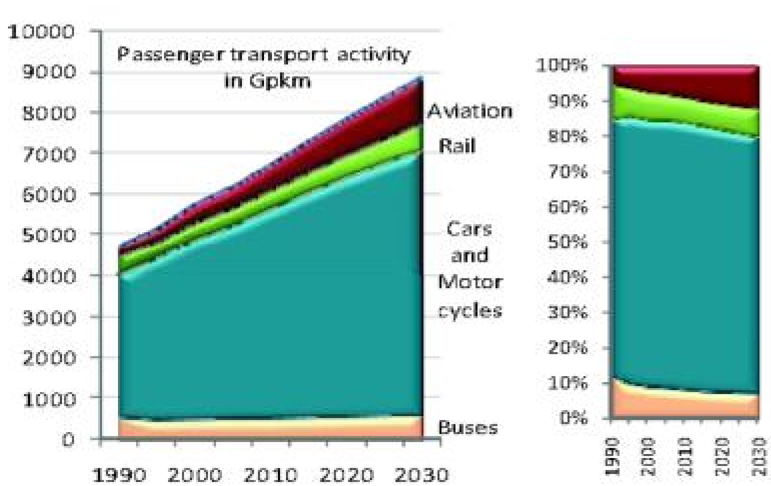

Figure 2.14 Passenger transport activity by mode 1990-2030

Source: European Commission (2008) (by Capros et al.)

Projections of passenger car ownership in the EU

The trend of increasing car ownership could enhance energy consumption in the EU. Capros et al. project that the motorization rate (cars per 1,000 inhabitants) in the EU will increase from 460 in 2005 to 710 in 2030 (54% increase).[180]

As mentioned before, the market trend toward larger, heavier and more powerful cars is a concern that could offset reduction policies. Bleijenberg believes that, as a result of this issue, greenhouse emissions from cars will grow at nearly the same rate as the number of kilometers driven. He also predicts that European car traffic will gradually stabilize after 2030 and may begin to decline after this growth period.[181] However, Capros predicts that, owing to the development of more efficient technologies, the energy consumption of new cars will decrease at a rate of 1.25% per year from 2005 to 2030, and average energy consumption will reach 7.5 liter/100 km by 2030.[182]

The effects of technology

The potential of technology for introducing more fuel-efficient vehicles and/or developing a new generation of alternative-fuel engines is limited for road transportation. Serious improvements need expensive infrastructure and costly investments.

The EU has aimed for an 80% reduction target by 2050. Passenger transportation accounts for a lower share of this target than other modes (road freight, aviation, inland shipping and maritime transportation).[183]

The UK experience

The United Kingdom's Department of Transport claims that, for producing low-carbon vehicles (LCVs), the car market should be regulated and obliged to manufacture cleaner cars. The Department hopes that decreasing average per-kilometer CO_2 emissions from new cars, combined with increased use of biofuels and also changes in consumer choices, will help to

[180] P. Capros et al, op. cit., p.53
[181] Arie Bleijenberg, (2012), *The Attractiveness of Car Use*, Published in Zachariadis, Th.I., *Cars and Carbon*, Springer, p.40.
[182] P. Capros et al, op. cit., p.53.
[183] Karst Geurs, K. et al., op. cit., p.55.

achieve a 50% reduction in average per-kilometer carbon emissions from cars across the UK. The Department considers deploying more restricted vehicle emissions standards to encourage the production of cars with lower carbon emissions output.[184]

2.3. Policies and regulations focusing on the automotive industry

2.3.1. Role of government in policy-making procedure

Both automakers (supply side) and passenger vehicle consumers (demand side) expect the government to intervene in the supply–demand relation for several reasons:

First, vehicle manufacturers face different kinds of risks, such as fluctuating fuel prices. They do not desire to invest in new technologies unless they are sure of a market for newly equipped vehicles. Fuel efficiency regulations can provide certainty for investors.

Secondly, consumers need reliable official sources to ensure them of proper performance of new vehicle technologies related to fuel efficiency and emission standards. They look for shorter payback on products in which they want to invest (goods such as vehicles and services such as public transportation and/or non-motorized mobility).

The International Transport Forum (ITF) gives a brief analysis of consumers' uncertainty when they decide to buy a car. According to this report, in the case of deciding which car to buy, uncertainty over future fuel prices is compounded by uncertainty over how intensively the car will be used and what level of fuel economy the vehicle will achieve in real-world use. This last can lead to high implicit discount rates and generally low willingness to pay for fuel economy.[185]

Kodjak et al. discuss the two greatest potential carbon reduction policies in road transportation: vehicle performance standards, and fuel and vehicle fees. The former require manufacturers to produce more efficient vehicles, usually at a very low cost, and the latter encourage consumers to

[184] Department for Transport (October 2007), *Towards a Sustainable Transport System: Supporting Economic Growth in a Low Carbon World*, London, Secretary of State for Transport, p.14.
[185] International Transport Forum (ITF), (2010), *Stimulating Low-Carbon Vehicle Technologies*, OECD/ITF, JTRC Discussion Paper 2010-13, p.7. Retrieved August 10, 2012, from: http://www.internationaltransportforum.org

choose the most efficient vehicles and therefore encourage automakers to improve the fuel efficiency of new vehicles continuously.[186]

They also discuss the synergistic effect of these policies. Consumers tend not only to choose more efficient vehicles and to drive less, but also prefer to live closer to work and use public transportation. These approaches can affect urban planning and land-use patterns that have greater benefits for global greenhouse gas emissions.

The International Energy Agency developed a scenario for the reduction of greenhouse gas emissions in transportation by 2050 to 40% below 2005 levels. They predict this achievement through improving vehicles' efficiency and developing alternative fuels, despite the predictable growth in transportation volume.[187]

According to the IEA scenario, three types of policy instruments are suggested:

1. Setting and tightening vehicle fuel consumption or CO_2 emissions standards.
2. Developing mechanisms for increasing fuel taxes. This approach generates an incentive for buying more fuel-efficient cars and also creates a kind of competition among automakers to improve the energy efficiency of their products.
3. Developing fiscal and financial incentives for purchasing fuel-efficient cars or higher technology vehicles, such as hybrids and fuel-cell vehicles (FCVs).

National and international regulations for carbon dioxide emissions reduction and fuel efficiency have improved since the first Corporate Average Fuel Economy standards imposed by the US Congress in 1975. Kodjak et al. introduced six best practices in policy design for low carbon transportation:[188]

1. In the case of weight-based vehicle performance standards, vehicle manufacturers may shift to producing heavier vehicles instead of using lightweight materials. Because of the lenient approach to heavier models, it is highly preferable to avoid weight-based performance standards.

[186] Drew Kodjak et al., p.8.
[187] Arie Bleijenberg op. cit., p.38.
[188] Drew Kodjak et al., pp.25-26.

2. It is better to use carbon dioxide (or carbon dioxide equivalent) as the metric. Thus, interested parties can monitor greenhouse gas emissions of all types of fuels in an equivalent manner and also cover all non–carbon dioxide greenhouse gases, such as fluorocarbons (refrigerants in an air-conditioning system). The latter advantage has the potential of reducing emissions by up to another 5%.
3. Proper standards should tighten limitations in a definite and predictable timeframe for automakers. Kodjak et al. discussed a 3 to 6% improvement of fuel efficiency annually through the deployment of a proper standard.
4. Regulations should provide a continual framework to push automakers to maximize efficiency improvements and emissions reductions across all models.
5. Standards should cover all types of vehicles, especially in developing countries. In the case of weak coverage for all vehicle types, automakers may switch to unregulated models.
6. Vehicles' test-cycle methods are different across different countries and test results are not the same as real-world driving. Governments should address this issue, especially in the regions where standards have been developed only recently.

2.3.2. Setting emission standards: A major step

The control of pollutants has a long history of regulation in the European Union since the mid-1960s. Germany and France gave the initiative to pollution regulations independently, but this approach was a barrier for free trade for other EU members. As a consequence, implementation of European emission regulations was delayed until the early 1990s.[189]

The first set on European emissions standards were introduced in the early 1990s and named Euro1 and Euro2, for gasoline and diesel-light duty vehicles. These standards regulate conventional pollutants from fossil fuel combustion (CO, PM, NO_x and SO_2). The European Union's emission standards were implemented over the following timeframe:[190]

[189] The International Council on Clean Transportation (ICCT), (2012), *Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles*, ICCT, Washington DC. p.2. Retrieved July 23, 2013 from: www.theicct.org
[190] Drew Kodjak et al., pp.14-15.

By the 1990s

- Before deploying the Euro1 standard, some technology innovations were introduced in the US that decreased emissions levels. Catalytic converters, along with the phasing out of lead in gasoline and exhaust gas recirculation, were the first significant steps.

1990s

- By introducing Euro1 and Euro2 standards, more improvements, such as catalyst and fuel injection improvements, were made, including multipoint fuel injection and improved air-fuel control with single oxygen sensor self-diagnosis technology required to meet new regulations.
- Over 80 USD/vehicle were spent for launching these technologies in total. It should be mentioned that these are the initial costs at the time of regulation and the costs are much lower now.
- In 1998, the first voluntary CO_2 emissions standards were developed in the EU.

2000s

- By deploying Euro3 standards, automakers have been regulated to reduce NO_x emissions by 25%.
- In 2005, Euro4 levels were deployed and 50% reductions in NO_x, HC and CO have been expected.
- The first mandatory greenhouse gas rules for the automotive industry were implemented in 2009.

2010s

- Euro5 levels of standard were deployed for the automotive industry. According to new regulations, automakers have used new technologies to meet new standards: advanced direct injection, turbochargers, engine downsizing, low-rolling-resistance tires, improved aerodynamics and transmissions, and lightweight materials.

The implementation of emissions standards and the continuous tightening of emissions levels has controlled conventional air pollution from transportation. Kodjak et al. calculated a huge gap between emissions before emission standards were set and 2011: 30 times less for carbon monoxide (CO) and 110 times for nitrogen oxides (NO_x) per kilometer traveled (Table 2.7).

Most conventional pollutants have significant greenhouse gas effects. For example, nitrous oxide (N_2O), round-level ozone and fine particulates contribute to climate change directly or indirectly. Fine particulate emissions (PM_{10} and $PM_{2.5}$) create regional pollution and are a serious health concern in urban areas. Black carbon has a significant climate change impact as a major component of fine particulates.

Table 2.7. Average emissions in the main automakers before 1975 and 2011

	Before 1975	2011 emission standards		
Pollutant (g/km)	US	US	EU	Japan
CO	60	2.6	1.0	1.92
HC	9	0.06	0.10	0.08
NO_x	4.4	0.04	0.06	0.08

Source: Kodjak 2012

Euro standard levels have decreased CO_2 emissions and fuel consumption in new vehicles. Euro3 gasoline cars entered the EU market between 2000 and in 2004 it was estimated that they consume 5% less fuel than their Euro2 counterparts. For Euro4 cars entering the market from 2005 onwards, the estimate of fuel efficiency was 7% less than the corresponding Euro2 vehicles.[191]

Owing to the national economic situation, available technologies, the financial concerns of consumers and investments in the vehicle industry, there are large differences in the implementation time schedule for Euro standard limits in different regions and countries (Table 2.8). The latest emission standard, known as Euro 6, came into force in the EU in 2014.

Table 2.8 Time schedule for implementation of emissions regulations in light-duty vehicles for selected countries

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Europe	EURO 4					EURO 5				EURO 6
Russia	EURO 1	EURO 2					EURO 3	EURO 4		
Taiwan	EURO 3			EURO 4			EURO 5			
Thailand	EURO 2	EURO 3						EURO 4		

Source: The International Council on Clean Transportation (ICCT), (2012),

191 Theodoros Zachariadis, *Assessing policies towards sustainable transport in Europe: An integrated model*, Energy Policy 33 (2005) 1509–1525, p.1516.

2.3.3. Introducing voluntary CO_2 standards

The issue of CO_2 emissions reductions from passenger cars appeared on the political agenda of the EU at the end of 1980s as part of the more general discussion about climate change. Article 6 of Directive 89/458/EC requires setting limits on CO_2 emissions from motor vehicles.[192]

According to this new approach, in the late 1990s the European Commission implemented a voluntary agreement with the European Automobile Manufacturers' Association (ACEA), the Japan Automobile Manufacturers' Association (JAMA) and the Korean Automobile Manufacturers' Association (KAMA).

Based on the Commission's proposal, the Council (i.e. the EU Environment Ministers) and the European Parliament specified in 1995 that an average CO_2 emission figure for new passenger cars of 120 gCO_2/km was to be met by 2010 at latest.

In the following years the European Commission, in co-operation with the Council and the European Parliament, negotiated with the ACEA in order to define the details of the agreement. In July 1998, the European Commission and the ACEA reached an agreement on the reduction of CO_2 emissions from passenger cars. In this agreement, the ACEA committed itself to achieve an average CO_2 emission figure of 140 gCO_2/km by 2008, by technical measures and related market changes, for all of its new cars registered in the European Union.

JAMA and KAMA committed similarly to reducing the CO_2 emissions of their passenger vehicles produced for EU market to 140 g/km by 2009.[193] This presents a 25% reduction over 1995 levels.

According to the UK Department for Transport assessment, the costs of implementing the EU's voluntary agreement package exceed the monetary benefits by over £11 billion:[194]

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[192] Karl-Heinz Zierock, (2012), *The Past and the Future of EU Regulatory Policies to Reduce Road Transport Carbon Emission*, Published in Zachariadis, Th.I., Cars and Carbon, Springer, p.75.

[193] International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps*, Paris, OECD, p.24. Retrieved June 14, 2012, from: www.iea.org

[194] National Audit Office (NAO) (2007), *Cost-Effectiveness Analysis in the 2006 Climate Change Programme Review*, p.17.

Costs:

- Costs to business of adopting new technologies (£9.67 billion).
- Costs to business and consumers of increased congestion, caused by the fact that consumers are expected to drive more as driving becomes cheaper (£7.96 billion).
- Costs of accidents, which will rise in number along with increased congestion.
- Air quality will worsen marginally, because consumers are expected to drive more as the cost per km of driving falls.

Benefits:

- Value of carbon saved, based on the social cost of carbon (£1.32 billion).
- Savings to consumers, because they will be purchasing less fuel (£3.82 billion). This figure takes account of the fact that consumers are expected to drive more as driving becomes cheaper.
- The benefits society receives from driving more (£0.69 billion).
- The benefits society receives from increased use of in-car appliances such as air conditioning (£0.17 billion).[195]

It can be concluded that policymakers look for some benefits, rather than reducing fuel consumption and greenhouse gas emissions. The Community would benefit from long-term benefits of energy security improvement, technology enhancement and growing high-tech employment.

Outcomes of voluntary regulations in the EU

Average actual CO_2 emissions of new ACEA cars have decreased continuously since the introduction of emissions standards. The ICCT reported that CO_2 emissions from new cars in the EU decreased from 170 g/km in 2001 to 136 g/km in 2011 (-20% in 10 years). This corresponds to a reduction in fuel consumption from 7 lit/100km to 5.6 lit/100km.[196] Figure 2.15 depicts the unbroken trend in CO_2 emissions with the 2003 target of 165-170 g/km reached in 2000, three years ahead of schedule. According to the ECMT, 2.8 million cars with CO_2 emissions of 140

[195] The two last items emphasize more on increasing welfare for the vehicles consumers and services providers (for example, through economic turnover).
[196] The International Council on Clean Transportation (ICCT), (January 2013), *Reducing CO_2 and fuel consumption: A summary of the technology potential for new cars in the EU*, Retrieved July 23, 2013 from: www.theicct.org

g/km or less were sold in 2001. This accounts for 23% of all sales and is an increase of 970% on 1995 figures. According to the ECMT, the reductions have largely been achieved by incremental advanced diesel technologies. The ECMT reported that the EU accounts for 90% of global passenger car diesel sales.[197]

The European Commission reported that between 1995 and 2004 average emissions from new cars sold in the EU-15 fell by 12.4%, from 186g CO_2/km to 163g CO_2/km.[198] However, this reduction was far from the planned schedule of the voluntary agreement. Zierock discussed that the automotive industry could not assure any more that the target could be met in 2008/9. The 2008 monitoring report of the Commission confirmed the results. The average CO_2 emissions from new passenger cars in 2008 were 153.5 gCO_2/km, far from the 140 gCO_2/km target. Nevertheless, compared to the situation in 1995, progress in CO_2 efficiency specifically of 17.5% was achieved, providing evidence that the voluntary approach was at least partially successful.[199]

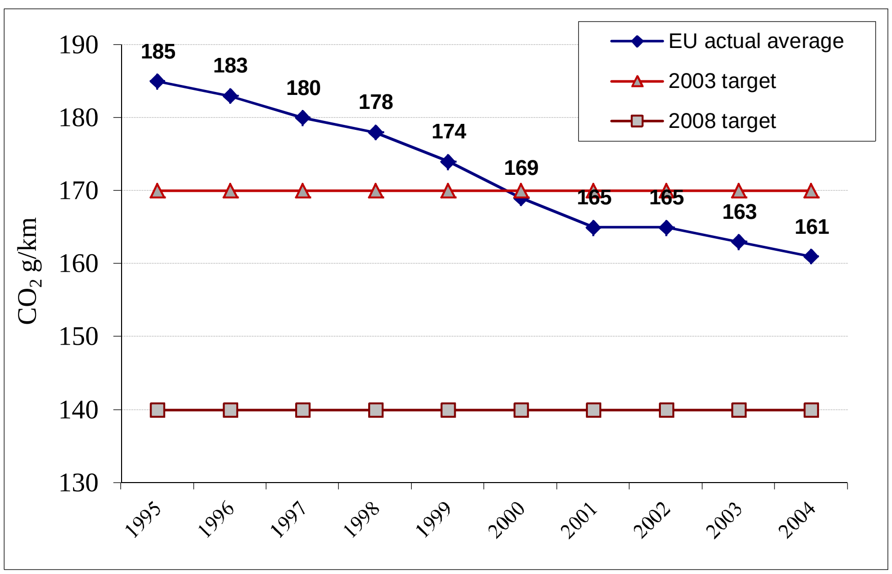

Figure 2.15. Average actual emissions of new ACEA cars, weighted by registrations

Source: Mikler 2009 in Commission of the European Communities (2006)

[197] John Mikler, (2009), *Greening the Car Industry: Varieties of Capitalism and Climate Change*, Edward Elgar Publishing, Inc., Massachusetts, USA, p.104.
[198] http://ec.europa.eu
[199] Karl-Heinz Zierock, p.78.

The Commission was prepared for such a situation and had some policy approaches to redesign the strategy through following roadmaps:

- Improvement in fuel efficiency of new vehicles
- Phasing-in of emission-neutral carbonaceous fuels or energy carriers that can be produced in the EU

Because of increasing wealth in the EU from 1990 to 2003, vehicle customers tended to purchase heavier and more powerful cars, so some technical options like engine downsizing and the weight reduction of cars were not on the list of priorities of automakers.

The EU's regulations according to international agreements

In January 2007, the European Commission proposed, in the context of international negotiations, the objective of a 30% reduction of GHG emissions by 2020 compared to 1990 levels, irrespective of reductions achieved by other developed countries. The objective was endorsed by the European Parliament and the Council.[200]

Although this objective did not specify any GHG reduction targets for transportation, it is clear that the sector must contribute to reduction plans. In 2005, EU transportation accounted for over 23% of GHG emissions.[201] If this trend continues to increase, it will significantly undermine reductions made by other sectors.

2.3.4. Introducing mandatory CO_2 standards

The International Energy Agency studied the International Policies for Vehicle Fuel Efficiency in 2008 and argued that communities are not necessarily able to meet voluntary targets. In light of this issue, Korea, Japan, the European Union and Canada have moved from voluntary to mandatory regulations in recent years.[202]

In April 2009, the European Parliament and the Council issued Regulation (EC) No 443/2009, introducing mandatory CO_2 emissions limits for new passenger vehicles. The standard was

[200] European Parliament, (23 April 2009), *Regulation (EC) No 443/2009: setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles*, p.1.
[201] Wolfgang Schade, op. cit., p.31.
[202] International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps*, Paris, OECD, p.19. Retrieved June 14, 2012, from: www.iea.org

developed based on vehicle mass and specified that automakers must achieve a fleet average annual CO_2 emissions target of 130 g/km by 2015 (compared with 161 gCO_2/km in 2005) and 95 g/km by 2020.[203]

In terms of fuel consumption, the 2015 target is approximately equivalent to 5.6 liters per 100 km (l/100 km) of petrol or 4.9 l/100 km of diesel. The 2020 target equates approximately to 4.1 l/100 km of petrol or 3.6 l/100 km of diesel.[204]

In order to meet the target of 120 gCO_2/km, a further 10 gCO_2/km should be achieved through complementary measures such as tire efficiency, gearshift indicator equipment, air conditioners and greater use of low-carbon biofuels.

European automakers have different approaches to dealing with the 95 $grCO_2$/km target. For example, Volkswagen has already committed itself to the 95 gr target. However, other German luxury carmakers, such as BMW and Daimler, claimed that the target is impossible. They say that the 95 gr limit cannot be met earlier than 2024. Since many important and well-known brands produce vehicles in Germany,[205] the country's automaker industry has strong lobbies in the European Parliament. Thus, the German government, joining Britain and Portugal, persuaded its EU partners to delay introducing the target.[206]

Calculation mechanism

The mandatory legislation defines a limit value curve of permitted CO_2 emissions from new vehicles according to the mass of the vehicle (Figure 2.16).[207] Following this value curve, a vehicle manufacturer should ensure that the average emissions of all its new vehicles do not exceed the limit in the given year. For example, if the average mass of a manufacturer's car in a

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[203] European Parliament, (23 April 2009), *Regulation (EC) No 443/2009: setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles*

[204] European Commission, (30 July 2012), *Road transport: Reducing CO2 emissions from vehicles.* Retrieved 17 July, 2013 from http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm

[205] Germany produced over 5.6 million vehicles (both cars and commercial vehicles) in 2012 and was ranked as the fourth country in the world after China, the USA and Japan.
Retrieved February 12, 2014, from: www.oica.net/category/production-statistics/2012-statistics/.

[206] Martin Banks, (October 15, 2013), *EU delayed introducing car CO_2 emissions limit*, The Telegraph, Britain. Retrieved February 12, 2014, from: http://www.telegraph.co.uk/news/worldnews/europe/eu/10380392/EU-delays-introducing-car-CO2-emissions-limit.html

[207] International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps*, Paris, OECD, p.24. Retrieved June 14, 2012, from: www.iea.org

given year is 1472 kg, the target for that manufacturer is 134.57 gCO_2/km, and in the case of 1272 kg average mass, the target will be 125.43 gCO_2/km.

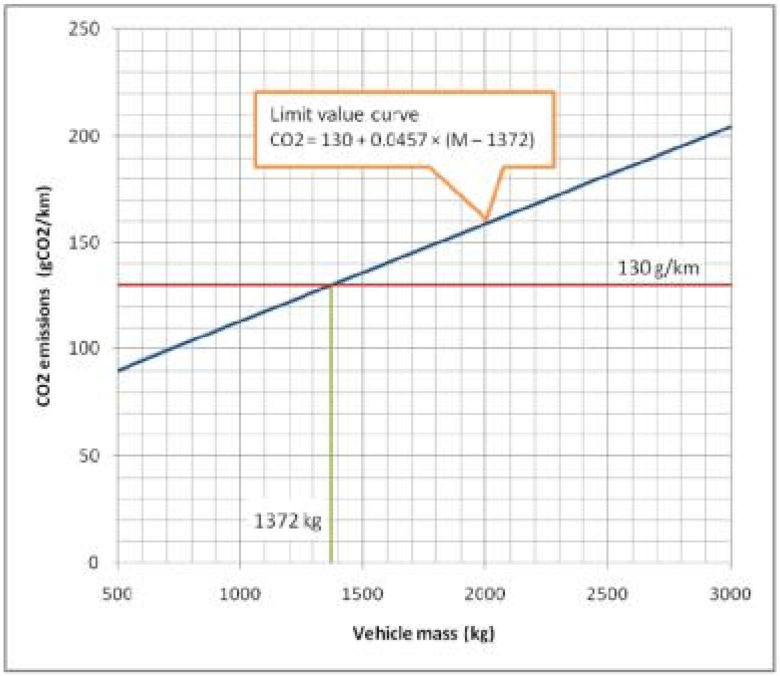

Figure 2.16. Limit value curve for passenger cars according to Regulation (EC) No 443/2009

Source: International Energy Agency(2010) from EU 2009

According to the Regulation, 65% of a manufacturer's newly registered vehicles in 2012 had to meet the limit curve. This limit rose to 75% in 2013, 80% in 2014 and 100% from 2015 onward.

The Regulation provides an incentive for the manufacturers that have excess CO_2 emissions. Its premium is based on the number of grams per kilometer (g/km) by which an average vehicle sold by the manufacturer is above the curve, multiplied by the number of vehicles sold by the manufacturer.

The regulation also specified a 'super-credit' for new passenger vehicles with CO_2 emissions lower than 50g/km. According to this credit, one very low-emitting car will be counted as 3.5 cars in 2012 and 2013, 2.5 cars in 2013, 1.5 cars in 2015 and 1 car from 2016 onward.

In the case of exceeding average CO_2 emissions limits, the manufacturer has to pay an excess emissions premium as penalty for each car registered. The premium amounts to 5 EUR for the first excess g/km, and 15, 25 and 95 Euro for the second, third and each subsequent g/km. From 2019, the cost will be 95 EUR from the first gram onwards.

The ICCT in 2013 estimated that, for meeting the 95 gCO_2/km target in 2020, an investment in new technologies of about € 1000 per vehicle was needed.[208]

Owing to the fuel efficiency of 95 gCO_2/km, the expected fuel cost saving for the first year of an average passenger car was €340, with a total of €2904-3836 (depending on the fuel price) over a car's lifetime (13 years). The European Commission estimated that consumers will save €27 billion per year in fuel cost. This value will rise to €36 billion in 2030 in comparison with the 2015/2017 targets.[209] The European Commission also estimated that the 2020 target could increase the EU GDP by €12 billion and spending on employment by some € 9 billion a year.[210]

The outcomes of mandatory regulations in the EU

The International Council for Clean Transportation (ICCT) recommended using stricter fuel efficiency standards and higher fuel taxes for both reduction of GHG emissions and reduction of oil dependence. The ICCT reported that, beginning with the new European mandatory regulations, the rate of CO_2 emissions from new passenger cars had started to reduce sharply: 1.6% in 2007, 3.2% in 2008 and 5.4% in 2009 (Figure 2.17).[211] The ICCT projected that, if the improvement rate since the mandatory standard for new cars continues, the proposed 95 gCO_2/km target for 2020 would be met on time.[212]

According to the EEA, the majority of the large automakers are well on track to achieve the emissions targets of the Regulation 443/2009 as well.[213]

[208] The International Council on Clean Transportation (ICCT), (January 2013), *Reducing CO2 and fuel consumption: A summary of the technology potential for new cars in the EU.* Retrieved July 23, 2013 from: www.theicct.org

[209] European Commission, (July 2012), *Proposed Regulation defining the modalities for reaching the 2020 target for CO2 emissions from new cars.* Retrieved 25 June, 2013 from: http://ec.europa.eu

[210] European Commission, (July 2012), op. cit.

[211] International Council on Clean Transportation (ICCT), (2011), *A Ten-Year Retrospective,* p.11. Retrieved July 23, 2013 from: www.theicct.org

[212] The International Council on Clean Transportation (ICCT), (January 2013), *Reducing CO_2 and fuel consumption: A summary of the technology potential for new cars in the EU*. Retrieved July 23, 2013 from: www.theicct.org

[213] European Environment Agency (EEA), (2012). CO_2 *emissions performance of car manufacturers in 2011*, Copenhagen, p.2. Retrieved June 10, 2012, from: http://www.eea.europa.eu

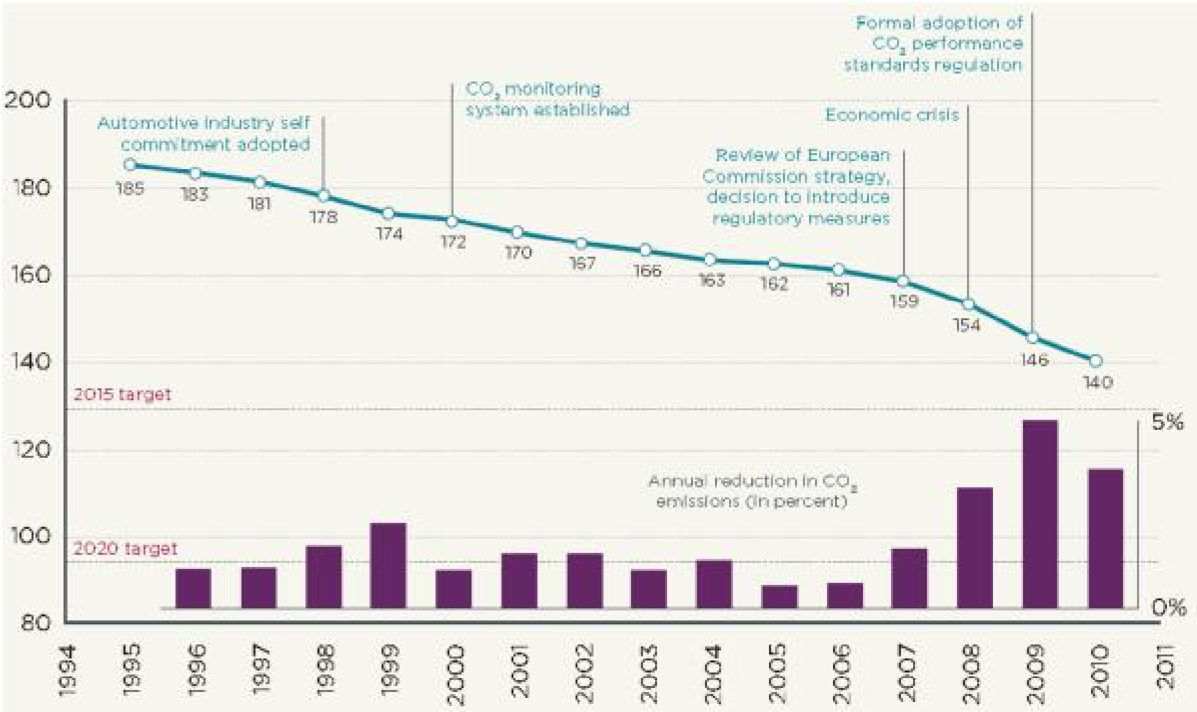

Figure 2.17 Average CO_2 emissions of new passenger cars in the EU (in g/km)

Source: ICCT, 2011

The EEA reports that the average CO_2 emissions of the European new car fleet in 2013 were 127.0 grCO_2/km. This is the first time that this indicator is below the 2015 target.[214]

The effect of alternative fuels in CO_2 emissions

Just about 6% of the total energy carriers consumed in European road transport are non-fossil fuels.[215] The huge oil consumption in the EU reflects both economic and environmental concerns for Member States. Thus, decarbonizing road transportation is a strategic priority for the EU through energy efficiency improvement and bringing lower carbon content fuels into the consumption market.

The European Commission identified biofuels, natural gas and hydrogen as possible future alternative sources of energy for road transportation. After some detailed studies, natural gas has

[214] European Environment Agency (EEA), (April 2014), *Monitoring CO_2 emissions from new passenger cars in the EU: summary of data for 2013*, Copenhagen, Denmark.
[215] Karl-Heinz Zierock, op. cit., p.74.

failed as a key alternative fuel, but the challenge is to define a sound calculation of an alternative fuel's life cycle in the EU so as to develop the low-carbon fuel standard (LCFS). The environmental success of hydrogen and electricity options strongly depends on the greenhouse emissions of primary energy.

The European Environment Agency (EEA) estimates that, in the case of using a mixture of petrol with 85% ethanol (E85) in capable vehicles, CO_2 emissions will be reduced by 5% in 2015.[216] This option needs to establish special infrastructure. For example, at least 30% of the gas stations in the EU should be equipped with this type of alternative fuel. Zierock in 2012 concluded that biofuels alone could not be a sustainable road transportation fuel in the future.

Performance of EU automakers in improving CO_2 efficiency

In 2011, the EEA studied the performance of automakers regarding vehicles sold in 2010 and considered the distance from 2012 and 2015 targets. Accordung to the results of this survey, 32 automakers, representing almost 80% of those registered in 2010 in the EU, achieved their 2012 specific emission targets two years in advance (Figure 2.18).[217]

Among the larger manufacturers, *Daimler AG, Skoda, Nissan International SA, General Motors, Daewoo*, *Mazda Motor Corporation* and *Dacia* placed over the limit value curve and will have to reduce the average emissions of their fleets over the next five years. *Fiat Group Automobiles Spa* had the lowest average CO_2 emissions in 2010 (125 g CO_2/km) as well.

The Regulation has provided incentives for vehicle manufacturers – including super credits, etc. – to reduce their CO_2 emissions. The European Commission and the EEA monitor manufacturers' progress annually in order to track their performance against individual targets.

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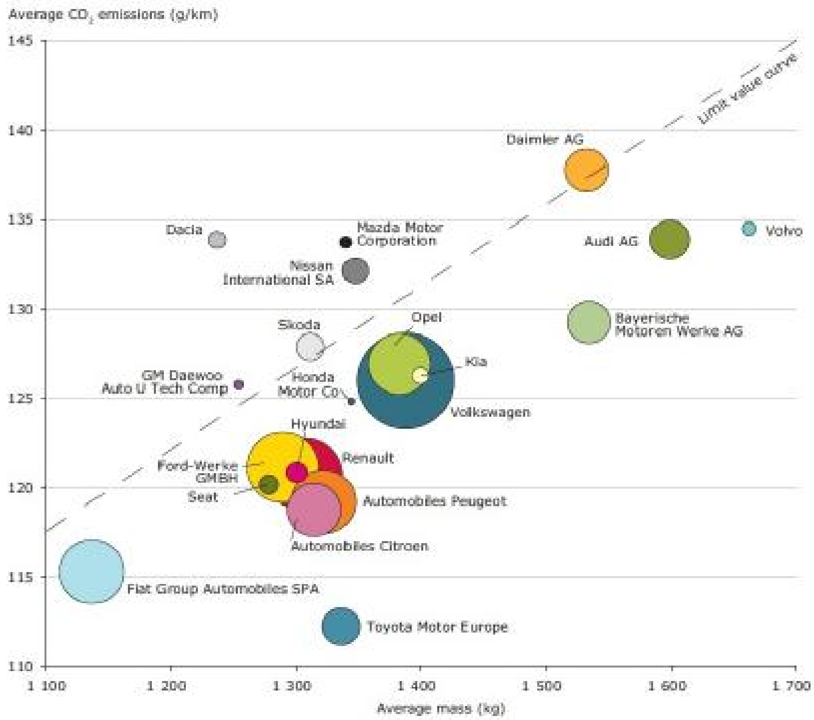
216 European Environment Agency (EEA), (2012). *CO_2 emissions performance of car manufacturers in 2011*, Copenhagen, p.3. Retrieved June 10, 2012, from: http://www.eea.europa.eu

217 European Environment Agency (EEA), (25 May 2012). *Most carmakers must further improve carbon efficiency by 2015*. Retrieved June 10, 2012, from: http://www.eea.europa.eu/highlights/most-carmakers-must-further-improve



Note: The size of the bubble is proportional to the number of vehicles registered in Europe

Figure 2.18. Distance from 2012 target of individual manufacturers in 2010
(only manufacturers registering>100000 vehicles in Europe)

Source: European Commission (2012)

The European Environment Agency has defined a procedure to monitor manufacturers' progress in CO_2 reduction. For this purpose, it aggregates new cars' registration data from Member States and issues it in a public EEA database. The database includes details on the volumes of vehicle models registered in each Member State and provides information on the vehicle weight, engine capacity, carbon footprint, fuel type and specific CO_2 emissions of each car.[218]

Following the introduction of voluntary and mandatory CO_2 standards, the market share of more fuel-efficient vehicles has gradually increased in the EU. The ACEA reported that, in 2012, 71% of new cars emitted less than 140g of CO_2 per kilometer, and more than half of those less than 120g (Figure 2.19).[219]

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[218] European Environment Agency (EEA), (2011), *Laying the foundations for greener transport, TERM 2011: transport indicators tracking progress towards environmental targets in Europe EEA*, Report No 7/2011, Copenhagen, Denmark, p.57.
[219] European Automobile Manufacturers Association (ACEA), (September 2013*), The Automobile Industry Pocket Guide 2013.*

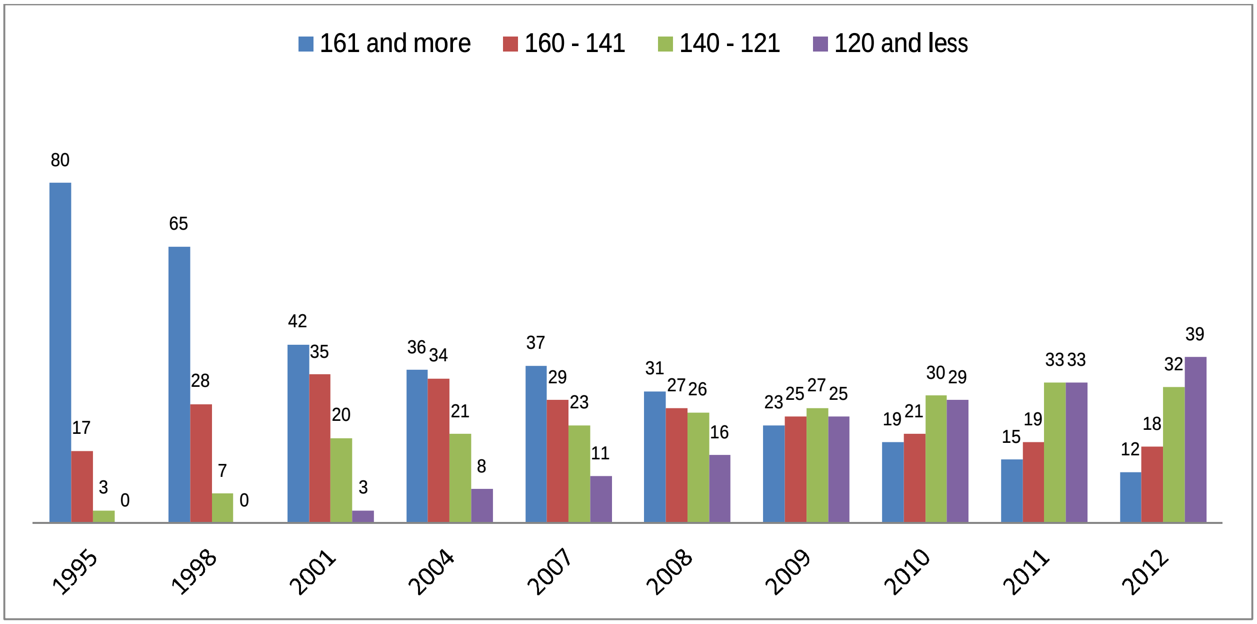

Figure 2.19. New passenger cars in the EU by CO_2 emissions (g/km) (1995-2012)

Source: ACEA 2013

CO_2 emissions in the transportation sector

The International Council on Clean Transportation (ICCT) developed a study comparing greenhouse gas emissions standards in the transportation sectors of seven countries. According to the results, the US has the most stringent CO_2 emissions standards in the world and the EU continues its smooth descent towards 95 gCO_2/km in 2020 (Figure 2.20).[220]

[220] International Council on Clean Transportation (ICCT), (2011*), A Ten-Year Retrospective*, p.11. Retrieved July 23, 2013 from: www.theicct.org

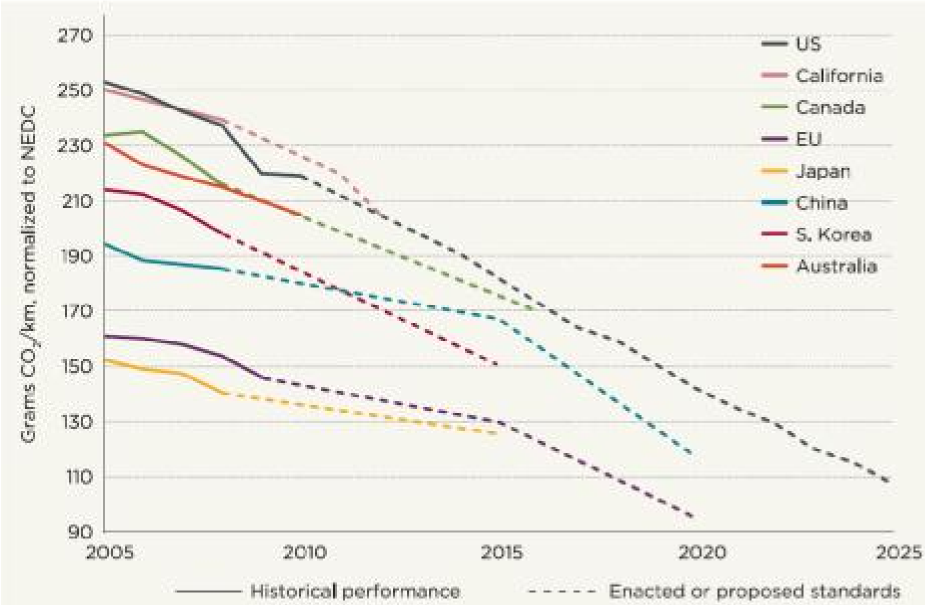

Figure 2.20. Average CO_2 emissions from vehicles and targets in the EU and selected countries

Source: ICCT (2011), A Ten-Year Retrospective

2.4 Policies and regulations for vehicle technology improvements

Regulation (EC) No 443/2009 does not determine any specific technology to be used by automakers. However, automakers can take different strategies to meet CO_2 levels: [221]

1- Improving fuel economy through fuel-saving innovations in new vehicles

2- Modifying vehicle characteristics (for example, light weighting)

3- Switching to alternative fuels/propulsion systems (for example, hybrid cars and FCVs)

4- Using price mechanisms to affect the mix of vehicles sold

Vehicle manufacturers should have flexibility in their targets in each strategy under the Regulation. They should ensure the average CO_2 emissions over their new car fleet, rather than each individual car.

Each automaker firm, based on available technology, local and international markets, and local regulations uses its own strategies to meet the Regulation's emission limits. Mikler discusses the

[221] Winston Harrington, (2008), *The Design of Effective Regulations of Transport*, OECD/ITF, JTRC Discussion Paper 2008-2, p.23. Retrieved August 10, 2012, from: http://www.internationaltransportforum.org

features of the main firms in terms of their CO_2 reduction approach. According to his survey, Japanese firms are focused on hybrids, while German firms are focused on diesels. German and US firms are focused on alternative fuels, but in different ways: for US firms, this is a strategy for addressing the fuel consumption of their larger light trucks, but for German firms it is an across-the-board strategy. Alternative fuels are not such a high priority for Japanese firms. While FCVs are a relatively distant prospect, Japanese firms want to introduce them as soon as possible, whereas German and US firms want to be ready to introduce them when the environment is appropriate.[222] Iranian firms have focused on CNG hybrid vehicles. They are also preparing to bring diesel passenger vehicles into the local market.

Mikler also compares the stringency of the CO_2 emission regulations in three territories: the US, Japan and the EU. According to Mikler, producing more fuel-efficient cars in the EU and Japan is a result of the higher fuel price and more stringent local standards than the US. He also concluded that tougher regulations at home can result in better environmental performance abroad as well.

Technology options

A range of technology-oriented options are available for the automakers. Most of the proposed technologies are useful for both pollution control and fuel efficiency improvement. Commercialization of the options depends on the conditions mentioned above. Obviously, customers' awareness of the benefits of change should be increased, leading them to choose the most fuel-economic vehicles. The vehicle industry has focused upon a number of appropriate available technologies:[223]

- Conventional and alternative power-train technologies e.g. CNG and LPG-fueled vehicles
- Increased use of stop-start technologies
- Improved energy management systems
- Improved direct injection systems
- Improved and more efficient transmissions

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[222] John Mikler, op. cit., p.74.
[223] The Society of Motor Manufacturers and Traders (SMMT) (March 2009), *New car CO_2 report 2009*, London, UK, p.5. Retrieved July 29, 2012 from: www.smmt.co.uk

- Regenerative braking technologies
- Materials, with focus on light-weighting
- Aerodynamics
- Improved energy efficiency of car components e.g. air conditioning, alternator, power steering, lighting system
- Driver information devices, e.g. gearshift indicators
- Using fuel-efficient tires
- Three-way catalysts

An overview of the technology costs

It is impossible to find exact and reliable information about technology costs. This information is confidential to vehicle manufacturers because of competitiveness concerns. The ICCT made a rough estimation about the technology costs of emissions standards developed in Europe (Table 2.9).[224]. The values include variable costs (hardware) and fixed costs (R&D, tooling and certification).

ENGINE TYPE	VEHICLE CLASS	EURO 1 (BASELINE)	EURO 1 TO EURO 2	EURO 2 TO EURO 3	EURO 3 TO EURO 4	EURO 4 TO EURO 5	EURO 5 TO EURO 6	NO CONTROL TO EURO 6
Gasoline	4 cylinders Vd= 1.5 L	$142	$63	$122	$25	$10	--	$362
Gasoline	4 cylinders Vd = 2.5 L	$232	$3	$137	$15	$30	--	$417
Diesel	4 cylinders Vd = 1.5 L	$56	$84	$337	$145	$306	$471	$1,399
Diesel	4 cylinders Vd = 2.5 L	$56	$89	$419	$164	$508	$626	$1,862

Table 2.9. Incremental costs for LDVs meeting European standards (2010 USD)

Source: ICCT, 2012

The ICCT discusses how the incremental emissions control costs for gasoline vehicles are much more favorable than those for diesel vehicles. The industry has reduced manufacturing costs of related technologies (such as three-way catalysts). On the other hand, diesel vehicles, owing to their inherently lean combustion process, and direct fuel injection require much deeper system modifications to achieve the emissions targets. The ICCT estimates that cumulative emission

[224] The International Council on Clean Transportation (ICCT), (2012), *Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles*, ICCT, Washington DC. Retrieved July 23, 2013 from: www.theicct.org

control technology costs for diesel will be incremental, which is not the case for gasoline (Figure 2.21).

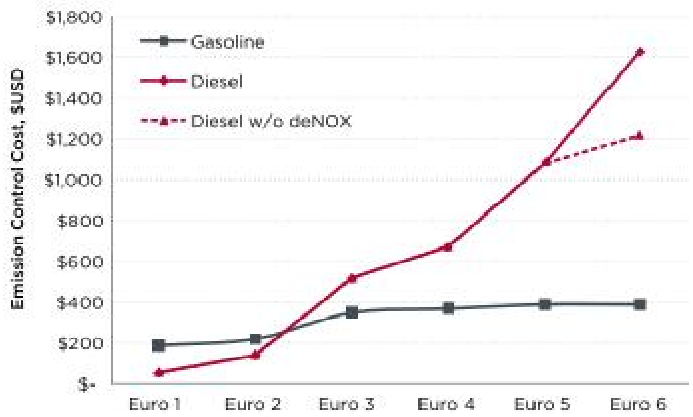

Figure 2.21. Estimated cumulative emissions control technology costs for gasoline and diesel light-duty vehicles, assuming a 2.0L engine

Source: ICCT, 2012

Vehicle performance standards have been successful in reducing the carbon dioxide emissions of cars. Kodjak et al. argue that this outcome owes to two reasons:[225]

- Goal-setting, and approaching market-oriented solutions for the most cost-effective technologies to achieve the prescribed performance improvements
- Focusing on automakers, rather than trying to influence millions of consumers

Concerns of diesel fuel

Sulfur content in diesel limits the diesel engine cars to be developed. Sulfur raises both technological and environmental concerns. Particulate matter that is emitted from diesel fuel combustion has serious health consequences, especially in urban areas. From the technological point of view, sulfur decreases the CO_2 performance of diesel engines significantly. It also is a catalyst poison, preventing catalytic converters from functioning correctly. Sulfur is a natural

[225] Drew Kodjak, Francisco Posada Sanchez, Laura Segafredo, (2012), *Policies that work: How vehicle standards and fuel fees can cut CO_2 emissions and boost the economy*, International Council on Clean Transportation (ICCT) and Climate Works Foundation, San Francisco, US, p.22.

content in the fuel and removing it is a costly process for refiners. Some developed countries and regions, such as the US, Japan and the EU, have established new norms for producing ultra-low-sulfur diesel. In many developing countries, state ownership of refineries and/or political priorities seeking to keep fuel prices low, make removing sulfur from fuels more difficult. Table 2.10 shows the standard limits of diesel sulfur in some selected countries.[226]

Table 2.10. Diesel fuel sulfur standard levels in selected regions (PPM)

Country	**2000**	**2005**	**2011**
Brazil	-	2000	1800
China (metros)	5000	350	50
China (nationwide)	5000	2000	2000
EU	500	50	10
Japan	500	50	10
US	500	500	15

Source: ICCT (2011)

Diesel vehicles in the EU

European transportation is currently dependent on fossil fuels derived from oil for around 96% of total energy consumption.[227] Diesel and gasoline shape the CO_2 emissions algorithm in the EU. Fuel consumption of the European passenger car fleet has gradually switched from gasoline to diesel during the last two decades. This change has reflected a decline in the total CO_2 emissions in the EU-15 (Figure 2.22).[228]

[226] International Council on Clean Transportation (ICCT), (2011), *A Ten-Year Retrospective*, Retrieved July 23, 2013 from: www.theicct.org

[227] European Environment Agency (EEA), (2011*), Laying the foundations for greener transport, TERM 2011: transport indicators tracking progress towards environmental targets in Europe,* EEA Report No 7/2011 , Copenhagen, Denmark, p.51.

[228] European Environment Agency (EEA), (27 May, 2012). *Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012*, Copenhagen, pp.193–194. Retrieved June 11, 2012, from: http://www.eea.europa.eu

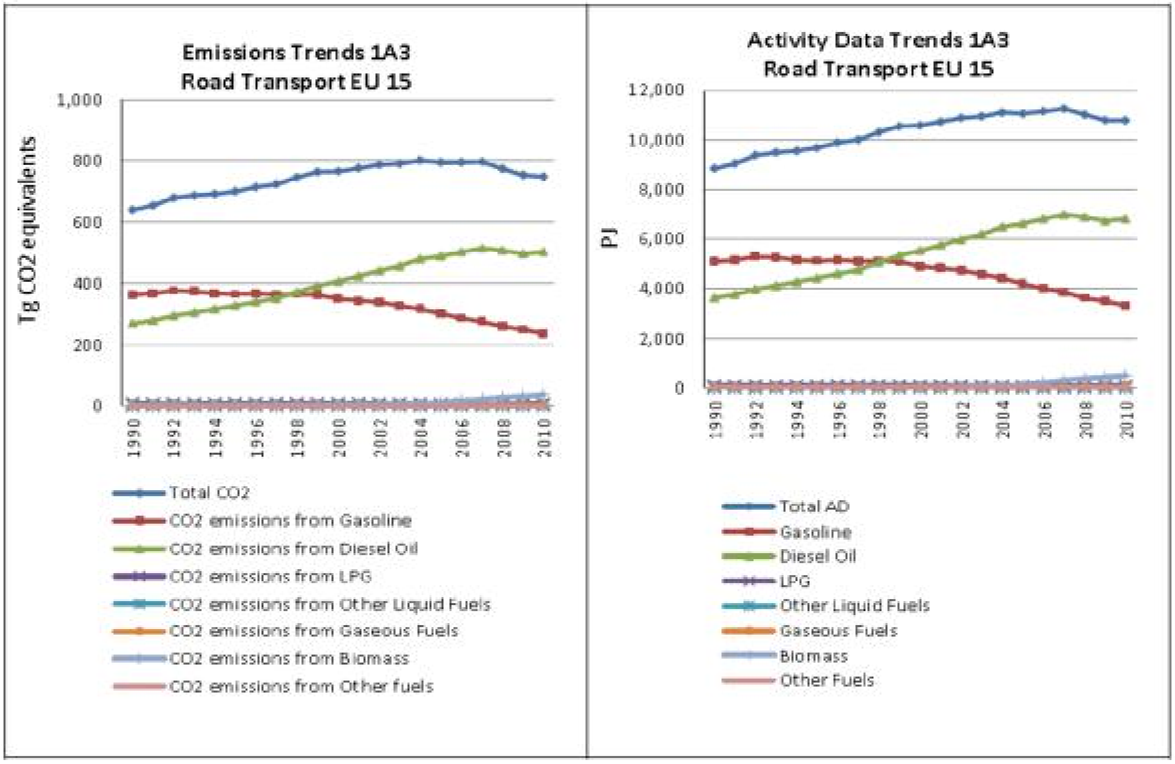

Figure 2.22. Road Transport: CO_2 Emission Trends and Activity Data

Source: European Environmental Agency (2012)

Diesel fuel contains about 10% more carbon and also more energy content than gasoline. CO_2 emissions from burning one liter of diesel are about 2636g, and for gasoline 2337g.[229] The fuel economy of a diesel vehicle is enhanced by both the energy efficiency and the greater energy content of the fuel when measured using liters per 100 kilometers. However, the greater energy content of diesel offsets carbon content in terms of fuel consumption and GHG emissions per 100 km. Mikler discussed how a diesel vehicle tends to be 20 to 40% more fuel efficient than a comparable petrol vehicle, so it emits 10 to 30% less CO_2 per kilometer travelled.

The other greenhouse feature of diesel is N_2O emissions. The EEA reports that N_2O emissions from diesel consumption in the EU accounted for 71% of total N_2O emissions from transportation in 2012.[230] N_2O emissions from diesel fuel in the EU-15 increased by 194% between 1990 and 2010. However, the fuel efficiency advantages of diesel fuel offset total greenhouse gas emissions by diesel, as is not the case with gasoline.

[229] John Mikler, op. cit., p.64.
[230] European Environment Agency (EEA), (27 May, 2012). *Annual European Union greenhouse gas inventory 1990–2010 and inventory report 2012*, Copenhagen, p.203. Retrieved June 11, 2012, from: http://www.eea.europa.eu

Thus, the large number of diesel vehicles affects total carbon dioxide emissions in the transportation sector. The Global Fuel Economy Initiative (GFEI) argued that the apparent discrepancy between Europe and Japan's performance on a gCO_2/km emissions basis is due to the large numbers of diesel vehicles in the European fleet.[231]

The market share of diesel cars has increased during the last two decades in the EU. For many years, diesel was cheaper than gasoline in European countries. By changing regulations to limit high-CO_2 emitting cars, diesel technology has improved, especially for larger and luxury car markets. The ACEA reports that diesel passenger vehicles are increasingly popular for consumers in the EU, especially in Western Europe. The share of newly registered diesel powertrain passenger cars has exceeded 50% in the EU-15 since 2010 (Figure 2.23). According to these statistics, European consumers purchased over 588,000 new diesel cars in 2013.[232] Eggar argued that diesel is being imported to meet the shortfall in supply from European refineries.[233]

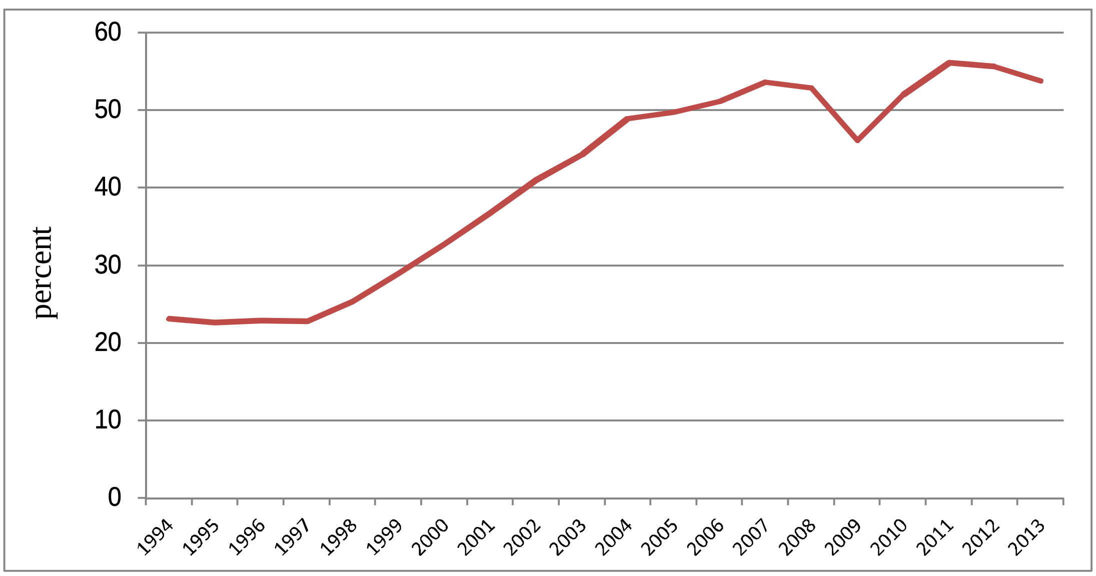

Figure 2.23. Share of diesel in new car registration in the EU-15 (1994-2013)

Source: ACEA 2014

[231] Global Fuel Economy Initiative (GFEI), (2010), *The European Union Automotive Fuel Economy Policy*, Retrieved September 25, 2013 from: www.unep.org/transport/gfei/autotool/case_studies/europe/cs_eu_o.asp

[232] European Automobile Manufacturers Association (ACEA), (2014), *Statistics: Trends in New Car Registrations*, Retrieved 23 November 2014 from: http://www.acea.be/statistics/tag/category/trends-in-new-car-registrations

[233] Duncan Eggar, (2007), *Toward a Policy Agenda for Climate Change: Changing Technologies and Fuels and the Changing Value of Energy*, published in Sperling, D., and Cannon, J. S., Driving Climate Change: Cutting Carbon from Transportation, Academic Press of Elsevier, p.36.

The European Petroleum Industry Association (EUROPIA) reports that most European refineries, which were designed for producing gasoline and diesel, struggle to meet growing demand for diesel. The gasoline to diesel ratio was 2 to 1 in 1990. This rate was inverted in 2011 (1 to 2) and is estimated to reach 1 to 3.5 in 2030.[234]

Feng An concluded that strong demand and sharply growing trends for purchasing diesel vehicles in the EU are mainly because of tax incentives that lowered taxes on diesel fuel and imported diesel cars in some EU countries, high fuel prices that encourage the purchasing of lower-cost diesel, and the superior driving capabilities of diesel engines.[235]

2.5. Policies for alternative fuels

As mentioned above, fossil fuels account for over 95% of total energy consumption in EU transportation. According to the European Commission 2050 roadmap, the EU should reduce the present level of fossil fuel consumption in the sector by 70% by 2050 to meet the long-term greenhouse gas reduction target.[236]

Achieving the target means moving beyond improvements in conventional internal combustion engines (ICE) alone. These solutions would include mixing a range of biofuels with conventional fuels to use in conventional internal combustion engines and alternative energy carriers, such as electricity and hydrogen, which require significant modifications in power trains.

Biofuels

Biofuels have the potential to reduce greenhouse gas emissions significantly. They can be blended with or potentially used instead of conventional gasoline or diesel. Harrington reports

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[234] European Petroleum Industry Association (EUROPIA), (April 2011), *White Paper on Fueling EU Transport*, Brussels, Belgium, p.28.
[235] Feng An, (2007), *International Comparison of Policies to Reduce Greenhouse Gas Emissions from Passenger Vehicles*, published in Sperling, D., and Cannon, J. S., Driving Climate Change: Cutting Carbon from Transportation, Academic Press is an imprint of Elsevier, p.155.
[236] European Environment Agency (EEA), (2011), *Laying the foundations for greener transport, TERM 2011: transport indicators tracking progress towards environmental targets in Europe*, EEA Report No 7/2011, Copenhagen, Denmark, p.51.

that biofuels require at most modest changes to existing vehicles and can also be distributed in the existing network.[237]

Biofuels' share has increased substantially over the last 10 years, from 0.2% to 4.3% that of conventional petrol and diesel fuels; however, most EU Member States are likely to fall far short of the 2010 indicative targets for biofuel use.[238]

Surveys on the CO_2 emissions of alternative fuel vehicles also show significant reductions from 208 g/km in 2000 to 126 g/km in 2010. This outcome is because of technology improvements in average engine capacity, from 1700 cm^3 at the beginning of the 2000s to less than 1400 cm^3 in 2010.[239]

Uncertainty regarding the use of biofuels

Biofuels constitute an important component of low-carbon fuel-related standards for achieving the desired reductions in GHG emissions. Carbon neutrality of tailpipe emissions is what makes biofuels a preferred choice, since tailpipe CO_2 emissions are counterbalanced by CO_2 sequestered during plant growth. It should be noted that the question of whether biofuels can reduce GHG emissions relative to fossil liquid fuels may ultimately depend on whether or not indirect land use changes (ILUC) are included in the scope of life-cycle studies. For example, preliminary estimates indicate that corn ethanol may emit more GHG than gasoline if GHG emissions from ILUC are considered as part of the life cycle.[240]

Use of biofuels as low-carbon fuels has the potential to reduce GHG emissions from the transportation sector but may create other environmental impacts such as eutrophication, acidification, soil erosion, and increased demand on water and land.

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[237] Winston Harrington, (2008), *The Design of Effective Regulations of Transport*, OECD/ITF, JTRC Discussion Paper 2008-2, p.19. Retrieved August 10, 2012, from: http://www.internationaltransportforum.org

[238] European Environment Agency (EEA), (2011), Laying the foundations for greener transport, TERM 2011: transport indicators tracking progress towards environmental targets in Europe EEA Report No 7/2011, Copenhagen, Denmark, p.51.

[239] European Environment Agency (EEA), (2011), *Laying the foundations for greener transport, TERM 2011: transport indicators tracking progress towards environmental targets in Europe,* EEA Report No 7/2011, Copenhagen, Denmark, p.58.

[240] Anil Baral, (October 2009), *Summary Report on Low Carbon Fuel-Related Standards*, International Council on Clean Transportation (ICCT), pp.1-13.
Retrieved 23 November 2013 from: www.theicct.org

Biofuels are key options for reducing GHG emissions. Furthermore, producing biofuels can provide economic opportunities for reducing poverty in developing countries. Geurs et al. debate whether biofuels are a sustainable solution. They discuss the issues such as risk of biodiversity loss, increase in food prices, the greenhouse gas balance of bio-fuels being negatively influenced by N_2O emissions, and indirect changes in land use.[241]

Geurs et al. argue that producing 100 Ej/year of biofuels for all transportation modes (long-distance road transport, aviation, and shipping), will basically require using partly waste and residues and partly specific cultivation. This target needs about 3 million km^2 of land. For comparison, the current total EU agricultural area is approximately 2.2 million km^2.

Restrictions of biofuels

The EU Member States face infrastructural limitations on meeting 2010 indicative targets for biofuel use (Figure 2.24). According to the EEA, with the implementation of the Climate Action and Renewable Energy Package there will be a further requirement of 10% renewable fuel use by 2020. In addition, there is a requirement that biofuels should meet sustainability standards, thus potentially restricting supply if sustainability cannot be documented.[242] Figure 2.24 shows the planned and actual share of biofuels in fuel consumption in the EU-27 in 2007.[243]

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[241] Karst Geurs, Hans Nijland, Bas van Ruijven, (2011), *Getting into the Right Lane for Low-Carbon Transport in the EU*, Published in Rothengatter, W. et al., Transport Moving to Climate Intelligence, Springer, New York, p.67.

[242] European Environment Agency (EEA) (2010), *Towards a resource-efficient transport system; TERM 2009: indicators tracking transport and environment in the European Union*, Copenhagen, p.19. Retrieved July 25, 2012 from: www.eea.europa.eu/publications/towards-a-resource-efficient-transport-system

[243] European Environment Agency, (November 2012), *Share of biofuels in fuel consumption for transport (%) in EU-27 in 2007 compared to 2010 and 2020 targets.* Retrieved October 17, 2013 from: http://www.eea.europa.eu/data-and-maps/figures/share-of-biofuels-in-fuel-consumption-for-transport-in-EU-27-in-2007-compared-to-2010-and-2020-targets

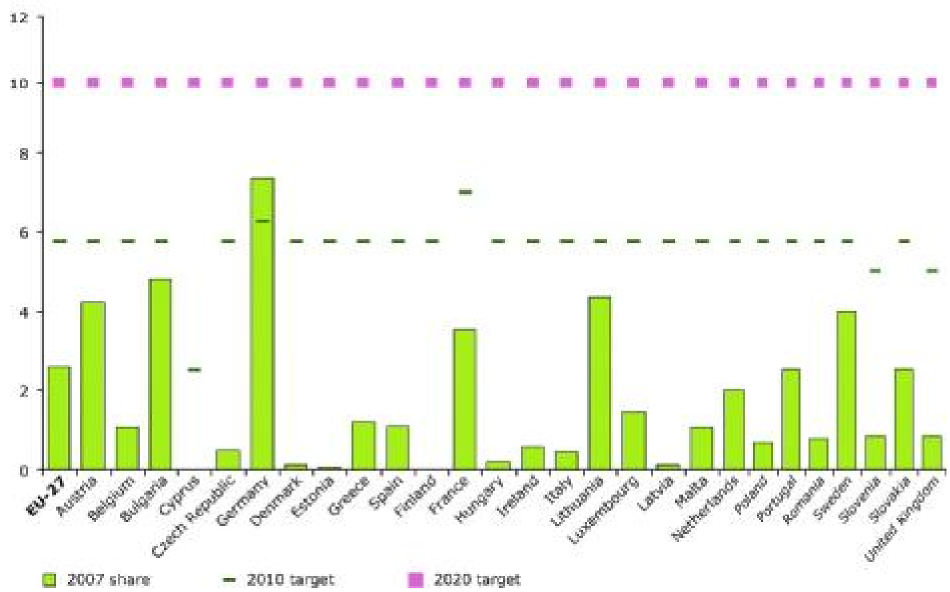

Figure 2.24. Share of biofuels for transport (%) in EU-27 in 2007 compared to 2010 and 2020 targets	
Source: EEA 2012	

BP projection for future fuels

British Petroleum projects that future fuels and energy carriers in transportation will move from internal combustion engines to hybrid electric and fuel cell drive-trains (Figure 2.25). On the fuel side, the path moves through dieselization to conventional bio-components, gas (or coal) to liquids, and on to advanced biomass conversion technologies and, perhaps in the long term, hydrogen.[244]

[244] Duncan Eggar, op. cit., p.36.

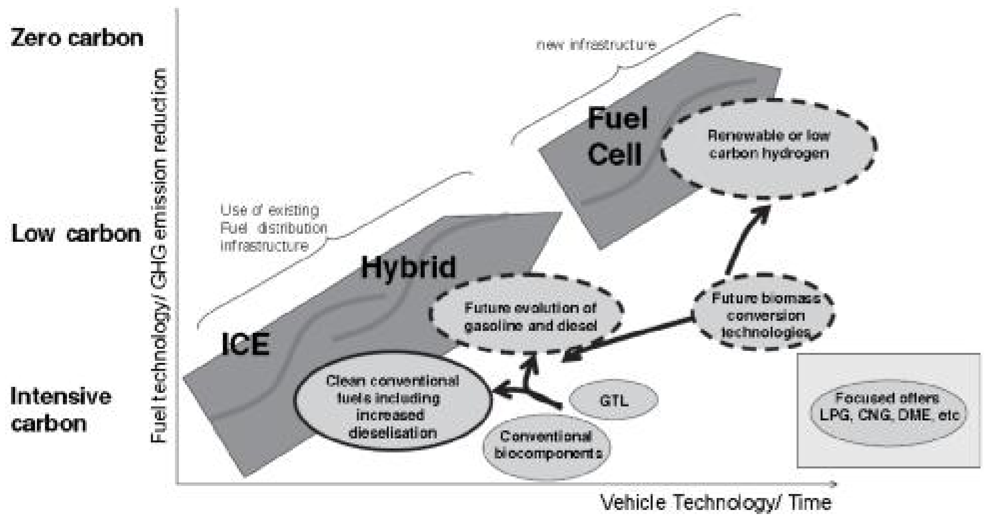

Figure 2.25. Future fuels pathway

Source: Eggar 2007 in: BP 2005

Hybrid vehicles technology

Hybrid vehicles are a good option for urban driving from a low CO_2-emissions point of view because of the frequent involvement of the electric motor and re-use of braking energy in batteries. According to Regulation 433/2009, producing zero CO_2-emission vehicles will bring super credits for the automaker. It should be mentioned that upstream electricity generation emissions are not calculated in the Regulation.

McKinsey & Company analyzed the role of biofuels and electricity providers in long-term efforts to reduce CO_2 emissions from passenger vehicles.[245] They illustrate different areas of focus:

Biofuel companies:

- Conducting research to produce alternative fuel sustainably on the commercial scale
- Establishing technical standards for biofuel production processes to avoid producing biofuels using unsustainable methods
- To ensure using land sustainably under governmental regulations

[245] McKinsey & Company, (March 2009), *Roads toward a low-carbon future: Reducing CO_2 emissions from passenger vehicles in the global road transport system*, 2009 McKinsey&Company, New York, p.24.

- Collaborating with governments and automakers to increase production volume and blending levels of biofuels as soon as possible

Electricity providers:

- Increasing electricity share from low-carbon technologies such as renewables
- Increasing energy efficiency of electricity supply to eliminate well-to-wheel CO_2 emissions

2.6 Financial policies

Gradual increases in fuel taxes for an environmental-oriented plan (here CO_2) can create an extra incentive for fuel-efficient vehicles. Higher fuel taxes increase state income, which can be balanced by lower taxes on labor and capital. From a macro-economic point of view it is better for most emerging economies to make car users pay fuel taxes to the state than to have a higher national bill for oil imports.[246]

Financial mechanisms have been implemented in Europe since 1998 to internalize external costs of transportation (i.e. climate change damage, other air pollution and noise damage, accidents and external congestion costs).[247]

The IEA argues that fiscal measures can address all three elements of the transportation paradigm recommended by the EIA (i.e. vehicle fuel efficiency, vehicle travel and the vehicle population) to enhance energy efficiency. Financial incentives in combination with sound information incentivize the purchase of more energy-efficient vehicles and accelerate the deployment of energy-efficient technologies. Much data shows the consumers quickly respond to such incentives, which is why many European countries have set up vehicle CO_2 emissions base tax systems. For example, in Ireland, in the five months after the introduction of the new CO_2 emissions differentiated annual motor and vehicle registration taxes on 30 July 2008, the

[246] Arie Bleijenberg, (2012), *The Attractiveness of Car Use*, Published in Zachariadis, Th.I., *Cars and Carbon*, Springer, p.41.
[247] Stef Proost, S., (2008), *Full Account of the Costs and Benefits of Reducing CO_2 Emissions in Transport*, OECD/ITF, JTRC Discussion Paper 2008-3, p.6. Retrieved August 10, 2012, from: www.internationaltransportforum.org

percentage of passenger cars sold in the lowest emissions bands A to C (under 155 g CO_2/km) soared from 41% to 83%.[248]

Market mechanisms via fuel taxes are one of the main fuel economy strategies in the EU, unlike Japan or the US. The EU has used the price difference between diesel and petrol to encourage the use of diesel cars as a way of reducing CO_2 emissions, owing to their greater efficiency.[249]

Many studies have been conducted about the impact of fuel prices on transport demand. Some researchers conclude that fiscal measures can promote using vehicles at optimum efficiency and reducing overall vehicle use. Sterner argues that lower fuel prices would result in increased travel demand. For example, fuel prices in the US are significantly lower than Japan and Europe and the travel demand in the US is much greater than in these regions.[250]

It should be mentioned that the European Commission has for many years called for the 'inclusion of a CO_2 element in car taxes' Europe-wide; however it has not received approval from the European Council and therefore this element of the European Union strategy remains the responsibility of individual Member States.

Fiscal incentives for manufacturers to produce more fuel-efficient cars play a significant role in encouraging consumers to buy low-emitting vehicles. However, as an adverse consequence, care must be taken that they do not reduce emissions at the expense of other environmental policy goals. For example, diesel sales in the EU rose dramatically as a result of CO_2-differentiated taxes, with the significant adverse effect of increasing NO_x emissions.

Harrington argues that fossil fuel taxes would automatically encourage the production of fuel-efficient vehicles and as well as the taking of other actions that would reduce CO_2 emissions, including reducing car-use and buying more fuel-efficient vehicles.[251]

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[248] International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps,* Paris, OECD, p.44. Retrieved June 14, 2012, from: www.iea.org
[249] John Mikler, op. cit., p.104.
[250] Thomas Sterner, (2007), *Fuel Taxes: An important instrument for climate policy*, Energy Policy, 35(6).
[251] Winston Harrington, op. cit., p.30. Retrieved August 10, 2012, from: http://www.internationaltransportforum.org

The effect of market mechanisms on fuel consumption: Another perspective

Policymakers expect that market mechanisms affect consumers' behavior in a way that leads them to demand cars with better fuel economy. Owing to related policies, fuel consumption would decline through lower fuel-use by vehicles and driving shorter distances by drivers.

Mikler studied the relationship between distances travelled and fuel consumption and changes in taxes and prices. He found that higher taxes and prices are not necessarily associated with less car-usage and concluded that fuel taxes and prices alone are not a determining factor in car use. Four specific reasons are give here:

- Variety of preferences

  The large number of individuals owning and driving cars are the source of CO_2 emissions. They have different preferences that are not easily generalized.

- Likely counteracted effects

  By raising fuel prices, consumers may initially stop using their cars as much and desire to obtain more efficient ones. In this case, they may drive further for the same price and produce the same amount of CO_2 as a result of larger trips.

- Price elasticity of demand for fuel

  Decision-making on higher prices depends on many economic factors. For example, an estimate for the UK found that, assuming a constant level of income, a 10% rise in the price of fuel produces only a 3% fall in fuel consumption.[252]

- Availability of alternative travel modes

  Higher fuel prices would cause negative effects on people with lower incomes who have little choice, especially for areas where people have to rely on car travel rather public transportation.

Fuel prices in the EU

According to statistics, road transport fuel prices have increased relatively in EU Member States since 1999 (Figure 2.26).[253] The IEA reports that fuel taxes account for a considerable share of fuel prices in the EU. The rates show an increase from 2002-2012 (Table 2.11).

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[252] In another study, Kodjak et. al. estimate that every 10% increase in fuel fees can reduce vehicle kilometers traveled by 5% (Kodjak et. al. 2012).

Table 2.11. Average fuel prices (in USD/liter) and percentage of taxes (brackets) in the EU-15 from 2002 to 2012

	2002	**2004**	**2006**	**2008**	**2010**	**2012**
Premium unleaded (95 RON) gasoline	0.91 (67.7%)	1.31 (65.8%)	1.53 (59.8%)	1.93 (57.8%)	1.79 (59.7%)	2.09 (54.8%)
Automotive diesel for non-commercial use	0.74 (60.0%)	1.09 (57.8%)	1.36 (50.8%)	1.86 (47.1%)	1.57 (51.7%)	1.94 (47.4%)

Source: IEA 2013[254]

Price mechanism is a well-experienced policy instrument for regulating vehicle market. In the case of increasing fuel prices, the car market tends toward more fuel-efficient vehicles. Mikler discussed how the magnitude of state-imposed taxes clearly encourage consumers to use less fuel, or purchase vehicles that are more fuel-efficient; EU states intervene in the market through regulating tax share in the fuel price.

The EEA analyzed increasing nominal prices of transportation fuels and concluded that the real price of road fuel in the EU (inflation corrected with HICP,[255] reference year 2005) has remained relatively stable during the last three decades, apart from short periods of price instabilities (EEA 2010).[256] The EEA mentioned that, during the same period, real disposable income has increased significantly and caused transportation fuel prices to sink.

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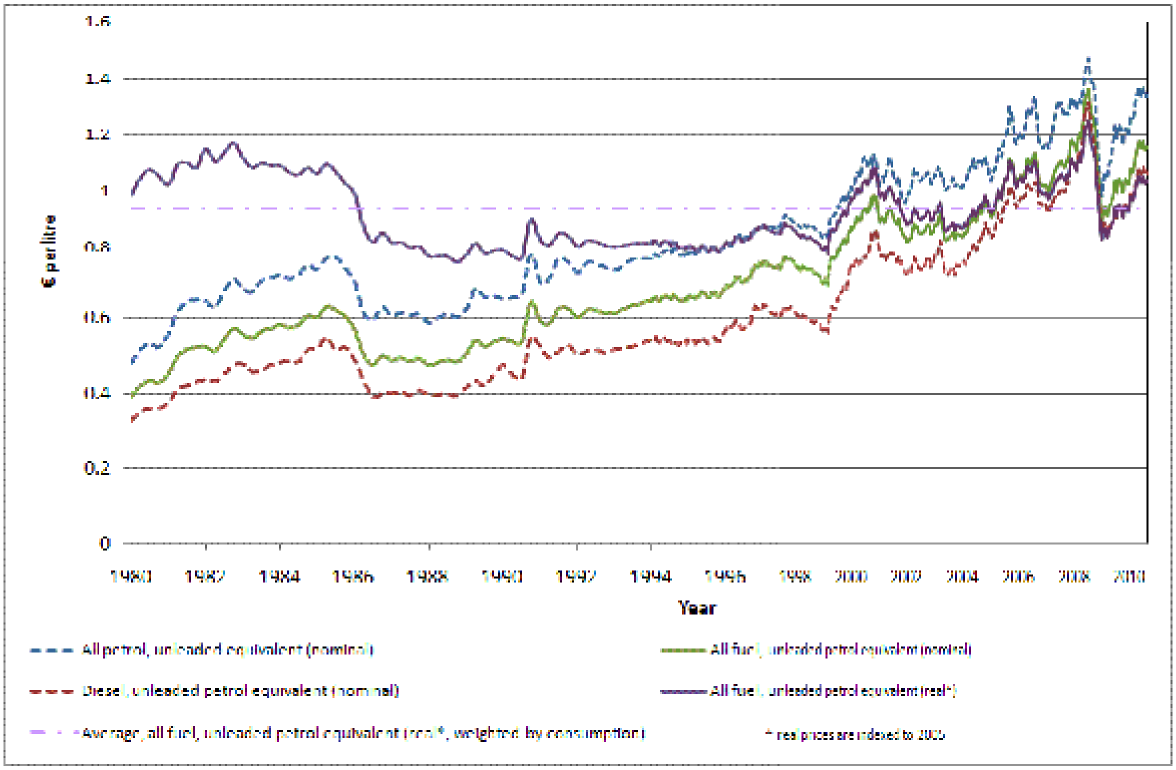
[253] European Environmental Agency (November 2012) Retrieved October 11, 2013 from: http://www.eea.europa.eu/data-and-maps/figures/road-transport-fuel-prices-including-1

[254] International Energy Agency (IEA), (2013), *Energy Prices and Taxes, 1st Quarter 2013*, Paris. Retrieved October 11, 2013 from www.iea.org

[255] Harmonized Index of Consumer Prices.

[256] European Environment Agency (EEA) (2010), *Towards a resource-efficient transport system; TERM 2009: indicators tracking transport and environment in the European Union*, Copenhagen, p.19. Retrieved July 25, 2012 from: http://www.eea.europa.eu/publications/towards-a-resource-efficient-transport-system



Note: All prices are in 'unleaded petrol equivalent liters.' [257]

Figure 2.26. Road transport fuel prices (including taxes) in EU Member States

Source: EEA 2012

Subsidization policies of biofuels in the EU

EU research on alternative fuels for transportation has been conducted in order both to reduce GHG emissions by the sector and to guarantee the security of energy supplies by diversifying fuel sources.[258]

Under the Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport, the EU established the goal of reaching a 5.75% share of renewable energy in the

[257] Definitions:
* 'All petrol' is a consumption-weighted average price of both leaded and unleaded fuel, corrected using energy-content to the equivalent amount of unleaded petrol.
* 'All fuel, unleaded petrol equivalent' is a consumption-weighted average price of unleaded, leaded petrol and diesel, corrected using energy content to the equivalent amount of unleaded petrol.
* 'Nominal' is the price with no adjustment for inflation.
* 'Real' is the price corrected for inflation, using 2005 as the baseline year.
* 'Average, all fuel, unleaded petrol equivalent (real, weighted by consumption)' is the consumption-weighted average of the 'All fuel, unleaded petrol equivalent (real)' line across the full time series.

[258] European Commission, (April 2008), *EU strategy for biofuels.* Retrieved October 17, 2013 from: http://europa.eu/legislation_summaries/energy/renewable_energy/l28175_en.htm

transportation sector by 2010, and according to the Directive 2009/28/EC on the promotion of the use of energy from renewable sources, this share will rise to a minimum 10% in every Member State in 2020. As a result, Member States have developed biodiesel production plants within their own capacities. Regarding the expansion of biofuels in the EU, the latter Directive aims to ensure the use of sustainable biofuels only, which generate a clear net GHG saving without negative impacts on biodiversity and land use.

According to European Biodiesel Board, total biodiesel production in the EU-27 hit 8,607,000 tons in 2011. Total nominal biodiesel production capacity for this year was over 22,117,000 tons for the region.[259] Given the specific situation prevailing in the European market for many years, a number of installed biodiesel plants have not been running for several years and were considered as long-term-out-of-production plants in 2011. Consequently, a share of the over 22 million tons of nominal installed capacity should be considered as idle capacity, i.e. not effectively able to start or operate any biodiesel production. Biodiesel production has significantly grown in the EU from 2003 to 2011 (Table 2.12). Harrington reported that dramatic increase in biofuel production is because of the generous use of subsidies.[260]

Table 2.12. Biodiesel Production in the EU-27 (2003 – 2007) (1,000 tons)

2003	2004	2005	2006	2007	2008	2009	2010	2011
1,065	1,434	3,183	4,890	5,713	7,755	9,046	9,570	8,607

Source: EBB 2014

European subsidization of biofuels began around 1992 as a part of the reform of the Common Agricultural Policy. Subsidies were given to ethanol and biodiesel equally, aimed at mixing them with gasoline and diesel respectively.[261]

2.7 Policies for the demand side

Drivers' awareness of the technological features of new vehicles is important in achieving the expected results of reduction policies. In fact, without public participation in fuel efficiency improvement, real reduction in carbon dioxide emissions is almost impossible.

[259] European Biodiesel Board (EBB), (2014), *Statistics of Biodiesel production in the EU.* Retrieved September 18, 2014 from: www.ebb-eu.org
[260] Winston Harrington, op. cit., p.20.
[261] Winston Harrington, op. cit., p.20. Retrieved August 10, 2012, from: http://www.internationaltransportforum.org

In addition, the public can help fossil energy savings through traffic management. For example, the UK Department for Transport estimates that nearly two thirds of trips and over half of car journeys in the UK are less than five miles long. This proves the significant potential of changing traffic behavior and reducing the need to travel in urban areas to reduce fuel consumption and CO_2 emissions.[262]

Apart from vehicle technology improvements and fuel price policies, improvements in driving techniques can significantly improve on-road fuel efficiency and reduce carbon dioxide emissions. A significant advantage is that they can be implemented with drivers of both new and old passenger vehicles.

FIA et al. listed a number of measures to aid using cars more efficiently, including better engine tuning; better driving styles; use of more efficient aftermarket replacement parts like tires and lubricating oils; reducing vehicle weight by removing unnecessary items; reducing drag by removing objects such as ski racks when not in use; and reducing traffic congestion.[263]

Mckinsey&Company estimates that CO_2 abatement potential from driving behavior and traffic flow alone is about 180 million tons in 2030 – that equals to 94 EURO/ton saving.[264]

The International Energy Agency defined eco-driving as 'the operation of a vehicle in a manner that minimizes fuel consumption and emissions.'[265] This concept may include:

- Optimizing gear changing.
- Avoiding vehicle idling, e.g. by turning the engine off when the vehicle is stationary.
- Avoiding rapid acceleration and deceleration.
- Driving at efficient speeds. The most efficient speed for most cars is between 60 km/h and 90 km/h. Above 120 km/h, fuel efficiency falls significantly in most vehicles.

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262 Department for Transport (October 2007), *Towards a Sustainable Transport System: Supporting Economic Growth in a Low Carbon World*, London, Secretary of State for Transport, p.12. Retrieved September 22, 2010 from http://www.thepep.org/ClearingHouse/docfiles/Towards.A.Sustainable.Transport.System.pdf

263 FIA, IEA, ITF and UNEP, (March 2009), *50by50 Report on making cars 50% more fuel efficient by 2050 worldwide,* pp.7-8.

264 McKinsey&Company, (March 2009), *Roads toward a low-carbon future: Reducing CO_2 emissions from passenger vehicles in the global road transport system*, 2009 McKinsey&Company, New York, p.11.

265 International Energy Agency (IEA), (Sep., 2010), *TRANSPORT ENERGY EFFICIENCY: Implementation of IEA Recommendations since 2009 and next steps,* Paris, OECD, p.37. Retrieved June 14, 2012, from: www.iea.org

- Reducing weight by removing unnecessary items from the car, and reducing wind resistance by removing roof attachments such as ski racks.

The IEA estimates an average saving of 5% to 10% across all drivers and up to 20% for some, according to eco-driving.

2.8 Analyzing the policies and strategies of the EU

As discussed above, the global community has committed to limit global climate change to a temperature not more than 2 degrees centigrade above pre-industrial levels. To achieve this target, global GHG emissions should be reduced by at least 50% globally by 2050 compared to 1990. The European Commission reports that transport is the only major sector in the EU where greenhouse gas emissions are still rising.[266] However, the European Commission reported that a reduction of at least 60% of GHG emissions is required from the EU's transportation sector.[267] The new European car fleet has become more fuel efficient, but it still depends on fossil energy for about 95% of its needs.

The European Union's low carbon targets for vehicles by 2015 and 2020 have economic consequences. A broad group of interested parties must follow up the potential outcomes of these strategies. The automotive industry should meet the standard levels in a competitive atmosphere. They should satisfy their customers and governmental bodies. Technology suppliers should supply practical and cost-effective solutions for emissions reductions. Labor groups should engage for new jobs that are due to newer technologies. Energy providers should consider the economic and technological concerns of conventional and alternative fuels in accordance with both the automotive industry and vehicle customers. And finally, environmental groups should aim to deploy policies.

Ricardo-AEA and Cambridge Econometrics reported that the innovations made for meeting the 95 gr CO_2/km target for new vehicles would add about 1,000 EUR to the price of the average car in 2020. But the extra cost would be offset in less than three years via fuel savings of about 400

[266] European Commission, (30 July 2012), *Road transport: Reducing CO2 emissions from vehicles*, Retrieved 17 July, 2013 from http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm

[267] European Commission, (28 March 2011), *WHITE PAPER; Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system,* Brussels, p.3.

EUR per year. This regulation could bring extra economic advantages by creating 350,000 to 400,000 jobs in Europe.[268]

The European Commission argues that ‘growing out of oil’ will not be possible relying on a single technological solution. The Commission says that technological innovation can approach more efficient and sustainable European transport by focusing on three main factors:[269]

- Vehicles’ efficiency through new engines, materials and design;
- Cleaner energy use through new fuels and propulsion systems; and
- Better use of networks and safer and more secure operation through information and communication systems

The main challenge is to bring low carbon technologies into the transportation market. Ricardo-AEA and Cambridge Econometrics studied the economic aspects of low-carbon transportation. According to the most efficient scenario in their study, they estimated market penetration of hybrid electric vehicles (HEVs) as 10% of new vehicle sales in 2020, 22% in 2025 and 50% penetration in 2030.

This issue is pertinent for the speed of progress in powertrain electrification and progress in batteries or energy storage technologies. Four breakthroughs areas are needed for batteries in the future: price, weight, operational lifetime and recharging time. Improving battery technology and reducing costs are significant challenging factors if HEVs are to penetrate the future car market.

Ricardo-AEA reported that internal combustion engine technology will continue to improve in fuel efficiency stop-start technology using advanced lead-based batteries. Other technology options that are expected to appear in the 2020-2025 timeframe include engine downsizing coupled with boost (e.g. combination of turbo- and super-charging) and direct injection for petrol engines.

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268 Ricardo-AEA and Cambridge Econometrics, (March 2013), *An Econometric Assessment of Low Carbon Vehicles*, London, United Kingdom Retrieved February 11, 2014 from: www.ricardo-aea.com/cms/assets/MediaRelease/Economic-Assessment-Vehicles-FINAL2.pdf

269 European Commission, (28 March 2011), *WHITE PAPER; Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system,* Brussels, p.12.

Additional improvements are also possible in later years including further downsizing engines, more sophisticated start-stop and direct injection technologies and their combination with other highly technologies, such as low temperature combustion, etc.

The other challenge is the growing demand for light-weight vehicles that focus on preparing and processing high-tech materials such as carbon fibers, natural/glass fibers, high-strength steels and aluminum, magnesium technology and hybrid materials and bio-plastics.

Although technological improvements can reduce GHG emissions, the potential emission decreases from new policies and technological strategies are uncertain. Geurs et al. have grouped carbon reduction options according to their potential emissions reduction and the degree of uncertainty in potential, costs, and/or side effects. Table 2.13 illustrates some of their results.[270]

Failure to decrease CO2 emissions from transport will require the energy sector to compensate. Zierock argues that for the long-term success of transport de-carbonization, policymakers should concentrate on what is happening outside the sector. He concludes that generating renewable electricity is the key policy for producing future low-carbon transport fuels.[271]

[270] Karst Geurs et al., op. cit., p.63.
[271] Karl-Heinz Zierock, op. cit., p.73.

Table 2.13. Examples of carbon dioxide mitigation options grouped by emissions reduction potential and uncertainty in potential, costs, and/or side effects

		Uncertainty in potential, costs, or side-effects	
		Low	High
CO_2 emissions reduction potential	Low	• Current carbon dioxide efficiency standards • Pricing measures, e.g. ETS for aviation and shipping, EU-wide road pricing for trucks • Energy-efficiency measures for road freight, shipping, aviation • Logistical-efficiency measures, e.g. green logistics • Land-use planning	• First generation biofuels (ethanol, bio-diesel) • Current commercial jet biofuels
	High	• Plug-in hybrid cars • Heavy oil biofuel substitutes for inland shipping and maritime transport	• Fully electric cars • Fuel-cell hydrogen road vehicles • Second-generation biofuels for road vehicles (ethanol, bio-diesel) • Second-generation and third-generation jet biofuels • Biomass-to-liquid biofuels with carbon capture and storage

Source: Geurs, K. et al. 2011

Combination of vehicle performance standards with fuel fees

Performance standards increase the fuel efficiency of vehicles and high fuel prices offset the consequences of low-cost driving. A combination of these two pivots encourages both demand and supply sides to pursue more fuel-efficient options and results in a significant reduction of greenhouse gas emissions.

Kodjak et al. estimate that the three main GHG emitters (i.e. the EU, the US and China) could reduce their combined annual CO_2 emissions by more than 1 gigaton by 2030. This is nearly equal to a net saving of 130 billion USD in 2030, or a cumulative savings of approximately 800 billion to 1.5 trillion USD by 2030.[272]

They conclude that fiscal policies complement vehicle emissions performance standards. These policies provide monetary incentives for consumers to drive less and to choose more fuel-efficient cars, and for the automakers to produce more fuel-efficient fleets, maintaining performance standards to keep their current and future market.

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[272] Drew Kodjak et al., op. cit., p.26.

3. Carbon dioxide emissions in the Iranian transportation sector

3.1. The status of CO_2 emissions in Iran

Fossil fuel consumption and consequent environmental impacts in Iran have grown in recent years. According to Iran Energy Balance, total CO_2 emissions in 2011 were over 547 million tons. This high rate has placed Iran among the top ten carbon dioxide emitters of the world.

Fossil fuels are the main source of energy in the country. The Iranian economy grows, the more fossil fuels are consumed. Total primary energy consumption in Iran reached 243.9 million tons of oil equivalent (MTOE) in 2013 with an average growth of 47% over ten years from 2004 to 2013 (Table 3.1).[273] European member countries do not show as significant growth, also having decrease owing to more productive policies.

Table 3.1. Iran's primary energy consumption (MTOE) from 2004 to 2013

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Iran	166.1	177.3	193.7	207.8	217.2	227.0	227.4	237.6	238.8	**243.9**
Germany	337.2	333.2	339.6	324.6	326.9	307.8	322.5	307.5	317.1	**325.0**
UK	227.3	228.2	225.4	218.2	214.5	203.9	209.2	196.3	201.6	**200.0**
Greece	34.3	34.0	35.2	35.1	34.6	33.4	31.4	30.7	29.3	**27.2**
Spain	150.1	151.7	153.6	157.5	154.0	143.9	144.7	142.4	141.1	**133.7**

Source: BP 2014

Iran's Ministry of Energy (MOE) reports on the energy production and consumption patterns of the country annually. According to Iran Energy Balance 2011, final consumption of energy carriers hit over 163 MTOE in 2011. This index has grown 32% from 2001 (Table 3.2).

Table 3.2. Iran's Final energy consumption (MTOE) from 2001 to 2011

2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
123.4	136.4	148.8	152.3	159.5	156.4	163.1

Source: Iran Energy Balance 2011, 2013

[273] British Petroleum (BP), (2014), *BP Statistical Review of World Energy*, (June 2014). Retrieved 11 February, 2015 from: www.bp.com/statisticalreview

As shown in Figure 3.1, the household, public and commercial sectors have been the main energy consumers, hitting 59.1 MTOE in 2011. The share of these sectors has grown at a 55% average rate since 2001. This trend is followed by transportation, which the above indexes put at 40.5 MTOE and 52.7% respectively. However, the industrial sector led in growth during this period by 117.3%. This sector consumed over 40.1 MTOE in 2011. According to Iran Energy Balance, the non-energy uses[274] sector has increased sharply from 5.9 to 17 MTOE (188.5%). It shows significant growth of related products, especially in petrochemicals.

For transportation, the second-largest energy consumer sector, the growing the number of cars, low energy efficiency of the road fleet and week structure of public transportation are the main contributors to the high-consumption trend.

Owing to the increase of the Iranian population and improvements in welfare, on the one hand, and growing rates of industrialization, on the other, the industrial sector saw the most changing rate during the period (117.3%).[275] However, the household, public and commercial sectors have been seen the most final energy consumption to so far. Low efficiency of energy consumption in industries owing to old structure and low energy prices, should not be ignored in analyzing the energy sector.

[274] Non-energy uses are defined as using petroleum products apart from energy production, eg., for producing lubricants, waxes, paraffin, etc. The Iranian MOE counts petrochemical feeds as non-energy use as well.
[275] Behrooz Abdolvand, David Ramin Jalilvand, Fardin Eskafi, (2012), Iran versus USA: Geburtswehen einer neuen Weltordnung, Eine geopolitische Analyse, WeltTrends Papiere 21, Universitätsverlag Potsdam, p.13.

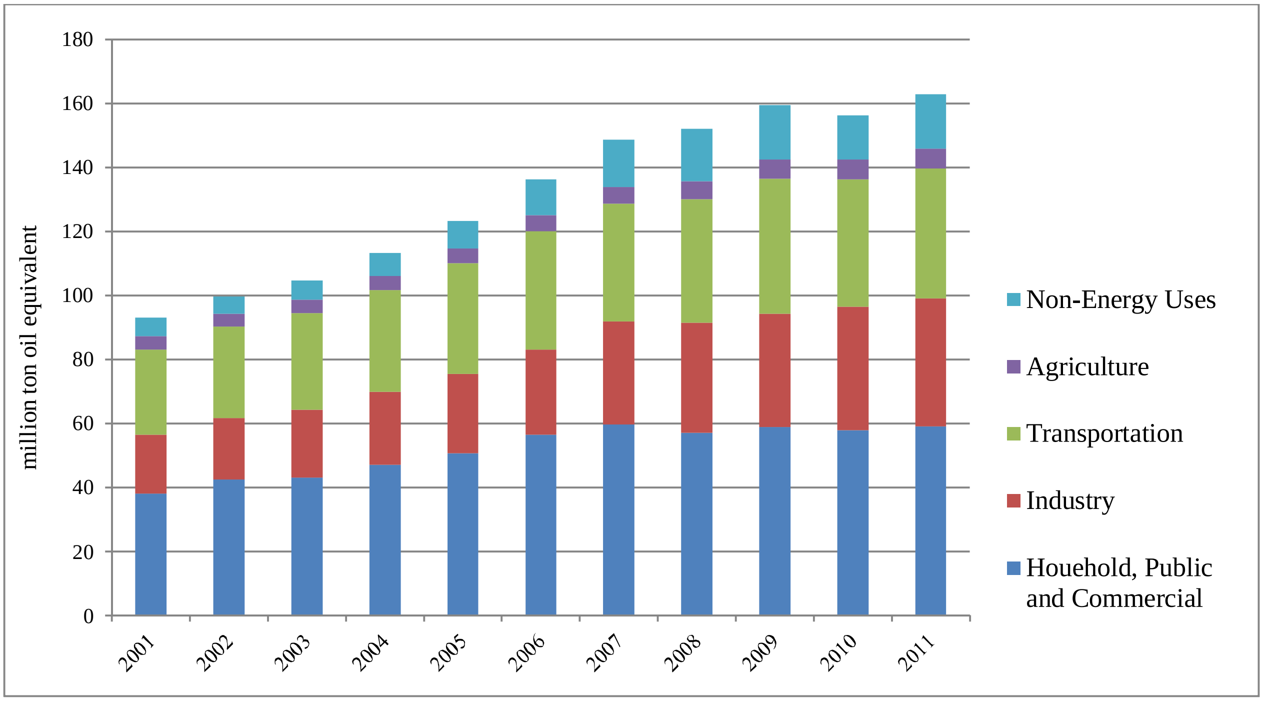

Figure 3.1. Iran's total final energy consumption in consumer sectors (2001 to 2011)

Source: Iran Energy Balance 2011, 2013

Natural gas, with 89.1 MTOE, was the most-used energy carrier in Iran (55%) in 2011. The second-most-used energy carrier was petroleum products, with 57.6 MTOE (35%) in the same year. Figure 3.2 shows changing trends in hydrocarbons following the enhancing of the share of natural gas to Iran's economy. This trend was started by introducing and developing natural gas, especially in the household and industrial sectors, and replacing other energy carriers, such as diesel, kerosene and fuel oil. The major environmental advantage of natural gas is its lower pollution and carbon emissions. Akram Avami and Bahare Farahmandpour have argued that natural gas is the leading opportunity for Iranian energy infrastructure.[276]

[276] Akram Avami, Bahare Farahmandpour, (2008), *Analysis of environmental emissions and greenhouse gases in Islamic Republic of Iran*, WSEAS Transaction on Environment and Development, Issue 4, Vol. 4, April 2008. Retrieved 5 December 2013 from: http://www.wseas.us/e-library/transactions/environment/2008/26-193.pdf

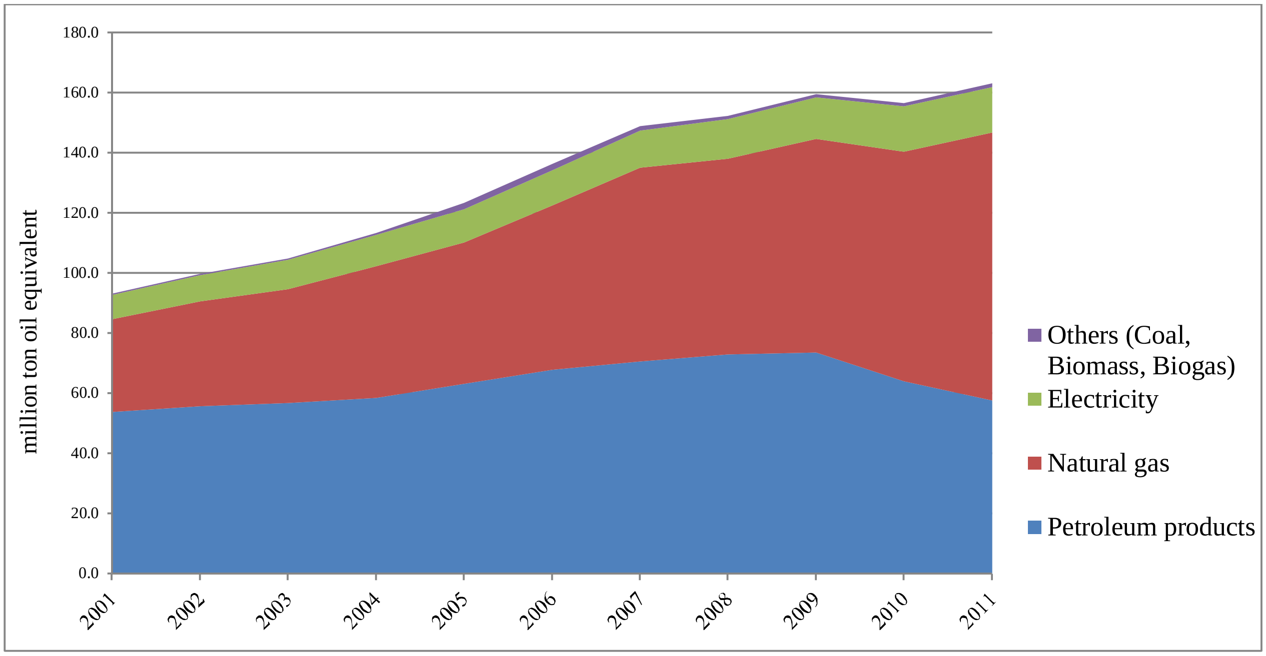

Figure 3.2. Iran's total final energy consumption from energy carriers (2001 to 2011)

Source: Iran Energy Balance 2011, 2013

Iran is a fossil energy–rich country with 157 billion barrels of proven oil reserves (9.4% of world total) and 33.6 trillion cubic meters of proven natural gas reserves (18% of world total).[277] Although Iran has a high potential for renewables (especially wind and solar), these technologies have not been developed seriously.

A large population (mostly rural), a growing economy, subsidized energy prices and poor resource management have contributed to increasing consumption of energy carriers and high energy intensity in comparison with the world average. The energy intensity in Iran is nearly twice as high as the world average (236.7 vs. 120.3 tons oil equivalent per million USD, based on purchasing power parity in 2008).[278] The increasing energy intensity index has seen an average 3.1% annual growth over the 30 years from 1981 to 2010, indicating a decreasing trend in energy efficiency for end users.[279]

[277] British Petroleum (BP), (2013), *BP Statistical Review of World Energy*, (June 2013). Retrieved 11 March, 2014 from www.bp.com/statisticalreview

[278] Iran Energy Balance 2009, 2010 in: IEA, Online Data Services.

[279] US Energy Information Administration (EIA), *Country Analysis Brief Overview: Iran*. Retrieved 21 December 2013 from: www.eia.gov/countries/country-data.cfm?fips=IR#tpe

The Iran Energy Association et al. discuss how Iran's final energy use rate to GDP ratio (1.27) compares to the world average (0.41), and how this reflects an unproductive use of energy. They argue that Iran's stage of economic development and energy subsidies (estimated 12% of GDP for 2007) are the main driving forces behind its growing energy intensity and inefficiency.[280]

3.2. CO_2 emissions in Iran's transportation sector

In 2011, Iran's transportation sector consumed nearly a quarter of the country's final total energy (Figure 3.3). The sector placed after the household, business and public sectors (36.1%) and before industry (24.6%), non-energy uses (10.4%), agriculture (3.8%) and other sectors (0.2%).[281]

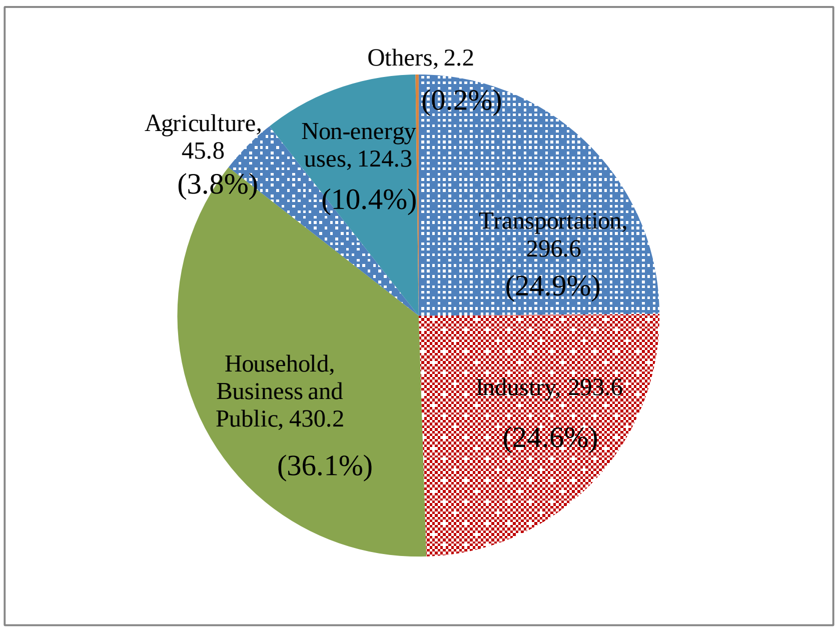

Figure 3.3. Iran's final energy consumption in 2011 (MBOE)

source: Iran Energy Balance 2011, 2013

From another point of view, the transportation sector consumed over 48% of the country's total petroleum products (gasoline, diesel and LPG) in 2011. Gasoline and diesel consumption in this year were 119.6 and 123.9 million barrels oil equivalent (MBOE) respectively, making up over

[280] Iran Energy Association and Wuppertal Institute for Climate, Environment and Energy, (March 2009), 'Energy Scenarios for Iran', Iranian German Cooperation Project, Tehran and Berlin.
[281] Iranian Ministry of Energy (MOE), (2013), *Iran Energy Balance 2011*, Tehran, Iran.

81% of the fuel consumption in the sector.[282] Inside the sector, road transportation consumed over 92% of energy and marine (3.24%), air (2.84%), pipeline (1.03%) and rail (0.78%) transport ranked after.

Demand for transportation has increased in parallel with Iran's population growth. Lacking adequate efficiency improvement, fuel consumption has increased as well. Owing to the growth of Iran's population and also GDP from 2001 to 2011, the total size of the passenger car fleet has grown from 3.1 to 11.1 million (over 260% growth) (Table 3.3).

During this period, the total number of vehicles grew from 4,345,798 to 13,975,432 (over 12.3% annual growth on average). It should be added that over 85% of registered vehicles in Iran in 2011 were passenger cars.[283]

Table 3.3. Statistics on Iran's population, GDP and size of passenger car fleet (2001-2011)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Population (million)	65.3	66.3	67.3	68.3	69.4	70.5	71.7	72.6	73.7	74.7	75.1
GDP (Billion USD)	115.4	116.4	135.4	163.2	192	222.9	286.1	356	362.7	422.6	514.1
Passenger car fleet (million)	3.1	3.5	4	4.8	5.6	6.4	7.2	8	9.1	10	11.1

Sources: Statistical Centre of Iran (2013), World Bank (2013), IFCO (2013)

Through renovating and developing the automotive industry after the Second Five-Year Development Plan, local manufacturers produced more modern cars for the internal market. Through increasing the average income of Iranian families, and also more demand for new passenger cars, the average age of the passenger cars fleet decreased (Table 3.4).

Table 3.4. Estimate of the average age of the Iran's passenger car fleet (2001-2011)

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
14.5	13.3	12	11	10.3	9.6	8.9	8.4	8	7.6	7.2

Source: IFCO 2013

[282] Iranian Fuel Conservation Company (IFCO), (2013), *Transportation Energy Data book 2011*, Tehran, Iran
[283] IFCO, (2013), op. cit., p.65.

According to Table 3.5, 78% of Iran's passenger vehicles in 2011 were under 10 years old. The number of light-duty vehicles per thousand inhabitants increased from 59.7 in 2001 to 170.5 in 2011.[284] According to the Iranian Fuel Conservation Company (IFCO) the motorization rate[285] of Iran grew 10.7% annually from 2001 to 2011.[286] In 2001, two out of ten Iranian families had a passenger vehicle, and this rate increased to five out of ten in 2011.[287] By introducing new cars, it is expected that the average energy consumption of each vehicle will decrease.

Table 3.5. Distance travelled of different age groups of Iran's passenger vehicles in 2011

Age of vehicles	Number of Vehicles	percent	Distance Travelled (million kilometers)
under 5	4,477,103	42	94,019
6 - 10	3,885,825	36	81602
11 - 15	1,068,979	10	22449
16 - 20	440,552	4	9252
21 - 25	159,501	1	3350
26 - 30	395,666	4	8309
31 - 35	247,216	2	5192
above 36	67,255	1	1412
Total	10,742,097	100	225,585

Source: IFCO 2013

The number of public vehicles per one thousand inhabitants has not grown as much as private vehicles. The IFCO reported that the growth rates for the former group were 5.7% for buses, 10.3% for taxis, and 1.3% for minibuses. However, these rates showed a 12.1% growth for private cars.[288]

Travelling by private vehicles has increased dramatically in the absence of efficient and reliable public transportation. According to the IFCO, distance travelled by private passenger vehicles

[284] IFCO, (2013), op. cit., p.224.
[285] Total number of vehicles per one thousand inhabitants.
[286] IFCO, (2013), op. cit., p.71.
[287] IFCO, (2013), op. cit., p.230.
[288] IFCO, (2013), op. cit., p.225.

has grown from 961 vehicle-kilometers traveled (VKT) per capita to 3002 VKT per capita in 2011 (212% growth).[289]

Market share of different classes in Iran

The largest share of Iranian-made cars in 2001 belonged to Compact Class vehicles (near 35%). In 2011, Sub–Compact Class vehicles took the main market share of the country, with over 38%.[290] In 2001, the market share of Large Class and above vehicles produced in local factories was only 4%. Those classes' market share grew significantly to 17% in 2011. In the same year, vehicles produced by local automakers with an engine volume between 1300 and 1400 cc took the largest market share with 45%.[291]

In parallel with GDP growth, local market demand for SUVs has increased in Iran during the last decade. Because of the higher engine volume and power of the vehicle, and also its weight, the average fuel consumption of SUVs is more than Sub–Compact and Compact Class vehicles. According to the IFCO, the total number of SUVs has increased in the country from over 3.2 thousand in 2005 to about 22 thousand in 2011 (Table 3.6).

Table 3.6. Number of SUVs in Iran (2004 - 2011)

	2004	2005	2006	2007	2008	2009	2010	2011
Local production	3,155	2,232	3,020	4,416	5,422	4,975	5,423	4,513
Imported cars	73	3,136	5,327	10,517	10,841	19,331	18,166	17,427
Total	**3,228**	**5,368**	**8,347**	**14,933**	**16,263**	**24,306**	**23,589**	**21,940**

Source: IFCO 2013

The average fuel consumption (weight based) of SUVs in Iran decreased from 2005 to 2011. This criterion for the local production fleet changed from 12.36 to 9.41 lit/100km (-23.9%) and for imported SUVs from 12.54 to 11.25 lit/100km (-10.3%) over this period.[292]

289 IFCO, (2013), op. cit., p.228.
290 IFCO, (2013), op. cit., p.98.
291 IFCO, (2013), op. cit., p.92.
292 IFCO, (2013), op. cit., p.94.

Fuel consumption and CO_2 emissions of Iran's road transport sector

The growth of the main fuel consumption criteria (GDP, population, number of vehicles and vehicle-kilometers travelled per capita) suggests that fuel consumption per capita will increase. This grew from 3.02 barrels of oil equivalent (BOE) per capita in 2001 to 3.83 BOE per capita in 2006.

In 2007, and following the start of the subsidies reform plan, the index fell to 3.67 BOE per capita (-4.2%). However, from 2008, it started to grow again and hit 3.96 BOE per capita in 2011 (2.73% annual growth on average from 2001 to 2011).[293]

Carbon dioxide emissions in road transportation have followed the same pattern. Despite falling CO_2 emissions in 2007, the index has grown again owing to the penetration of other fuels (especially CNG) into road transportation (Figure 3.4).

Total CO_2 emissions in Iran's road transport sector increased from 68.6 million tons in 2001 to 102.9 million tons in 2011.[294]

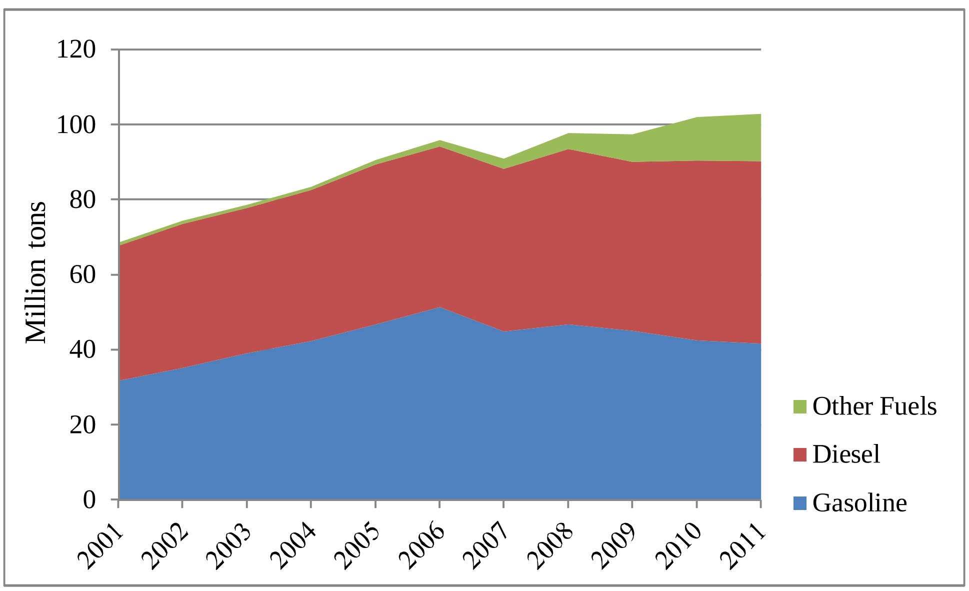

Figure 3.4. CO_2 emissions Iran's road transport sector

Source: IFCO 2013

[293] IFCO, (2013), op. cit., p.55.
[294] IFCO, (2013), op. cit., p.296.

3.3. Policies and regulations focusing on the automotive industry and vehicles

Fuel consumption in Iran's transportation sector

Emissions of carbon dioxide are directly linked to fuel consumption. When a conventional fossil fuel (gasoline and diesel) or alternative fossil fuel (CNG and LPG) is burned for energy in an engine, the main by-products are water and CO_2. Carbon dioxide is the most significant greenhouse gas contributing to climate change, although it is not directly harmful to human health. I focus on the fuel consumption concept here, addressing carbon dioxide.

Improving fuel conservation and reducing energy intensity are general policies of the I.R. of Iran proposed by the Expediency Discernment Council on 13 January 1999 and confirmed and communicated by the Supreme Leader of the I.R. of Iran on 22 January 2001.[295] However, this issue was also considered in the national development plans:

Second FYDP

The only policy instrument that mentioned fuel conservation for transportation sector in the Second FYDP (from 1995 to 1999) was financial policies. As a fuel conservation policy, the Iranian government was authorized to raise the prices of petroleum products in such a way that total taxes reached eleven thousand billion IR Rial at the end year of the Plan. The prices of the four main fuels in 1995 were 100, 20, 20 and 10 IR Rial for each liter of gasoline, kerosene, diesel and fuel oil respectively. The prices were equal to 0.057, 0.011, 0.011 and 0.006 USD respectively, following 1995 exchange rates.[296]

Third FYDP

In Article 121 of the Third FYDP (2000-2004), the government was required to develop technical specifications and criteria for fuel-consuming equipment (such as vehicles) for fuel conservation and environmental protection.

According to the Article, the Ministry of Petroleum (MOP) established the Iranian Fuel Conservation Company (IFCO) as a subsidiary of the National Iranian Oil Company (NIOC) in

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[295] Expediency Discernment Council, *General Policies: Energy Sector*, Retrieved 20 February 2014 from: http://maslahat.ir/DocLib2/Approved%20Policies/Offered%20General%20Policies/policy%2011-07-1377-Energy.aspx

[296] Central Bank of Iran, *Reference Exchange Rates*, http://www.cbi.ir/exrates/rates_fa.aspx

2000. The mission of the IFCO is to regulate the fuel consumption of different sectors (transportation, building and industry) through implementing conservation measures nationwide.

Iran's fuel consumption standard

Iranian National Standard No. 4241-2, entitled 'Gasoline vehicles – Criteria for fuel consumption and energy labeling instruction', was issued in 2006 and first revised in 2009. The standard was issued according to the Article 121 of the Third FYDP and revised later according to Article 20 of the Fourth FYDP.

Iran's national standards for vehicle manufacturing are derived from European standards 80/1268/EEC, 93/116/EEC and 99/100EEC. Local automakers produce vehicles under license or in cooperation with their European partners.

According to the latest revision, the authorized Iranian official body measures fuel consumption in both '*Type Approval*' and '*Conformity of Production*' stages to define the range of energy labels. Figure 3.5 shows a sample of Iranian energy consumption labels for gasoline-fueled cars.

Figure 3.5 A completed sample of the gasoline-fueled vehicles energy consumption labels in Iran

A 'Criteria-Defining Committee for Energy Consumption' specifies fuel consumption criteria and energy labels for at least three-year periods. Table 3.7 shows the fuel consumption criteria for each class of locally produced and imported gasoline-fueled vehicles in the Iranian year 1391 (20 March, 2012 to 19 March, 2013).

Table 3.7. Criteria and classifications of the fuel consumption for gasoline-fueled cars in Iran from March 2012 to March 2013

Criteria for imported cars from 20 March, 2012 to 19 March, 2013	Criteria for locally produced cars from 20 March, 2012 to 19 March, 2013	Range of engine volumes (cc)	Class
4.02	5.11	V≤1000	1
4.34	5.43	1000<V≤1100	2
4.66	5.85	1100<V≤1300	3
5.21	6.28	1300<V≤1400	4
5.54	6.38	1400<V≤1500	5
5.71	6.7	1500<V≤1600	6
6.21	7.34	1600<V≤1800	7
6.51	7.98	1800<V≤2000	8
7.01	8.83	2000<V≤2200	9
7.51	8.94	2200<V≤2400	10
7.69	9.68	2400<V≤3000	11
9.24	11.38	3000<V≤4000	12
10.69	11.91	4000<V≤5000	13
11.50	12.87	5000<V	14

Source: ISIRI 2009

Fourth FYDP

The Fourth FYDP (2005-2009) was a milestone in policymaking for energy efficiency in Iran, especially for the transportation sector. Article 3 of the Plan required the government to develop public transportation and to improve energy efficiency through the following approaches:

- Pricing fuel oil, diesel and gasoline according to Persian Gulf FOB[297]

[297] Free on Board

- Developing and improving quality of public transportation, producing dual-fuel vehicles, and paying subsidies for CNG in public transportation
- Developing conservation plans for energy consumers (e.g. vehicles) through technology enhancement

For implementing the Plan, 'Remark Number 13'[298] of the 'Budget Law of the [Persian] Year 1386'[299] authorized the government to allocate a national budget for developing public transportation and replacing old vehicles. For doing so, a working group representing related bodies was established, named 'The Deputy of Remark 13', under the supervision of the presidency. This deputy is now called 'The Deputy of Fuel and Transportation Management.'

On 9 December 2007, Iran's Parliament ratified the 'Public Transportation Development and Fuel Consumption Management Law.'[300] According to the Law, the government is required to plan financial and technical support for both consumers of transportation services and producers of vehicles (automotive industry). The law has defined the targets for gasoline consumption by public transportation from 2007 to 2011 (Table 3.8).

Table 3.8. National targets for gasoline consumption from the Public Transportation Development and Fuel Consumption Management law.

	2007	2008	2009	2010	2011
Liters per day per capita	1.1	1.0	0.9	0.8	0.7

Article 5 of the Bylaw of Remark 13 specified that all registered passenger cars and pickups, whether produced in local factories or imported vehicles, should be CNG fueled, CNG dual-fueled, or gasoline-fueled with 6 lit/100km or less fuel consumption. For locally produced vehicles exceeding these limits, it is necessary to get permission from the Deputy of Remark 13. And for imported cars with over 6 lit/100km fuel consumption, an old car should be phased-out.

298 'Tabsare-ye Sizdah'.
299 Ratified by the Parliament on 15 March 2007 (24 Esfand 1385).
300 'Ghanoon-e Tose'e-ye Haml-o-Naghl-e Omoomi va Modiriat-e Masraf-e Sookht'.

Policy-making process of the 'Public Transportation and Fuel Consumption Management Law'

As described above, the lack of infrastructure in public transportation in Iran has encouraged people to use private modes. The cheap price of fuels (gasoline and diesel) and increasing rate of motorization in the country has also resulted in a dramatic increase of fuel consumption in the transportation sector.

The increase in national expenses and environmental degradation on the one hand, and threats to the energy security of the country on the other, have persuaded the government to define the problem.

There are three criteria for getting a problem onto an agenda: its being important for many people, intensive effects and impacts, and its being a problem for a long time. Dramatic increases in fuel consumption were the main problem defined by the governmental think-tanks and research centers. Inefficient fuel consumption has been the major concern of policymakers because of its extensive impacts on society.

Fuel consumption in transportation has been considered since the First and Second Five Year Development Plans in Iran. Dealing within many studies, articles and reports has institutionalized the problem as a public concern. But, despite the importance of the problem, weak flows of information in Iranian society, and even among policymakers, have postponed solutions for 20 years.

The former 'Management and Planning Organization' prepared the first draft of the law with the cooperation of the IFCO, the World Bank and some Korean and Japanese experts. Referring the draft to the legislative entity and processing it, the research center of the Parliament (ICARC)[301] formed a research group for preparing the final draft. The Parliament ratified the law finally on 9 December, 2007.

The government was the first entity for agenda-setting and the representatives were active in the whole process of policy-formulation in the working group.

The private sector did not play a significant role in the policy-making process. Fuel is a public good in Iran, produced and distributed by the government, and the government prefers to decide

[301] The Islamic Consultative Assembly Research Center.

about the problem alone. The syndicate of gas station owners was the only representative of the private sector that cooperated in the process, and via an opinion poll.

The weak status of civil institutions and the lack of non-governmental bodies in this area caused weak media output that could enhance public awareness.

Being a milestone in Iran's energy policy, this law follows two objectives for improving public transportation and fuel prices and requires the government to fulfill the following:[302]

- Improving demand of transportation services (through improving rail transportation, dismantling old vehicles, developing dual-fueled CNG vehicles, developing freeways and highways, improving energy prices, developing public road transportation, etc.)
- Improving supply of transportation (through improving administrative processes, developing communication and information technology, land-use planning, traffic management, training, etc.)
- Improving energy consumption (through developing fuel smart cards, developing CNG fueling stations, etc.)
- Improving vehicle production (through developing CNG-fueled vehicles, developing fuel consumption standards for new vehicles, producing electric and hybrid vehicles)
- Removing subsidies from gasoline and diesel from 20 March, 2012

There have been many opinions and different solutions to deal with the problem. For instance, Article 3 of the Fourth FYDP required the government to price oil, gasoline and diesel according to the Persian Gulf F.O.B. from 12 March, 2005. Implementing such a regulation might have brought the risk of huge inflation in the economy. However, some non-monetary instruments, such as dismantling old cars, developing rail transportation, developing CNG fuel stations, and producing low-consumption vehicles, were considered in the 'Public Transportation and Fuel Consumption Management' law to control the inflation potential.[303]

Article 12 of the law required the government to prepare and ratify the Executive Bylaw. The Bylaw defines the executive tasks of institutions for meeting its objectives. The Bylaw was ratified on August 28, 2008, i.e. delayed near 6 months.

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[302] Article 1 of the law.
[303] Rahmatollah Gholipour, and Ebrahim Gholampour Ahangar, (2010), *Farayand-e Siasatgozari-ye Omoumi dar Iran*,(in Persian), The Islamic Consultative Assembly Research Center (ICARC), Tehran, Iran, p.227.

The precise quantitative and qualitative objectives of these regulations have defined specific time-spans for the responsible players.

The Islamic Consultative Assembly Research Center (ICARC) conducted a study to evaluate the performance of the regulations one year after ratification. According to the report, some objectives have not been met completely.[304] Gholipour argued that factors such as lack of facilities, non-coordination among the players and overestimating the objectives for the available facilities contributed to this.[305]

The Iran Standard and Quality Inspection Company (ISQI) reported the average gasoline consumption trends of the new passenger car fleet from 2003 to 2013 (Figure 3.6).[306] According to the Vehicle Quality Enhancement Law, the average fuel consumption of the passenger car fleet should have fallen to 6.95 lit/100km in 2011.

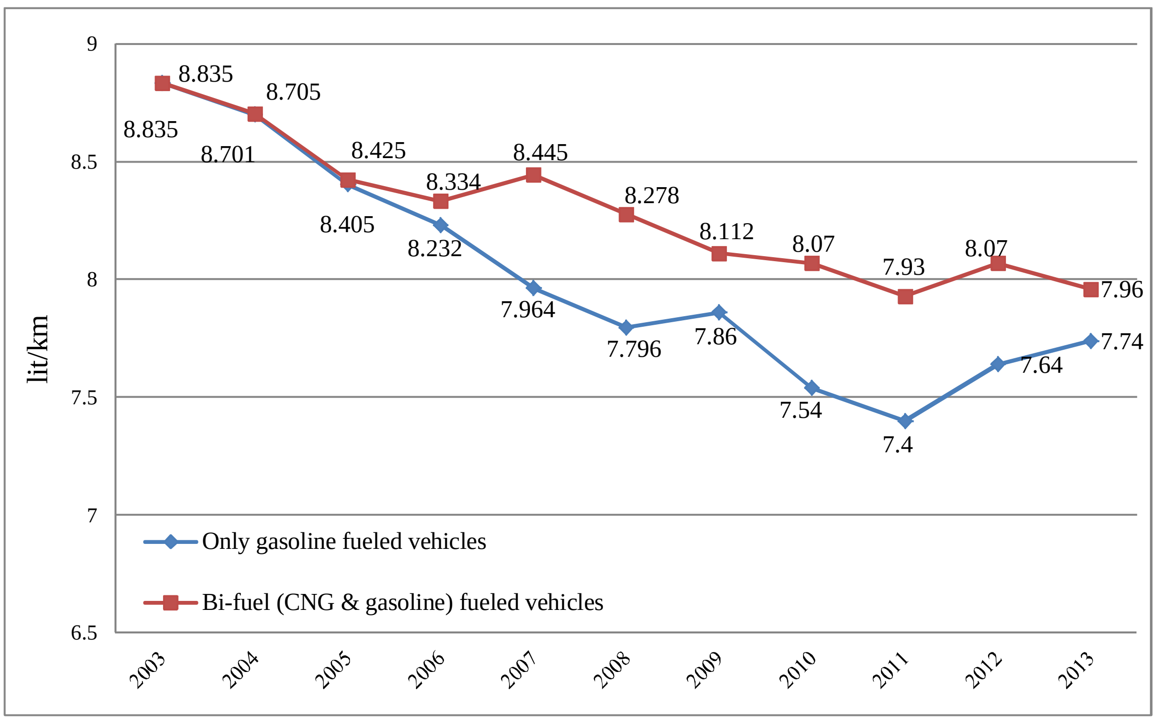

Figure 3.6. Average gasoline consumption per capita of new locally produced passenger vehicles in Iran (2003-2013)

Source: ISQI 2014

[304] Asádi, F., (May 2009), *Arzyabi-ye Amalkard-e Ghanoon-e Modiriyat-e Haml-o-Naghl va Sookht*, The Islamic Consultative Assembly Research Center, Tehran, Iran, p.16.
[305] Rahmatollah Gholipour, and Ebrahim Gholampour Ahangar, op. cit., p.227.
[306] Iran Standard and Quality Inspection Co (ISQI), (2014), *Gozaresh-e Haml-o-Naghl va Khadamat 1392*, p.33. Retrieved 22 February 2014 from: www.isqi.co.ir/

Fifth FYDP

Article 162 of the Fifth FYDP extends the implementation of the 'Public Transportation and Fuel Consumption Management' law during the Plan's years (2011-2015).

In Article 125 of the Fifth FYDP, the government is required to prepare 'The Iranian National Strategy for Energy' as an upstream document for a 25-year time-span. This document has been developed and is being prepared for publication.

Prohibition of diesel-fueled passenger vehicles

Diesel passenger vehicle registration in Iran has been prohibited since 1971.[307] The quality of diesel fuel supplied in the country was much lower and the price was also lower than gasoline at that time. The Iranian government decided to protect cities from so-called pollution and to support producing gasoline-fueled vehicles locally.

Diesel engine technology has recently progressed significantly. New technologies also help refineries to produce very low-sulfur diesel fuel. Sulfur is the main source of air pollution and a fuel efficiency disordering factor.

The new Minister of Industry, Mining and Trade (MIMT) of President Rohani's Cabinet, Mr. Mohammadreza Nematzadeh, believes in producing diesel passenger cars in Iran again after 45 years. The members of the 'Vehicle Policymaking Council' of the MIMT decided in their latest session to reduce the tariffs on importing new diesel, hybrid and electric vehicles by 20%.[308] However, they know that, before producing diesel vehicles locally, the infrastructure of both diesel engine technology and diesel fuel supply sides should be prepared appropriately. Article 160 of the Fifth FYDP authorized related bodies to produce and import diesel passenger vehicles.

The IFCO recently modified the fuel basket of Iran's passenger car fleet. According to the IFCO, 24% of the passenger car fleet should be fueled by diesel by 2025.

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[307] '*Khodroha-ye Savari-ye Dizeli dar Khiabanha-ye Iran,'Sgargh Daily*, (25 May 2010), Vol. 8, No.1255, Tehran, Iran, Retrieved January 4, 2014, from: http://old.sharghdaily.ir/pdf/90-03-04/9.pdf

[308] *'Sarnevesht-e Por-Ebham-e Khodroha-ye Dizeli,' Donya-ye Eghtedad Daily*, (17 November 2013), No.3065, Tehran, Iran, p.16. Retrieved January 4, 2014, from: http://www.donya-e-eqtesad.com/news/766443/

Natural gas share of energy consumption in the sector has grown sharply to 14% of the total. The annual growth rate of natural gas consumption was 33.6% on average from 2001 to 2011 (Figure 3.7). This increasing trend is due to national strategies for energy security and air pollution control.

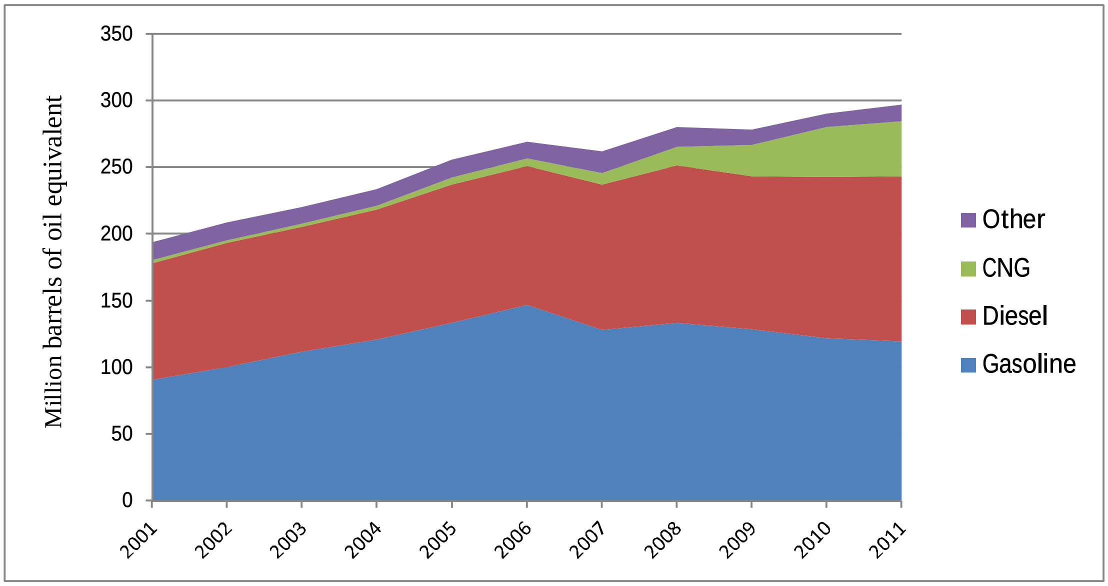

Figure 3.7. Fuel consumption in Iran's transportation sector (MBOE)

Source: Transportation Energy Data Book 2011, 2013

Mr. Abbas Kazemi, Associate Director of Iran's Ministry of Petroleum (MOP) and Managing Director of the National Iranian Oil Refining and Distribution Company (NIORDC), declared three government approaches to control increasing gasoline consumption:[309]

- Enhancing diesel share in the fuel basket of the fleet
- Developing CNG industry in the transportation sector
- Reforming fuel prices

[309] Deputy of Transportation and Fuel of Iran Presidency, (2014), *3 Barnameh-ye Dolat Baraye Kahesh-e Masraf-e Benzin*. Retrieved February 21, 2014, from: http://www.hamsu.ir/Portal/Home/ShowPage.aspx?Object=NEWS&ID=a934d882-a652-4bba-a84c-89efb10a4d93&WebPartID=c30a3600-9956-4829-8885-19c0d47cae21&CategoryID=79ca601d-1998-4db1-a164-0659a32da855

3.4. Policies and regulations focusing on emissions

Using emission standards in Iran

On 28 November 1978, the Council for Environmental Protection ratified Regulation number 104 on 'Emission Standards for Gasoline Engine Vehicles.'[310] The regulation took European Standards (ECE-15) as the base for emission standards for gasoline engines in Iran. However, this law was not deployed at that time because of restrictions for vehicle production in the country resulting from political issues, and also the war with Iraq.

Iran's automotive industry has been required to meet environmental standards limits since 2000, i.e. seventeen years after Europe. ECE-R 15/04 was the first regulation that was communicated officially to the industry at that time.

Meeting ECE R-83 standard limits was possible by removing lead from gasoline in 2002. The Ministry of Industry made the standard mandatory for all local automakers from April 2003.[311] Nine years after Europe, the Euro 2 standard was required in Iran from 2005. Local automakers had to meet the emissions levels of Euro 3 from 2010, but this requirement was lifted because of some problems, such as low fuel quality.

On 6 March 2012, Iran's government required local automakers to meet Euro 4 standards for all of their products gradually from April 2014. According to this regulation, all local vehicles produced after April 2013 have to meet Euro 4 standard limits. In other words, Iran's emission standards for vehicles directly improved from Euro 2 to Euro 4 over a short time-span. Table 3.9 compares the time schedules for implementing vehicles emission standards in Iran and Europe.

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[310] This emission standard dealt with just two pollutants, carbon monoxide (CO) and non-burned hydrocarbons (HC), for 24 and 2 grams per kilometer driving distance, respectively.

[311] Air Quality Control Co., (May 2013), *A Comparison of Regulated Pollutants Emissions Levels of European Standards of Euro II and Euro IV*, Technical Report No. QM92/02/01(U)/01, pp.8-9.

Table 3.9. Time schedule for implementing vehicle emissions standards in Iran and Europe

ECE Standards	Euro Standards	Implementation in Iran	Implementation in Europe
15-04	83/351/EEC	2000	1983
R83-00	88/76/EEC	2003	1988
R83-01	Euro 1	2003	1992
R83-02	Euro 1	-	1993
R83-03	Euro 2	2005	1996
R83-04	Euro 2	2005	1998
R83-05	Euro 3	-	2000
R83-05	Euro 4	2013	2005
R83-06	Euro 5	-	2009
R83-06	Euro 6	-	2014

Source: AQCC 2013

In May 2014, the Iranian government communicated the standard limits for vehicles that should be met by automakers (Table 3.10). According to this regulation, new local dual-fueled and CNG-based fueled vehicles should meet Euro 4 from April 2016.

Table 3.10. Time schedule for light and heavy-duty vehicles produced by local automakers

<table>
<tr><th></th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th></tr>
<tr><td>Light-duty vehicles (gasoline fueled)</td><td colspan="5">Euro 4</td><td colspan="5">Euro 5</td></tr>
<tr><td>Heavy and semi-heavy-duty vehicles</td><td>Euro2</td><td colspan="2">Euro 3</td><td colspan="3">Euro 4</td><td colspan="4">The same as the EU</td></tr>
</table>

Source: Iran Department of Environment portal, 2014

Sulfur content limitations to meet Euro 4

It should be added that, to meet Euro 4 emission levels, appropriate fuels should be available. For dual-fuel vehicles, emission levels had to be met with both fuels (gasoline/diesel and CNG/LPG).

Sulfur is a poisonous element and decreases the quality of fuels. Sulfur prevents catalytic converters from functioning correctly and increases emissions of hazardous pollutants such as NO_x and CO. The more sulfur is in a fuel, the greater emissions of PM and SO_2 to the atmosphere. Thus, removing sulfur from fuel is a necessary condition for meeting higher standards and attaining better air quality.

As it regards carbon dioxide emissions, sulfur content of fuel affects the energy efficiency of the engine negatively and can therefore increase the CO_2 emissions of the vehicle. According to the EU reference test fuels, the sulfur content of fuels, to meet Euro 4 standards, should be decreased significantly in comparison with Euro 2 procedures (Table 3.11). This issue will help local vehicle manufacturers to improve fuel efficiency and decrease the CO_2 emissions of newer vehicles.

Table 3.11. Sulfur limit of the reference fuel for testing procedures for Euro 2 and Euro 4 standards (ppm)

	Unleaded gasoline	Diesel
Euro 2	≤400	≤3000
Euro 4	≤10	≤10

Source: AQCC 2013

3.5. Policies and regulations focusing on the Fuel Consumption and Subsidies Reform Plan

Because of the lack of adequate and reliable data for decision-making about fuel consumption in the transportation sector, Iran's government deployed fuel smart cards. The plan was carried out in three stages. First, the government started to issue fuel smart cards for each vehicle (whether gasoline or diesel) to know the exact numbers of vehicles and their locations in the country. Secondly, decision makers analyzed the exact amount of fuel that each vehicle consumed on average during six months, and finally, they prepared a comprehensive database for management and decision-making processes relating to fuel consumption.[312]

As mentioned above, the government designed fuel smart cards both to control fuel consumption and to collect data for every kind of vehicle in Iran. In this system, all fuel nozzles in all gas

[312] Islamic Consultative Assembly Research Center, (October 2005), *Gozaresh-e Tojihi-ye Lozoom-e Elhagh-e Tarh-e Samandehi-ye Haml-o-Naghl va Masraf-e Benzin-e Keshvar be Barname-ye Chaharom-e Tose-eh*, Tehran. Retrieved March 5, 2014 from: http://rc.majlis.ir/fa/report/show/731137

stations in Iran were equipped with card-readers connecting to a central control system. One specific and individual card assigned to each vehicle is necessary for taking fuel from each gas station all over the country.

In the next phase, the government launched a rationing plan for fuel consumption. Passenger cars could consume 60 liters of unleaded gasoline monthly at 0.11 USD in a first quota, but they had to pay 0.43 USD for the second quota (up to 500 liters monthly) as of 26 June 2007. There are no more quotas for over 500 liters consumption per month. Drivers can save from the first quota for the next month, but saving the second quota is impossible. Table 3.12 presents unleaded gasoline prices in Iran before and after the fuel-rationing plan, and a comparison with the prices of selected countries.

Table 3.12. Gasoline prices in Iran and selected countries (USD/lit)

	2002	**2003**	**2004**	**2005**	**2006**		**2007**	**2008**	**2009**	**2010**	**2011**
Iran	0.06	0.08	0.09	0.09	0.09	1st	0.11	0.10	0.10	0.10	0.36
						2nd	0.43	0.42	0.40	0.39	0.64
US	0.36	0.47	0.50	0.60	0.74		0.74	0.86	0.62	0.73	0.96
Germany	0.97	1.21	1.38	1.50	1.59		1.82	2.05	1.80	1.88	2.24
Turkey	-	-	-	1.96	1.94		2.60	1.73	2.44	2.54	2.60
Saudi Arabia	0.24	0.24	0.24	0.24	0.24		0.16	0.14	0.14	0.14	0.14

Source: IFCO 2013

Fuel consumption behavior after the rationing plan

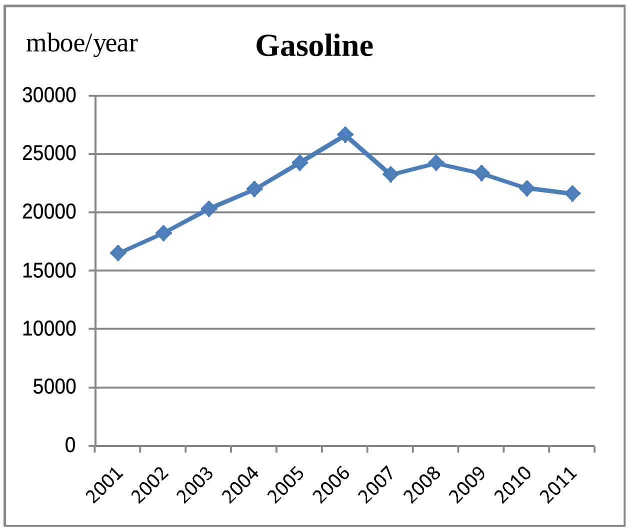
Fuel consumption in Iran's transportation sector grew until 2006, when it hit 26.7 billion liters for gasoline and 16.6 billion liters for diesel. Iran's Ministry of Energy reported 61.4 and 19.2% growth for gasoline and diesel respectively in the period 2001 to 2007.[313]

After the rationing of fuels in June 2007, gasoline consumption fell sharply. The former Deputy of Remark 13 reported a 21% decrease in gasoline consumption during the 60 days after the

[313] Iranian fuel conservation company (IFCO) (2013), *Transportation Energy Data Book 2011*, Tehran, Iran

launch of the Plan (from 22 June to 22 August) in comparison with the same period in 2006 (near 16 million liters totally).[314]

Despite the growing size of the passenger car fleet, gasoline consumption fell from 146.8 MBOE[315] in 2006 to 119.6 MBOE in 2011 because of the subsidies reform plan. However, diesel consumption continued to increase during the whole period, from 13.9 MBOE in 2001 to 18.8 MBOE in 2011 (7.1% annual average growth) (Figure3.8).[316] Petroleum products consumption of light-duty vehicles continued to decrease after the Plan. This trend was not followed by heavy-duty vehicles. The Plan has not affected the transportation demand of commercial vehicles in the country.



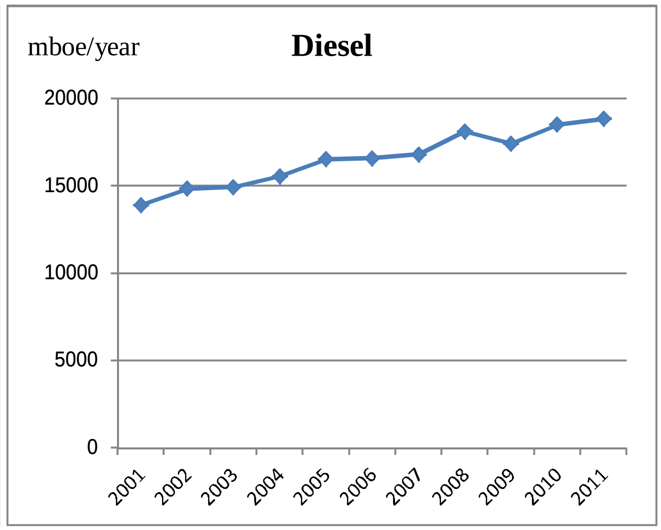


Figure 3.8. Gasoline (left) and diesel (right) consumption in Iran's road fleet (2001 - 2011) (mboe/year)

Source: Transportation Energy Data Book 2011, 2013

Subsidies in Iran's transportation sector

38% of total subsidies for energy consumption in 2006 belonged to the transportation sector. However, this decreased to 23% in 2011 (nearly -40%).[317] Gasoline and diesel have taken the most share of subsidies in the transportation sector. The total amount of the subsidies for the

[314] Islamic Consultative Assembly Research Center, (9 September 2007), *The Survey of Traffic and Optimization of Oil Consumption*, Report No. 8554, Tehran.
[315] Million Barrel of Oil Equivalent.
[316] Iranian Fuel Conservation Company (IFCO), (2013), Transportation Energy Data book 2011, Tehran, Iran.
[317] IFCO, (2013), op. cit., p.265.

sector increased by over 39% from 2006 to 2011. During this period, subsidies decreased 10% for gasoline, but increased 81% for diesel fuel (Figure 3.9).

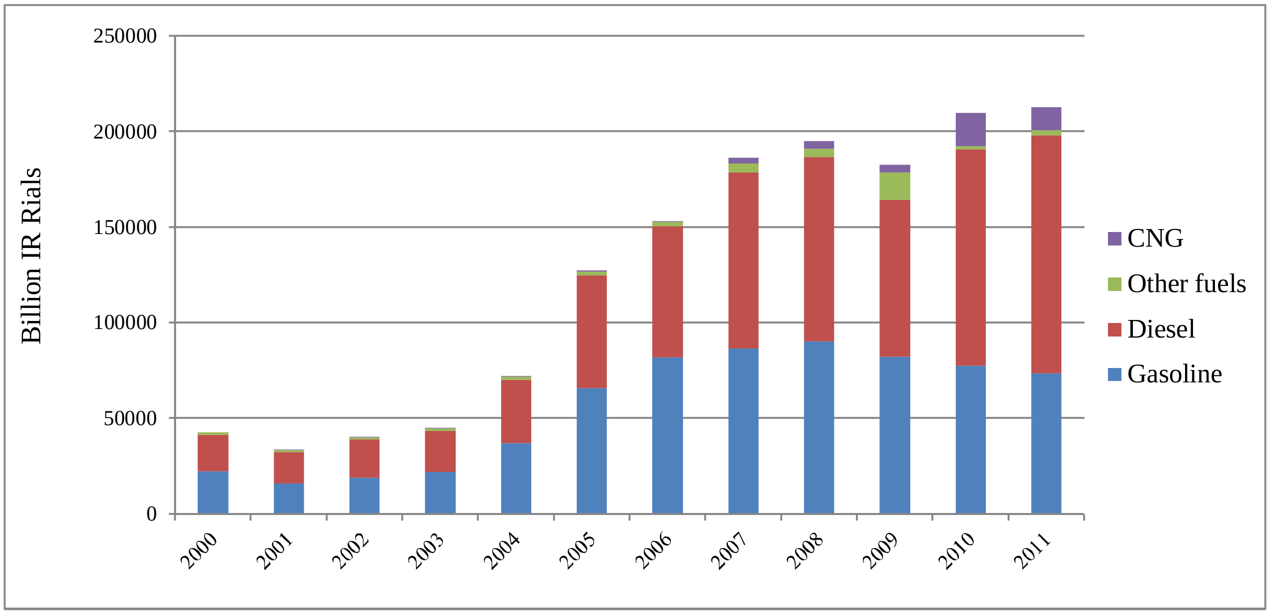


Figure 3.9. Subsidies for the transportation sector in Iran (2006 – 2011)

Source: IFCO 2013

According to 'The Targeted Subsidies Reform Act' ratified by the Iran's parliament in March 2010, energy prices should gradually increase over a five-year period (2010-2015). It is expected that the retail prices of gasoline, diesel, fuel oil, kerosene and LPG should grow to no less than 90% of Persian Gulf free on board (FOB) prices.

The Iranian government initiated the subsidies reform plan with strong political support. They organized a comprehensive strategy with an extensive public relation campaign to familiarize people. The media informed people and helped the state to control negative impacts of the plan on low-income level households and to educate the nation about the expected benefits. The banking system was upgraded to accomplish nationwide cash transfers for direct payments. For deploying the plan, planners considered the lowest energy consumption period of the year, with the fewest holidays, and least travelling and air conditioning demand – after the harvest season.[318]

The subsidies reform plan in Iran has been influenced by the unique economic circumstances of the country. The foreign exchange market was faced with instability after the imposition of sanctions in January 2012. The value of the US dollar against the Iranian Rial increased 150% and the official exchange rate of IRR, 12,260, was hovering at around IRR 26,000 after a short time. Hassanzadeh concluded that the subsidies reform plan in Iran was hit by large-scale international sanctions.[319]

3.6. Policies and regulations focusing on CNG

Natural gas as an alternative fuel

Natural gas has been used as an alternative fuel since the 1920s. During the oil crises of 1974 and 1979, western countries mostly tended to use natural gas vehicles (NGV) because of the severe restrictions of conventional gasoline and diesel fuels. By mass-supplying liquid fuels, use of NGVs has gradually decreased in developed countries. For countries with appropriate access to natural gas or special priorities for controlling air pollution, the number of CNG vehicles has increased during the last decade. A car with CNG-fueled equipment emits CO_2 over 15% less than the same car when switched to gasoline.[320]

CNG is an appropriate fuel in comparison with gasoline from technical point of view. Owing to the British Standard EN 15403:2008, the octane number of CNG as the vehicle's fuel is 115 to 135.[321] This is above the conventional super-gasoline octane number (i.e. 95).

Many developing countries have introduced natural gas as a strategic and long-term fuel for transportation. In the World Energy Council annual summit held in Tokyo in 1995, natural gas was supported as a reliable alternative fuel. The International Association for Natural Gas

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[318] Dominique Guillane, Ronak Zytek, Mohammad Reza Farzin, (2011), *Iran-The chronicles of the subsidy reform*, International Monetary Fund

[319] Elham Hassanzadeh, (October 2012), *Recent Developments in Iran's Energy Subsidy Reforms*, Global Subsidies Initiatives, International Institute for Sustainable Development, Canada, p.8

[320] *'Iran Khodro Nasl-e Tazeh Motor-e Payeh Gaz-sooz Misazad,'* Fararu News, Retrieved February 18, 2014 from: http://fararu.com/fa/news/57521/%5C%5Cwww.itcala.com

[321] IFCO, (2013), op. cit.,

Vehicles (IANGV) estimated over 22.4 million registered NGVs in 2014. According to IANGV, Iran ranked as having the largest natural gas vehicle fleet in the world in 2014 (Table 3.13).[322]

Table 3.13. The first five NGV fleet countries in the world in 2014

Rank	Country	Natural Gas Vehicle Numbers (million)	Refueling Stations
1	Iran	4.0	2,268
2	China	4.0	6,502
3	Pakistan	3.7	2,997
4	Argentina	2.5	1,939
5	India	1.8	936
6	Brazil	1.8	1,805
7	Italy	0.9	1,060
	Total World	**22.4**	**26,677**

Source: The International Association for Natural Gas Vehicles

CNG in Iran's transportation sector

The Tehran Municipality first got permission for developing dual-fueled LPG vehicles in Iran during the First FYDP (1989-1993).[323] By changing the government's objectives, the vehicle industry switched to CNG as an alternative fuel.

Owing to legislative restrictions, all the passenger vehicles in Iran are gasoline fueled. This mono-source issue limits fuel-supply for the vehicles and threatens the energy security of the transportation sector. Diversifying the fuel basket has been one of the priorities for the government for the following reasons:

- Limited capacity of local refineries for increasing gasoline production
- Increasing motorization rate
- Increasing rate of fuel consumption in passenger cars because of low efficiency
- Fuel smuggling to neighbor countries
- Air pollution enhancement, especially in big cities

[322] The International Association for Natural Gas Vehicles, (2014), *Worldwide NGV statistics*, Retrieved April 9, 2015 from: www.ngvjournal.com/worldwide-ngv-statistics/

[323] Islamic Consultative Assembly Research Center, (12 February 2007), *Operation Appraisal in Connected with Administration of Bi-Fuel Vehicles: Policy in Iran and the World*,' Report No. 8229, Tehran, p.20.

To cope with this issue, CNG has being highlighted as an alternative fuel because:

- Iran is among the three countries with proven natural gas reservoirs in the world
- The final price of CNG is much lower than gasoline in Iran
- The environmental impacts of CNG are lower than gasoline
- CNG-fueled vehicles production technology is available in Iran

Iran's national rules for CNG development

Reducing both energy intensity and environmental pollution are two subtitles of the Comprehensive Policies of the I.R. of Iran in the transportation sector.[324] The Iranian government has addressed developing CNG vehicles for both national energy security and controlling air pollution, especially in big cities. This issue was noted in the national development plans as well. For example, the government defined specific targets for developing dual-fuel vehicles in Article 22 of the Fourth Five-Year Development Plan (2005-2009):

- The government is required to develop mechanisms to reach at least 30% of total registered (produced or imported) vehicles as bi-fuel.[325] To reach this target, appropriate pricing mechanisms for CNG and encouraging policies for local automakers should be deployed.
- The ministry of oil should support the private and cooperative sectors to expand and construct CNG stations across the whole country, especially in big cities.
- The price of CNG should not exceed 40% that of gasoline (in equivalent thermal value).

The government supported CNG vehicles development in the Fifth FYDP (2011-2015). Article 26 emphasized a public transportation approach:

- The Ministry of the Interior is required to prepare appropriate financial facilities for dual-fuel passenger vehicles (CNG and gasoline) for public transportation.

[324] Iran Parliament, '*Siasatha-ye Kolli-ye Nezam-e Jomhoori-ye Eslami-ye Iran.*' Retrieved February 17, 2014 from: www.parliran.ir/index.aspx?siteid=1&pageid=3367

[325] CNG with gasoline or diesel.

CNG fleet in Iran

In 2004, just 1.8% of all vehicles in Iran were alternative fuel vehicles (AFV) (1.3% LPG and 0.5% CNG). Owing to incentivizing policies and mass-producing CNG dual-fuel vehicles, the share of this type of AFV in the transportation fleet increased to over 17% in 2011 (Table 3.14).[326]

Table 3.14. Estimate of Iran's total number of vehicles by fuel types (2004 – 2011)

year	Fuel type			
	LPG	CNG (dual)	Gasoline	Diesel
2004	83,120	30,791	5,817,208	419,760
2005	81,157	100,681	6,662,717	458,217
2006	80,483	318,302	7,368,754	497,591
2007	49,001	766,851	7,808,678	552,821
2008	36,031	1,187,463	8,404,746	604,919
2009	28,758	1,603,838	9,199,549	654,289
2010	22,753	2,028,319	9,831,337	690,788
2011	13,405	2,431,061	10,785,220	745,746

Source: Transportation Energy Data Book 2011, 2013

According to IFCO's statistics, producing dual fuel (CNG and gasoline or CNG and diesel) vehicles in Iran's automotive industry started in 2004. The total numbers of AFVs produced was just 66 in 2004 (0.008% of total). Owing to intensive investment, governmental incentives for fuel and the demand market, producing dual-fuel vehicles by local automakers increased sharply and hit over 314,000 in 2007 (one third of total local production). According to the IFCO, Iran's local automakers have produced nearly 1.5 million dual-fuel vehicles during seven years (from April 2004 to March 2011).[327] The IFCO reported that over two thirds of CNG vehicles are used for passenger transportation (Table 3.15).

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[326] IFCO, (2013), op. cit., p.150.
[327] IFCO, (2013), op. cit., p.93.

Table 3.15. Estimate of Iran's CNG vehicles by use (2011)		
	Number of vehicles	%
Total vehicles for passenger transportation (passenger vehicle, taxi, bus, minibus, etc.)	1,722,206	71
Total vehicles for freight transportation (van, minivan, truck, etc.)	688,080	28
Other vehicles (vehicles for governmental sector, free zones, etc.)	20,775	1

Source: Transportation Energy Data Book 2011, 2013

CNG consumption in Iran

The Iranian government has supported CNG for transportation as a national strategy. The government relies on the local automotive industry for developing CNG vehicles, especially for public transportation. The NIOPDC reported the CNG-consuming road fleet grew over ten times during the Fourth FYDP (from 0.8 million cubic meters in 2005 to 9.3 million cubic meters in 2009). This amounts to six million liters of gasoline that replaced by natural gas.[328] Owing to these supportive strategies, the level of CNG consumption in the transportation sector grew sharply in the last five years before 2011 (Figure 3.10).

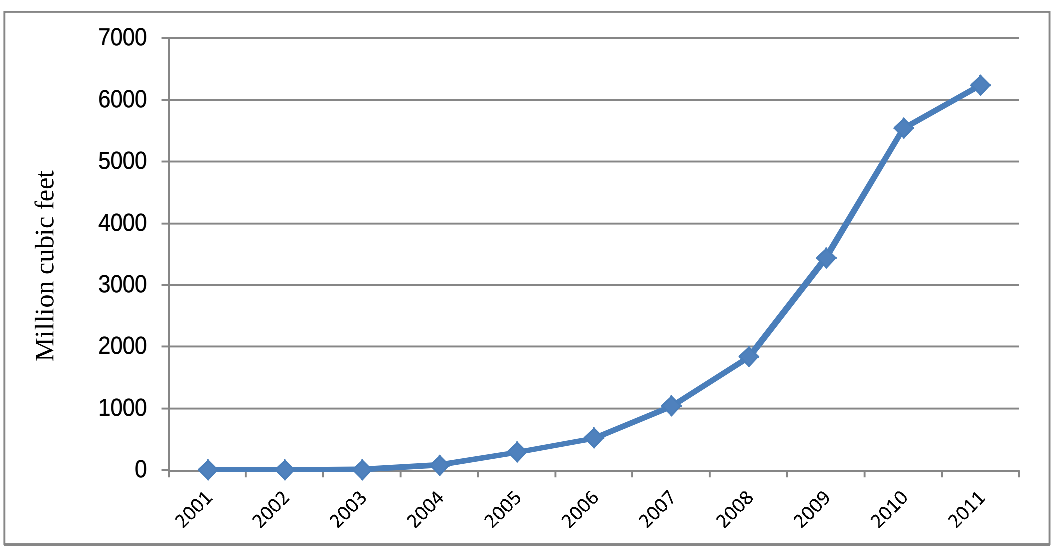

Figure 3.10. Natural gas consumption in Iran's transportation sector (million cubic feet)

Source: Transportation Energy Data Book 2011, 2013

[328] National Iranian Oil Products Distribution Company (NIOPDC), (2010), *NIOPDC Data Book 2009*, Tehran.

Environmental specifications of CNG

Natural gas contains methane (over 80%), ethane (around 12%) and some other hydrocarbons such as propane, butane, etc. Methane (CH_4) has a greenhouse gas effect around 24 times greater than CO_2. Any unburned methane emissions are usually included in natural gas vehicles' GHG calculations. The International Association for Natural Gas Vehicles reports that, through improving the efficiency of the natural gas internal combustion, this issue is progressively being minimized.

The Air Quality Control Company (AQCC) reports that the main pollutant source in Tehran and big cities is particulate matter (PM).[329] The emissions of PM from gasoline and diesel engines are much higher than for CNG engines. However, CNG engines produce more NO_x than gasoline and diesel engines. Iranian automakers have not prepared appropriate technology-based infrastructure to control emissions from CNG combustion. Using natural gas for heavy vehicles, especially for public transportation, is a good option. PM emissions from these vehicles are significantly high when they consume diesel. Using natural gas in the transportation sector could eliminate air pollution concerns in big cities.

Fuel consumption of CNG-fueled vehicles

Conventional gasoline and diesel engines can use natural gas after some modifications. The modifications for diesel engines (especially heavy vehicles) are more complicated than passenger gasoline engines. According to these changes, the price of diesel dual-fuel (diesel and natural gas) vehicles may rise by 20 to 30%.[330] Using CNG for the transportation sector could be cost effective if preparing fuel is economic for the demand side.

There are two types of natural gas passenger vehicles (NGV) in Iran. Dual-fuel or bi-fuel vehicles are traditionally designed for gasoline and can use CNG as an alternative fuel after a number of modifications to the engine system. We can name this type 'dual-fueled gasoline and CNG vehicles.'

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[329] Air Quality Control Company (AQCC), (2012), *Tehran Air Quality Annual Report in 1390*, Tehran. Retrieved February 15, 2014 from: http://air.tehran.ir/Portals/0/Users/002/02/2/Air%20Quality%2090%20Final.pdf

[330] Seyed Mehdi Mirfattah,and Alireza Saleh, (2007), *Contrastive Analysis of Alternative Fuels in Transportation Sector*, Energy Economics Surveys, Vol. 3, No. 10, Autumn 2007, p.6.

The second type is CNG-based engine vehicles that are designed for using natural gas and can be switched to gasoline if necessary. The fuel efficiency of these vehicles is more than the others, owing to sound modifications and the original equipment manufacturer (OEM) CNG fuel engine.

According to Kohkilouie et al., fuel consumption of dual-fuel (gasoline and CNG) vehicles is significantly more than gasoline vehicles while using gasoline as fuel. Their findings were based on a series of standard tests that were conducted on ten different vehicles having two types of engine, gasoline and dual (gasoline and CNG)-equipped. The tests were carried out in the ISQI. They found an average of over 10% fuel efficiency across the two groups (Table 3.16).[331]

Table 3.16. Results of the gasoline consumption test for ten selected vehicles in both gasoline and dual fuel types

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6	Vehicle 7	Vehicle 8	Vehicle 9	Vehicle 10
Gasoline	7.2	8.92	8.67	8.43	6.9	8.59	9.85	13.47	10.5	9.5
Dual (gasoline & CNG)	8.01	9.19	9.95	9.47	8.08	9.3	10.3	15.24	11.7	10.76
Change (%)	11.25	3.03	14.76	12.34	17.10	8.27	4.57	13.14	11.43	13.26

The Iran Standard and Quality Inspection Company (ISQI) claimed that dual-CNG vehicles usually consume more fuel because of higher weight (from the CNG tank) and other technological issues. The ISQI argued for different fuel-calculation criteria following vehicle types and classes.[332]

Limitations of CNG development in Iran

Despite legal support and financial mechanisms, some limiting factors have restricted developing CNG in the country's transportation sector:

- Limited driving distance after fueling (CNG is up to one third that of gasoline and diesel)

  The maximum volume content of a CNG fuel tank is nearly 80 liters. The vehicle can be driven around 200 km with a full tank.

- Insufficient CNG station numbers

[331] Tahmasb Kohkilouie, Entezarimoghaddam, Azadeh, Pashmchi, Farid, (2009), *New Approaches for Gasoline Consumption Reduction in Iran*, 6th International Conference on Internal Combustion Engines, 17-20 November 2009, Tehran, Iran. Retrieved 23 February 2014 from: http://www.civilica.com/Paper-ICICE06-ICICE06_120.html
[332] Iran Standard and Quality Inspection Co (ISQI), (2010), *Gozaresh-e Haml-o-Naghl va Khadamat 1389*, p.38. Retrieved 22 February 2014 from: http://www.isqi.co.ir/

According to statistics from the National Iranian Oil Refining and Distributing Company (NIORDC), there were 2075 active CNG stations in Iran in October 2013. Nevertheless, the government should support developing new stations to meet the requirement of at least 2550 gas stations. Mohammad Hassan Ansari, a member of the Energy Commission of the Iran Parliament, criticized the lack of a national plan for producing dual-fuel vehicles and developing CNG stations.[333]

- Limited trunk space from placing the CNG tank

  The CNG tank should be placed normally in the trunk of a passenger car. In this case, the trunk space would be very limited for ordinary usages.

- Increased vehicle weight from CNG equipment
- Decreasing engine power (about 10%)
- Increasing maintenance costs of the vehicles

However, many people tend to purchase CNG-fueled vehicles for the lower price of CNG in comparison with other conventional fuels. Local market customers are mostly lower income-level people or taxi drivers who are sensitive to fuel prices.

High fuel prices can affect the local market directly. Every change in the price of CNG may affect its demand significantly. Mr. Yousef Rashidi, the former Managing Director of the Air Quality Control Company, argued that people's tendency to use CNG vehicles has dropped sharply after increasing CNG prices following the Subsidy Reform Plan.[334]

CNG needs more complicated refueling stations as well, mainly because the station needs special equipment to compress and inject natural gas to the fuel tank safely. The Iranian Fuel Conservation Company estimates that constructing a CNG refueling station is 10 times more expensive than a gasoline/diesel station. [335]

Most locally manufactured vehicles were designed for gasoline or diesel. The vehicle's pollution control system parts, e.g. its catalytic converter, do not function efficiently when the driver

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[333] '*Ta Konoon Barname-ye Jeddi Baraye Afzayesh-e Khodroha-ye Gaz-sooz Tadvin Nashodeh Ast,'* Khabar Khodro, (25 September 2013). Retrieved February 17, 2014, from: www.khabarkhodro.com/detail.asp?id=230298

[334] '*Moshkel-e Asli-ye Hava-ye Tehran, Zarrat-e Moallagh Ast,'* Tabnak News, 4 November 2011, No. 201851, Retrieved February 15, 2014, from: www.tabnak.ir/fa/news/201851

[335] Seyed Mehdi Mirfattah,and Alireza Saleh, op. cit., p.6.

switches to natural gas. Iranian automakers should develop technologies to control the emissions of CNG engines. However, significantly less hazardous gas is emitted from natural gas than from conventional diesel and gasoline-fueled vehicles.

Mr. Mohammad Saeed Ansari, Member of the Energy Commission of Iran's Parliament, argued that Iran has not yet implemented a serious national plan both to produce CNG dual-fuel vehicles and to increase the number of equipped refueling stations.[336]

3.7. Policies and regulations focusing on dismantling old vehicles in Iran

Energy intensity in the transportation sector is too high because of low prices and the low energy efficiency of engine technology. The increasing the capacity of local automakers' factories, improving vehicles standards and an increasing motorization rate encourage the government to support dismantling old cars.

Iran's government suggested the first Bylaw for Dismantling Old Cars in July 8, 2002. The regulation was never deployed successfully, however, because of a lack of finance and a weak allocation of responsibilities.

Article 62 of the Fourth FYDP required the government to set policies and plans to phase out all old vehicles and motorbikes. This article determined the number of old cars that should be dismantled annually.[337] However, financial and executive limitations prevented the regulation from coming into effect.

A Bylaw, ratified on 8 July, 2006, defined an old car as:

1. Not meeting the technical specifications
2. Passenger cars with four cylinders and over 30 years old, or passenger cars with more than four cylinders and over 25 years old
3. Public cars over 15 years old
4. Pickups over 20 years old

[336] '*Ta Konoon Barname-ye Jeddi Baraye Afzayesh-e Khodroha-ye Gaz-sooz Tadvin Nashodeh Ast,*' Khabar Khodro, (25 September 2013), Retrieved February 17, 2014, from: www.khabarkhodro.com/detail.asp?id=230298

[337] According to the regulation, 200, 300, 400, 500 and 600 thousand vehicles should have been dismantled from 2005 to 2009.

The government set the age of an old car as 20 years until the end of Fifth Five-Year Development Plan on 6 October, 2013. The regulation also required dismantling 4 to 6 old cars for each imported passenger car with over 6 lit/100km fuel consumption.[338] This bylaw was developed to encourage importing companies to dismantle old cars.

Over 92% of the 1.88 million Iranian vehicles dismantled before 2011 were light-duty vehicles that all consumed gasoline. 185,778 of 234,504 vehicles dismantled in 2011 were passenger vehicles and over 99% of those were over 31 years old.[339] Table 3.17 shows estimates of the number of vehicles dismantled from 2005 to 2011.

Table 3.17. Estimate of the vehicles dismantled in Iran from 2005 to 2011

	Passenger car	Bus	Minibus	Pickup	Truck, Lorry, etc.	Total
2005	57,200	1,647	1,996	10,676	741	**72,260**
2006	126,596	1,307	2,631	5,694	409	**136,636**
2007	164,734	1,363	1,589	36,565	8,597	**212,848**
2008	145,934	1,450	1,880	30,476	8,680	**188,419**
2009	135,575	1,506	2,103	22,278	8,761	**170,223**
2010	209,484	1,477	2,046	46,776	8,353	**268,136**
2011	185,778	1,420	3,669	35,238	8,398	**234,504**

Source: IFCO 2011 and 2013

Most old cars owners are low-income level and the government has allocated some loans for dismantling their cars. However, allocating some financial incentives has not required all the owners to dismantle their own cars. The Headquarters of Transportation and Fuel Management invalidated the fuel card of all pickups and passenger vehicles over 25 and 30 years old respectively from April 2014. The Headquarters expected to override over 1.4 million fuel cards via this program.

Dismantling old cars affects fuel consumption directly and may decrease maintenance expenses in the long-term as well. This approach may bring auxiliary benefits, such as turnover in the vehicle industry, a decreasing accident rate and less air pollution. According to a survey, about

[338] '*Eslah-e Joz-é 'Dal' Band-e 3 Tasvib-Nameh Shomareh 92308 Movarkhe 7 Shahrivar 1387,*' Rooznemeh Rasmi, (October 10, 2013) Retrieved February 17, 2014, from www.rooznamehrasmi.ir/Files/Laws/%D8%A7%D8%B5%D9%84%D8%A7%D8%AD%20%D8%AA%D8%B5%D9%88%D9%8A%D8%A8%20%D9%86%D8%A7%D9%85%D9%87.pdf
[339] IFCO, (2013), op. cit., p.74.

20% of fatal accidents in Hamedan (the capital city of the Hamedan province) were due to old cars in 2011.[340] In April 9, 2014, the Governor of Tehran declared over 30,000 taxis to be among the 100,000 old vehicles in Tehran. These vehicles have significant impact on the air pollution issue.

However, despite the focus of the government on dismantling passenger vehicles over 20 years old, there are many old cars, especially heavy-duty vehicles, still on the road (Table 3.18). The Deputy also developed the new plan for cancelling the fuel cards of old vehicles[341] after April 2014. Mr. Hosseyn Hashemi, the Vice President of Industry and Energy, predicts that implementing this plan will cancel over 1.4 million of fuel cards in the whole country.[342]

Table 3.18. Estimate of the age of the Iranian fleet (percent)

Age (year)	Passenger Car	Bus	Minibus	Pickup	Truck, Lorry, etc.
Below 10	82	63	27	81	37
10 – 20	12	30	23	19	12
21 – 30	5	6	27	0	19
Over 31	1	1	23	0	32
Total	100	100	100	100	100

Source: IFCO 2013

Dealing with fuel consumption and energy conservation in Iran’s transportation sector, the government has implemented two different regulations:

1. Laws relating to energy consumption (e.g. Article 121 of the Third FYDP)
2. Criteria and national standards relating to fuel consumption (e.g. Iranian National Standard No. 4241-2)

[340] ‘*Kahesh-e Amar-e Tasadofat beh Donbal-e Kahesh-e Taradod-e Khodroha-ye Farsoodeh,’* (April 7, 2014). Retrieved May 23, 2014, from: http://news.farsodeh

[341] Passenger cars over 30, pickups over 25 and motorbikes over 10 years old.

[342] *‘Ebtal-e Kart-e Soookht-r Khodroha-ye Farsoodeh,’* (21 Feb. 2014), Retrieved April 23, 2014 from: http://hamshahrionline.ir/details/250390

4. Analysis of fuel consumption and greenhouse gas emissions trends in Iran

4.1. Developing a 25-year scenario based on a continuing current situation

Without knowledge of trends from past to present, the future is uncertain. Gathering data and information, analyzing effective variables and finally predicting qualitative and quantitative changes in a phenomenon allows us to formulate a strategic plan.

Scenario planning is an effective method for mid-term and long-term planning in uncertain conditions. This approach helps policymakers to analyze the current trends of different variables to deal better with predictable situations. In fact, scenarios are not a mere planning tool. They are effective tools for learning as well. Policymakers can study causes, constant parameters, actors and key factors in their changing environment through the scenario planning process.

Scenario planning specialists mention two basic applications for scenarios:

- Scenarios as learning tools
- Scenarios as planning tools

From a policy formulation point of view, scenario setting prepares an appropriate mechanism for organization after problem detection and agenda setting. Through this approach, a policymaker can make more reliable decisions for the organization or the policy system in uncertain situations.

Scenarios study organizations' growth capacities (inter-organizational perspective) and improvement directions (intra-organizational perspective) in the future. It should be noted that scenarios do not include final organizational objectives. They explain the future potentials of current events.

For sound scenario setting, we need a base in historical data. Data-based scenarios describe the future via data analysis. Most econometrics models take a data-based approach. These models describe future events quantitatively. For example, an econometrics model can predict the inflation rate in future by calculating the liquidity and volume of money. In such a model, different economic conditions in the input will bring a different output and analyses for each condition. Scenario specialists analyze the outputs according to their knowledge and experience.

Some variables, such as a nation's population, are predictable more precisely in models and others, which are inherently relevant to uncertain factors, have a more qualitative nature and need more description.

There are various issues affecting energy policies in the world. However, scenario specialists focus on both energy security and climate change in setting energy systems scenarios.[343]

The economic sector in this study is light passenger transportation in Iran. I study energy consumption within this sector and simulate energy consumption behavior through indicators such as energy intensity. I can hence develop a model of energy demand by defining relations between the main drivers and the consumption rate. The model can estimate energy demand via the basic assumptions of population growth and economic and technologic indicators for the future. Finally, by estimating different situations in the form of scenarios and through changing variables based on different policies, I investigate probable situations and analyze sound policies to find the most favorable situation. The model of energy consumption and carbon dioxide emissions in the Iran's transportation sector is developed for 25-year time period (2011 to 2036).

4.1.1. The Business As Usual (BAU) Scenario

According to the European Environment Agency, the baseline scenario or Business As Usual scenario deals with the situations by examining the consequences of continuing current trends in the economy, technology, population and human behavior.[344] In fact, the BAU scenario describes an approach to energy demand development with no significant change of consumption behavior. BAU assumes the economy and energy sectors continue the same trends of the past.

Two determinants of energy demand are *gross domestic product* and *population*. The Wuppertal Institute for Climate, Environment and Energy et al. predicted the energy demand of different

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[343] Abbas Maleki, (January 13, 2011), *Workshop on Future Study of Energy for Industry and Technology: Assessing Scenarios of the Energy*, Research Institute of Science, Technology and Industry Policymaking, Sharif University of Technology, Tehran Retrieved November 5, 2014 from: http://ristip.sharif.ir/index.php/news/9-1389-11-16-08-21-41

[344] European Environment Agency (EEA), (2014), *Environmental Terminology and Discovery Service*, Copenhagen, Denmark. Retrieved November 5, 2014 fr
om: http://glossary.eea.europa.eu/terminology/concept_html?term=business-as-usual%20scenario

sectors of the Iranian economy, including transportation, through these factors, from 2005 to 2030 (Table 4.1).[345]

Table 4.1. GDP and Population Growth Assumptions in Iran in BAU Scenario

	2005 - 2010	**2011 - 2020**	**2021 - 2030**
GDP growth (percent)	5.5	3.4	3
Population growth (percent)	1.3	1.4	0.9

Source: Wuppertal et al, 2009

They reviewed the historic data on energy consumption, identified the major drivers of energy demand in the sector, and finally applied the BAU assumptions to predict future energy demands. Econometrics methods were applied for estimating the effects of the major factors.

For transportation, they compared BAU with the Efficiency Scenario. According to their BAU Scenario, fuel consumption in the transportation sector will grow from 218 MBOE in 2005 to 356 MBOE in 2030 (63%). Introducing cars with higher technology in energy consumption (more efficient engines, lighter weights, reduced friction and drag, etc.), may reduce the energy consumption of the sector (High Efficiency Scenario). Thus, the energy consumption of the sector could reach 232 MBOE in 2030 (just 6.4% growth from 2005). It is expected that more efficient cars could replace low-efficiency vehicles in the High Efficiency Scenario.

They concluded that continuous growth of domestic energy consumption owing to the BAU scenario will diminish the country's ability to export oil.

Vakili et al. developed scenarios for predicting energy consumption in Iran's transportation sector for 15 years from 2006. They used data based on a period of eight years for the parameters of *population, gross domestic product* and *income per capita*.[346] According to their BAU scenario, the energy consumption of the transportation sector will grow from 270 MBOE in the base year (2006) to 808 MBOE in 2031 (over three times). They predicted that gasoline consumption growth rate will be the highest (from 148 to 555 MBOE).

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[345] Wuppertal Institute for Climate, Environment and Energy, Iran Energy Association, Science Centre North Rhine-Westphalia, and Heinrich Büll Stiftung, (2009), *Energy Scenarios for Iran*, Iranian German Cooperation Project, Tehran and Berlin, March 2009, p.38.

[346] Vakili, A., Hoorojafari, H., Fathi, A.R., (2013), *The Comprehensive Iran Energy Plan: An Analysis of the Current and Favorable Condition of Energy Demand in Transportation Sector*, The International Institute of the Energy Studies (IIES), Tehran, Iran, p.210.

4.1.1.1. New scenario planning for the mid-term and long-term

After the end of the war with Iraq in 1988, rapid economic growth in Iran led to an increasing demand for energy, especially in the transportation sector. Heavy energy subsidies for consumers increased energy demand dramatically and brought difficulties in developing energy efficiency policies. This trend led to serious challenges, with the implementation of the Subsidies Reform Plan being matched by attempts to attract foreign investment to boost oil and gas production.

I intend to analyze the different scenarios facing energy consumption over the next 25 years. To this end, the study provides a BAU scenario taking into account trends from the last 10 years, as well as future policies and developments in the transportation sector. In these scenarios, fuel consumption is considered as the function of four parameters: *population*, *gross domestic product*, *fuel price* and *energy efficiency* (in terms of grams of carbon dioxide emissions per kilometer of driving).

It should be mentioned that these models are for passenger carriages and goods carriages that consume gasoline or CNG. These vehicles are classified in Iran as M_1, M_2 and N_1.[347]

As mentioned above, owing to national regulations, there are not any diesel-fueled passenger vehicles in Iran yet. Developing diesel engine LDVs is an appropriate policy for reducing energy consumption and carbon dioxide emissions in the EU. The recent regulations in Iran support importing and producing LDVs equipped with diesel engines.

4.1.1.2. Macroeconomic Trends

a. Population

According to the latest statistical survey conducted by the Statistical Center of Iran, the population of the country was 75,149,664 in 2011. The population growth rate was 1.29 and 1.62

[347] Iranian automakers use European standards as well. The European Commission has classified vehicles as part of its emissions standards and other vehicle regulations. According to the regulations:
Category M_1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat.
Category M_2: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass not exceeding 5 tons.
Category N_1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tons.

during 2006-2011 and 1996-2006 respectively. The United Nations Population Division estimates that Iran's population will hit 94.746 million in 2036 (moderate growing rate) (Table 4.2).[348] We use this estimate in all of our scenarios.

Table 4.2. Estimate of Iran's population (million) following medium growing rate

1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2036
38.9	47.5	56.4	60.5	65.9	70.2	74.5	79.5	84.1	88.1	91.3	94.2	94.7

Source: UN 2012

b. Economic Growth

Iran's GDP growth has fluctuated since the Islamic Revolution in 1979. According to the World Bank, Iran's economy experienced a stagnation period after the revolution until the end of the war with Iraq in 1988 (average -2.3%) and a boom period after the war and before economic sanctions (average 4.9%). The World Bank calculates the average GDP growth of Iran to be equal to 2.7% from 1979 to 2013.[349]

In this way, I consider four rates for Iran's economic growth for the scenarios:

- high rate; 5%
- moderate rate; 3%
- low rate; 1%
- very low rate; -2.3%

For the BAU scenario, I use the average GDP growth after the revolution, 2.7%.

c. Fuel efficiency

Diesel vehicles' fuel efficiency

Despite a lower motorization rate than many developed countries', gasoline consumption in Iran is much higher. Ahead of factors such as the low efficiency of light passenger vehicles and a weak public transportation system, low diversification of the fuel basket for light duty vehicles (LDVs) is the most significant.

[348] United Nations, (2012), Department of Economic and Social Affairs, Population Division, Population Estimates and Projections Section Retrieved January 11, 2015 from: http://esa.un.org/unpd/wpp/unpp/p.2k0data.asp

[349] World Bank, (December 19, 2014), *World Development Indicators*, Retrieved January 13, 2015 from: http://databank.worldbank.org/data/views/reports/tableview.aspx?isshared=true

Diesel is a reliable fuel for LDVs. The share of diesel in the fuel basket of many economies is growing because of its favorable fuel efficiency and price. In most European countries, the ratio of gasoline to diesel consumption in the transportation sector is below one. This is because automakers focus more on diesel-fueled LDVs and more freight transportation is carried out via trucks and lorries. Financial policies encourage European customers to purchase diesel vehicles. New diesel LDVs consume less fuel and emit fewer pollutants.

The official US government source for fuel economy information reports that diesel engines are between 30 to 35% more powerful and fuel-efficient than similar-size gasoline engines.[350]

Improved fuel injection and electronic engine control technologies provide better performance in power, acceleration and fuel efficiency in new diesel cars. New diesel engines are quieter and smoother, and cold weather starting has been improved in these types of engines as well. Automakers have overcome the air pollution issue of diesel engines with light and ultra-light diesel fuels.

The National Road & Motorists Association conducted a study that concluded that driving diesel vehicles could reduce fuel consumption by up to 33% in comparison with the same-model vehicles running on petrol (33% on city road and 20% on highways leading to an overall 28% reduction in a combination driving cycle).[351]

In 2011 the Iranian fuel conservation company (IFCO) published a fuel consumption guide for Iranian users and introduced diesel for light passenger vehicles. The guide noted some technical comparisons between two types of vehicles, with similar power and engine sizes (Table 4.3).[352]

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[350] The Official U.S. Government Source for Fuel Economy Information, (2014), *Diesel Vehicles*, US Department of Energy, Retrieved 23 November 2014 from: http://www.fueleconomy.gov/feg/di_diesels.shtml

[351] The National Roads & Motorists' Association (NRMA), (2014), *Petrol vs Diesel*, Retrieved 23 November 2014 from: http://www.mynrma.com.au/motoring-services/motorserve/tips/petrol-diesel.htm

[352] Iranian fuel conservation company (IFCO), (2011), *Iran's Fuel Consumption Guide*, Tehran, Iran, p.39.

Table 4.3. Comparison of fuel consumption between similar vehicles using diesel and gasoline fuel

Name of the company and model	Technical specifications		Fuel type	Max engine power (hp)	Fuel consumption (lit/100km)			Difference (%)	Emission Standard
	Gearbox	Engine volume (cc)			City road	Highway	Combination cycle		
Engine Volume Range: 1.2 lit / Maximum Engine Power: 50 to 100 hp									
Volkswagen Polo	M-5	1199	Diesel	75	4.1	3	3.4	-67.6	Euro 5
SKODA New Roomster	M-5	1197	Gasolin	85	7.1	4.9	5.7		Euro 5
Engine Volume Range: 1.2 lit / Maximum Engine Power: 100 to 150 hp									
Peugeot 308	A-6	1560	Diesel	112	5.9	3.9	4.5	-28.8	Euro 5
Ford Fiesrta	M-5	1596	Gasolin	119	7.9	4.6	5.8		Euro 5
Engine Volume Range: 1.2 lit / Maximum Engine Power: 150 to 200 hp									
Audi A4 Saloon	M-5	1968	Diesel	170	6.2	4.4	5.1	-43.1	Euro 5
Volkswagen Passat CC	D-7	1984	Gasolin	160	9.8	5.8	7.3		Euro 5
Engine Volume Range: 1.2 lit / Maximum Engine Power: 200 to 250 hp									
Audi A5 Coupe	D-6	2967	Diesel	240	8.3	5.7	6.6	-39.4	Euro 5
Volkswagen Eos	D-6	3189	Gasolin	250	13.2	6.8	9.2		Euro 5
Engine Volume Range: 1.2 lit / Maximum Engine Power: 350 to 400 hp									
Audi A8	A-8	4134	Diesel	350	10.2	6.1	7.6	-25	Euro 5
Audi A8	A-8	4163	Gasolin	372	13.3	7.2	9.5		Euro 5

Source: IFCO 2014

Introducing diesel-fueled light vehicles into Iran's local market

According to the IFCO's study *Iran's fuel basket*, 24% of light duty vehicles in Iran should be equipped with diesel engines by 2025.[353] This target is impossible under current economic and technologic conditions, so I divided it to two steps; 12% by 2025 and 12% by 2036. Accordingly, I assume diesel passenger vehicles are 30% more fuel-efficient than similar gasoline LDVs.[354]

Iran's automotive industry is the second-largest industrial sector after oil and gas. Owing to investment in the industry, production started to grow at the beginning of the Third FYDP in 2000 and hit a maximum (over 1.6 million) in 2011. Most of the produced vehicles are destined

[353] Iranian Fuel Conservation Company (IFCO), (November 2008), *Fuel Basket Suggestions for Transportation Sector*, p.45.
[354] It should be noted that diesel cars emit less CO_2 than gasoline cars. This difference is estimated on average to be equal to 25%.

for the local market. The IFCO reports that the total number of registered passenger vehicles sharply increased from 3.1 million in 2001 to 11.1 million in 2011. The energy consumption of light-duty vehicles (M_1 and M_2) and pickups (N_1) grew from 90 MBOE in 2001 to 140 MBOE in 2011 as well.

The number of passenger vehicles per one thousand inhabitants (motorization rate) is a welfare index. This rate in Iran increased from 60 in 2001 to 171 in 2011 (+185%).[355] Meanwhile, the total number of LDVs grew from 3.9 million (89% of the total road fleet) in 2001 to 12.8 million (92% of total) in 2013. In other words, use of light-duty vehicles that consume gasoline and CNG (as the alternative fuel) grew 220% during this time.

Along with the growing energy demand of the LDVs, fuel efficiency of new local passenger vehicles improved from 8.835 lit/100km in 2003 to 7.96 lit/100km in 2013. This is equal to a reduction from 233.9 grCO_2/km to 186.6 grCO_2/km over this period of time.[356]

Mr. Nematzadeh, the Minister of Industry, Mining and Trade, claimed in the International Vehicle Industry Conference in Tehran in December 2014 that the average carbon dioxide emissions of the new Iranian passenger fleet should be reduced from 190 grCO_2/km in 2012 to 100 grCO_2/km in 2025.[357] It should be noted that the EU's targets for 2015 and 2020 are 130 grCO_2/km and 95 grCO_2/km respectively.

The European Commission of the European Parliament is setting a range of 68-78 grCO_2/km for cars sold after 2025.[358] This is the most stringently efficient target that can be assumed according to the available sources.

I use grams of carbon dioxide per kilometer of driving distance as the fuel efficiency index. For this parameter I assume three growth rates:

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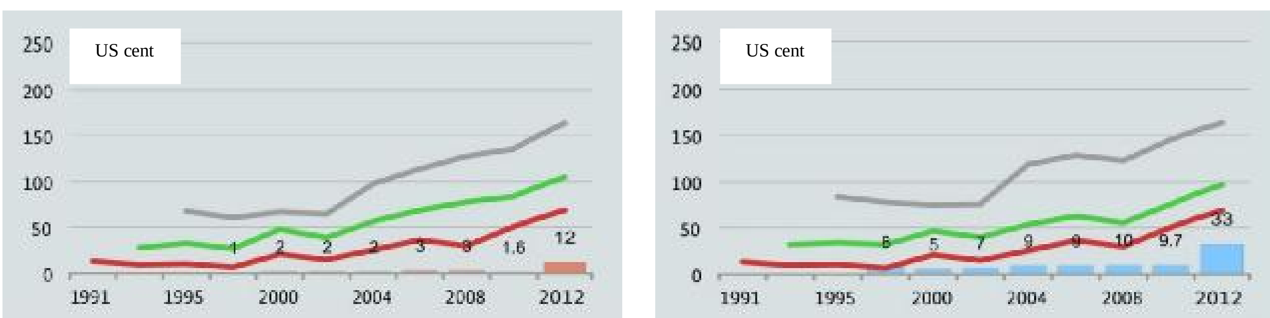
355 Iranian fuel conservation company (IFCO) (2013), *Transportation Energy Data Book 2013*, Tehran, Iran, p.223.
356 Iran Standard and Quality Inspection Co (ISQI), (2014), *Gozaresh-e Haml-o-Naghl va Khadamat 1392*, p.64. Retrieved 22 February 2014 from: http://www.isqi.co.ir/
357 '*Iran Noozdahomin Tolid-konandeh Khodro-ye Jahan Shod,*' Tabnak, (December 1, 2014). Retrieved from: www.tabnak.ir/fa/news/454172
358 European Federation for Transport and Environment AISBL, (2015), *Cars and CO_2*, Transport and Environment, Retrieved February 6, 2015, from: www.transportenvironment.org/what-we-do/cars-and-co2

- high rate, from 190 grCO_2/km in 2013 to 100 grCO_2/km in 2025 and 68 grCO_2/km in 2036 (25 years from 2011)
- moderate rate, from 190 grCO_2/km in 2013 to 100 grCO_2/km in 2025 and 95 grCO_2/km in 2036
- low rate, from 190 grCO_2/km in 2013 to 130 grCO_2/km in 2036

d. Fuel price growth

Fuel price plays an important role in fuel efficiency policymaking. EU member countries deploy this instrument to encourage both producers and consumers of transportation products to deal with more efficient vehicles. However, there is a different story for more subsidized countries.

Iran's fuel prices are highly subsidized in comparison with the EU and most of the neighboring countries. After deploying the Subsidies Reform Plan (SRP), fuel prices started to grow, but rising exchange rates have prevented the expected price modifications (Figure 4.1).[359]



Grey Benchmark Line: Retail price of gasoline and diesel in Luxembourg. In November 2012, gasoline and diesel prices in Luxembourg were the lowest in Europe. Prices in the EU countries are subject to VAT, specific fuel taxes as well as other country-specific duties and taxes.

Green Benchmark Line: Retail price of gasoline and diesel in the US. Cost-covering retail prices including industry margin, VAT/sales tax and approximately US 10 cents for two road funds (federal and state). This fuel price is without other specific fuel taxes and may be considered as the international minimum benchmark for a non-subsidized road transport policy.

Red Benchmark Line: Price of crude oil on the world market.

Figure 4.1. Detailed time series of gasoline (right) and diesel (left) prices in Iran (US cent) (1991-2012)

Source: GIZ 2014

However, in accordance with the Fifth FYDP, Iran's fuel prices (including gasoline and diesel) should be modified to not less than 90% of the Persian Gulf market (F.O.B) by the end of the

[359] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, (2014), *International Fuel Prices 2012/2013*, 8th Edition, Germany, p.36.

Fifth FYDP (2015). It should be added that gasoline prices in the market were 0.88-0.91 USD/lit at the first half of 2014.

F.O.B. prices have decreased owing to decreasing global oil prices since the end of 2014. Thus, the new gasoline price in Iran is very close to the SRP-defined target (Table 4.4).[360] Tabnak reports that Iranian neighbor countries, such as Turkey and Azerbaijan, and also EU member countries, have decreased the final retail prices of gasoline and diesel. These new prices are not reliable, especially for highly subsidized countries. Despite new prices, EU automakers continue their efforts to meet fuel efficiency regulations.

Table 4.4. Gasoline price in Iran and Persian Gulf F.O.B. after the drop of oil prices in January 2015 (IR.R/liter)[361]

	Octane number # 87	Octane number # 90-92
Persian Gulf F.O.B.	10,000-10,500	12,000-14,000
Iran local market	10,000	11,000

Source: Tabnak

The Iranian government has paid huge subsidies to energy in the country. According to the Subsidies Reform Plan Law, the Persian Gulf F.O.B. is the base for fuel retail pricing in Iran. Defining fuel price depends on the inflation rate and exchange rate. Thus, fuel price seems a policy-oriented variable rather an economic variable.

Estimating 15% for Iran and 3% for world inflation rates gives a 12% growth for the exchange rate. With this rate, and calculating 90% of the F.O.B as the constant parameter, gasoline prices will reach over 210,000 IR.R in 2036 (15% annual growth from 2014).

If the Iran’s inflation rate falls to 9%, we expect 6% growth for the exchange rate. In this condition, gasoline prices will reach over 60,000 IR.R in 2036 (8% annual growth from 2014).

Thus, we can use two different rates for fuel price growth in our scenarios:

- high rate: 15% annually
- moderate rate: 8% annually

[360] *‘Jadval-e Gheymat-e Benzin dar Iran va Khalij-e Fars pas-az Soghot-e Gheymat-e Naft,’* Tabnak, (January 12, 2015). Retrieved January 19, 2015 from: http://www.tabnak.ir/fa/466082
[361] Exchange rate of 265,000 IR.R. for one USD.

We assume that Iran's government will implement one of the rates for bringing gasoline prices into accordance with the Subsidies Reform Plan. However, the latter growth rate is negligible and will not affect gasoline demand significantly.

4.1.1.3. Scenario development

In this part of the study, I develop 24 specific scenarios for the energy demand of the light-duty vehicles segment (M_1, M_2 and N_1) according to the probable rates for the four variables of population, economic growth, fuel efficiency and fuel price defined above.

Each scenario estimates the fuel demand function using the time series data of 1999 to 2013. These scenarios evaluate the effects of population, economic growth, fuel efficiency and fuel price on energy consumption. For achieving more sound results, we use *HIS EViews* software. This is a well-known computing tool for econometric analysis, forecasting and simulation.

Two profiles are highlighted in our scenarios: 2025 and 2036. The former is the end of Iran's 20-Year Vision Plan from 2005 and the latter is the end of the 25-year period from 2011 (Table 4.5).[362]

[362] The Expediency Discernment Council (Persian pronunciation: Majmaé-e Tash'khees-e Maslahat) prepared the 20-Year Perspective Document (Persian pronunciation: Sanad-e Cheshmandaz-e Bist-Saleh) for Iran during the 5 years before 2003. The document defines the country's development perspectives over a 20-year time-span. The Supreme Leader communicated the document to the Legislature, Executive and Judicial systems on November 14, 2003. The document was intended to guide the four Five-Year Development Plans as of 2005.

Table 4.5. Scenarios results of fuel consumption in Iran's light-duty vehicle fleet					
	Economic growth rate	Fuel efficiency growth rate	Fuel price growth rate	Fuel consumption estimate (MBOE)	
				2025	2036
Scenario 1	Moderate	Low	Moderate	242	382
Scenario 2	Moderate	Moderate	Moderate	237	370
Scenario 3	Moderate	High	Moderate	237	337
Scenario 4 (BAU)	Moderate	Low	High	229	345
Scenario 5	Moderate	Moderate	High	210	313
Scenario 6	Moderate	High	High	210	285
Scenario 7	High	Low	Moderate	257	431
Scenario 8	High	Moderate	Moderate	252	418
Scenario 9	High	High	Moderate	252	381
Scenario 10	High	Low	High	224	391
Scenario 11	High	Moderate	High	240	379
Scenario 12	High	High	High	240	345
Scenario 13	Low	Low	Moderate	224	331
Scenario 14	Low	Moderate	Moderate	220	321
Scenario 15	Low	High	Moderate	220	292
Scenario 16	Low	Low	High	219	300
Scenario 17	Low	Moderate	High	209	290
Scenario 18	Low	High	High	209	264
Scenario 19	Very low	Low	Moderate	147	104
Scenario 20	Very low	Moderate	Moderate	146	102
Scenario 21	Very low	High	Moderate	146	93
Scenario 22	Very low	Low	High	138	91
Scenario 23	Very low	Moderate	High	136	89
Scenario 24	Very low	High	High	136	81

4.1.1.4. Scenario descriptions

Scenario 1: In this scenario, the economic growth rate is moderate (3% annually). Nevertheless, in addition to a low rate of fuel efficiency, fuel price grows moderately (non-price policy). Under these conditions, the model projects fuel consumption for 2025 and 2036 horizons as 242 (68% growth from 2013) and 382 (156% growth from 2013) million barrels of oil equivalent respectively. Accordingly, fuel consumption for this scenario is 4th rank among all scenarios in 2036.

Scenario 2: Economic growth is moderate here. Fuel efficiency follows policies defined by the Ministry of Industry, Mining and Trade (moderate rate) and fuel prices grow moderately as well. In these conditions and following the current situation, fuel consumption of light-duty vehicles reaches 237 (65% growth from 2013) and 370 (157% growth from 2013) in 2025 and 2036 respectively. Accordingly, fuel consumption in this scenario is 7th among all scenarios in 2036.

Scenario 3: In this scenario, both the economy and fuel prices grow moderately. However, fuel consumption standards lead automakers to produce more efficient vehicles (high fuel-efficiency rate). Therefore, the scenario projects fuel consumption in 2025 and 2036 as 237 (65% growth from 2013) and 337 (134% growth from 2013) million barrels of oil equivalent respectively. Accordingly, fuel consumption in this scenario is 10th among all scenarios in 2036.

Scenario 4: This scenario is the Business as Usual (BAU) scenario. It assumes that economic growth continues to grow at a moderate rate of 3%. Meanwhile, the vehicle industry cannot develop fuel-efficiency standards effectively (low fuel-efficiency rate). On the other hand, the government deploys fuel price policies (15% growth annually) to minimize or remove subsidies for energy and to control energy consumption in the segment. The scenario projects fuel consumption in 2025 and 2036 as 225 (60% growth from 2013) and 345 (140% growth from 2013) million barrels of oil equivalent respectively. According to this scenario, the government implements only the price policy. Accordingly, the fuel consumption of this scenario is 8th among all scenarios in 2036.

Scenario 5: Despite continuing moderate economic growth rate, the vehicle industry succeeds in developing moderate standards of fuel-efficiency. In addition, the government deploys stringent policies for fuel price (high growth rate). According to this scenario, fuel consumption of the segment in 2025 and 2036 210 (about 46% growth from 2013) and 313 (117% growth from 2013) million barrels of oil equivalent respectively. Accordingly, the fuel consumption of this scenario is 13th among all scenarios in 2036.

Scenario 6: Despite the moderate rate of economic growth (3% annually), both vehicle industries succeed in deploying stringent fuel-efficiency standards and the government follows price policy (15% growth annually). In the conditions of scenario 6, fuel consumption of the segment in 2025 and 2036 reaches 210 (about 46% growth from 2013) and 285 (98% growth from 2013) million barrels of oil equivalent respectively. Accordingly, the fuel consumption of scenario 6 is 17th among all scenarios in 2036.

Scenario 7: This scenario has the highest energy demand growth among all scenarios. Continuing high economic growth of 5%, new vehicles are not equipped with new fuel-efficient technologies and the government is not serious about implementing the Subsidies Remove Plan (i.e. non-fuel efficient and non-price policies). In such conditions, fuel consumption of light-duty vehicles in 2025 and 2036 reaches 257 (78% growth from 2013) and 431 (about 200% growth from 2013) million barrels of oil equivalent respectively. Accordingly, the fuel consumption of scenario 7 hits is highest among all scenarios in 2036. Comparing to scenario one, this scenario shows the strong effect of economic growth on the segment’s fuel demand in long-term.

Scenario 8: Economic growth rate is 5% in this scenario as well. Here, automakers follow national policies on fuel-efficiency standards (moderate rate). Meanwhile, the government does not implement stringent price policies (non-price policy). In these conditions, fuel consumption of the light-duty vehicles in 2025 and 2036 reaches 252 (75% growth from 2013) and 418 (190% growth from 2013) million barrels of oil equivalent respectively. Accordingly, the fuel consumption of scenario is second among all scenarios in 2036.

Scenario 9: Economic growth is high in this scenario. Despite non-price governmental policy, automakers produce highly energy-efficient light-duty vehicles. This scenario projects that fuel consumption of light-duty vehicles in 2025 and 2036 will reach 252 (75% growth from 2013) and 381 (165% growth from 2013) million barrels of oil equivalent respectively. In spite of governmental policies for controlling energy prices, keeping a steady fuel price under high economic growth is unlikely. Nonetheless, fuel consumption of scenario 9 is 5th among all scenarios in 2036.

Scenario 10: The scenario assumes high economic growth and that the vehicle industry is not strong enough to improve the energy efficiency of new vehicles (low rate). The government emphasizes price polices to control fuel consumption growth. As a result, fuel consumption of light-duty vehicles in 2025 and 2036 reaches 224 (56% growth from 2013) and 391 (172%

growth from 2013) million barrels of oil equivalent respectively. The fuel consumption of scenario 10 is third among all scenarios in 2036.

Scenario 11: Economic growth is high in this scenario and the government continues fuel price policy. Moreover, automakers deploy moderate policies of energy efficiency. These conditions also show the effective role of economic growth in increasing fuel consumption. Consequently, fuel consumption of the light-duty vehicles in 2025 and 2036 reaches 240 (67% growth from 2013) and 379 (163% growth from 2013) million barrels of oil equivalent respectively. In this scenario, fuel consumption of the segment is 6th in 2036.

Scenario 12: This is the ideal scenario. Economic growth is high (5%) and automakers develop more stringent standards on fuel efficiency (high efficiency policy). Under these conditions, it is expected that the fuel consumption of light-duty vehicles in 2025 and 2036 reaches 240 (67% growth from 2013) and 345 (140% growth from 2013) million barrels of oil equivalent respectively. Fuel consumption under scenario 12 is ranked 9th in 2036.

Scenario 13: The low economic growth of this scenario (1%) implies economic recession. In additions, vehicle industries are not able to implement energy-efficient technologies (low efficiency), and the government does not follow fuel price policy (moderate rate of price growth) either. Thus, the scenario expects fuel consumption of light-duty vehicles in 2025 and 2036 to reach 224 (56% growth from 2013) and 331 (130% growth from 2013) million barrels of oil equivalent respectively. Accordingly, the fuel consumption of scenario 13 hits is 11th among all scenarios in 2036.

Scenario 14: In this scenario, we have economic recession and, despite non-price policy from the government side, automakers succeed in developing national standards (moderate efficiency). In these conditions, it is expected that fuel consumption of the segment in 2025 and 2036 will reach 220 (53% growth from 2013) and 321 (123% growth from 2013) million barrels of oil equivalent respectively. This scenario is 12th for fuel consumption among all the others in 2036.

Scenario 15: economic growth is low in this scenario and the government (same as scenario 14) does not follow price policy. However, the vehicle industries develop highly energy-efficient technologies for new vehicles (high efficiency). Owing to these conditions, fuel consumption of the segment in 2025 and 2036 reaches 220 (53% growth from 2013) and 292 (103% growth from

2013) million barrels of oil equivalent respectively. It should be noted that developing expensive technologies for high fuel-efficiency is unlikely during economic recession and without supporting price policy. In these economic conditions, the government cannot continue paying huge subsidies for energy and increases fuel prices significantly. Nonetheless, fuel consumption in this scenario is ranked 15th among all scenarios in 2036.

Scenario 16: Continuing economic recession (1% growth), vehicle industries are not able to deploy fuel efficiency policies (low efficiency) in this scenario. Nevertheless, the government uses price-policy instruments to control fuel consumption. Thus, it is expected that the fuel consumption of light-duty vehicles in 2025 and 2036 will reach 219 (52% growth from 2013) and 300 (108% growth from 2013) million barrels of oil equivalent respectively. Accordingly, fuel consumption in scenario 16 is 14th among all scenarios in 2036.

Scenario 17: This scenario assumes low economic growth (recession). Meanwhile, the vehicle industry deploys governmental policies of efficiency (moderate) and the government increases fuel prices by the high rate of 15%. In these conditions, fuel consumption of light-duty vehicles in 2025 and 2036 reaches 209 (45% growth from 2013) and 290 (101% growth from 2013) million barrels of oil equivalent respectively. Among the scenarios with low economic growth (13 to 18), situations of moderate fuel-efficiency and price policy are more likely. This scenario is ranked 16th among all scenarios in 2036.

Scenario 18: Economic growth is low here, and the vehicle industries implement more stringent standards in new vehicles. In addition, the government emphasizes real prices for fuel (price policy). In these situations, the fuel consumption of the segment in 2025 and 2036 reaches 209 (45% growth from 2013) and 264 (83% growth from 2013) million barrels of oil equivalent respectively. It should be noted that producing highly energy-efficient vehicles is costly and so is unlikely in an economic recession. This scenario's fuel consumption is 18th among all the others in 2036.

Scenarios 19 to 24: These scenarios assume the economy is in a deep recession because of crises such as war and hard sanctions. However, such conditions probably do not continue for 25 years. Developing fuel consumption standards is difficult during a deep recession and the government cannot continue paying fuel subsidies for a long time. In other words, in the assumed scenarios, there is low energy efficiency along with price policy (scenario 22).

Obviously, economic growth is the most effective factor in the growth of fuel demand (e.g. scenarios 7, 8 and 10). In conclusion, emphasizing more fuel-efficient technologies can lead to better results than following just price policies. According to these assumptions, the model has projected the number of light-duty vehicles shown in Table 4.6.

Table 4.6. Estimate of number of LDVs in Iran for different economic growth rates in 2025 and 2036 (million)

	High economic growth (scenarios 7-12)	Moderate economic growth (scenarios 1-6)	Low economic growth (scenarios 13-18)	Very low economic growth (scenarios 19-24)
2025	20.0	18.7	16.2	14.9
2036	29.0	25.3	19.3	13.0

Accordingly, the conditions of scenarios 2, 4, 5, 8, 11, 12, 14, 16 and 22 are more probable than the others (Figure 4.2).

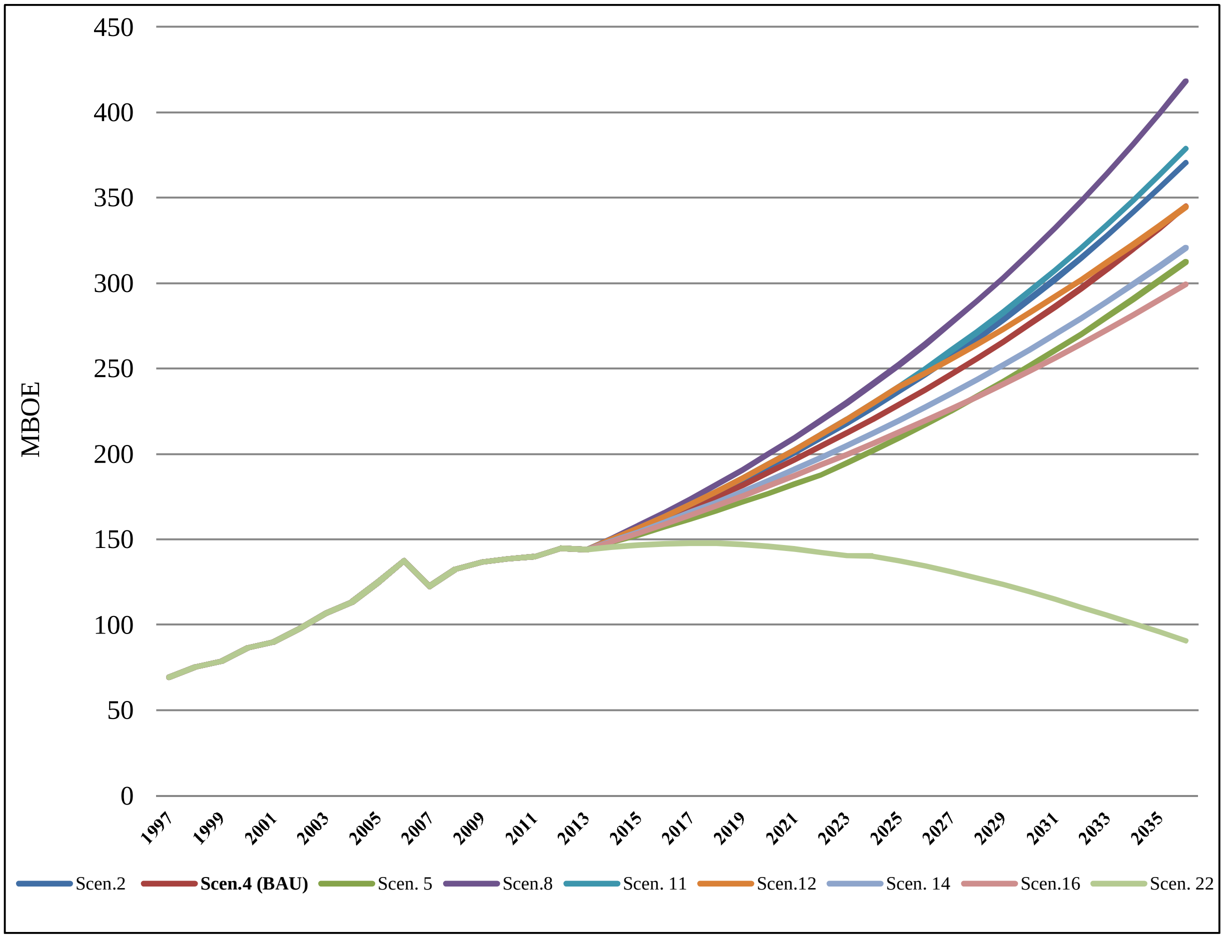


Figure 4.2. Fuel Consumption Scenarios for Iran's LDVs up to 2036

4.2. Investigating current laws and regulations in Iran for reducing energy consumption and greenhouse gas emissions (SWOT analysis)

The main goal of this part of the study is to benchmark the experienced approaches of the European Union's CO_2 reduction policies in the sector and to identify the gaps in Iran's policies. For gaining more precise results, we concentrate transportation with light-duty vehicles. I chose SWOT as a decision support system tool to analyze the internal and external situations in Iran's transport sector (the light-duty vehicles' fleet segment).

SWOT as a strategic planning instrument

Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis originates from business management literature in the 1980s.[363] This instrument has been used for strategy formation given a specific system boundary (from the range of a region or country to an organizational concept) and from both internal and external perspectives.[364] Each of the four elements of a SWOT analysis is a definite entity:

- A strength: a source of capacity that the system can use effectively to achieve its objectives
- A weakness: a limitation, fault or defect in the system that will keep it from achieving its objectives
- An opportunity: any favorable situation in the system's environment
- A threat: any unfavorable situation in the system's environment that is potentially damaging to its strategy

Sample data collection

For gaining the most reliable results, I developed a questionnaire with 71 questions relating to the four SWOT areas (see annex A). Table 4.7 includes the main concepts of the questionnaire. As mentioned before, the SWOT here focuses on the ligh- duty vehicles' (LDV) segment of Iran's transportation sector.

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[363] Natasa Markovska, Verica Taseska,and Jordan Pop-Jordanov, (2009), *SWOT analysis of the national energy sector for sustainable energy development*, Energy 34 (2009), 752–756.
[364] Ilari Karrpi, Merja Kokkonen, Kaisa Lähteenmäki-Smith, (2001), *SWOT analysis as a basis for regional strategies*, Nordregio Working Paper 2001, vol. 4, Stockholm, Sweden, p.15

Table 4.7. SWOT analysis of Iran's transportation sector: Light-Duty Vehicles' (LDV) segment

Strengths	**Weaknesses**
- Vehicle manufacturing technology and experienced workforce in Iran - Experience of designing new engines with more fuel-efficiency in Iran - Relative development of CNG infrastructure in Iran - Supportive regulations for fuel-efficiency (Targeted Subsidy Reform Plan) in Iran - Current fuel-controlling system through fuel smart card in Iran - Support of local automakers by the Iranian government - Learning from the technological advantages of CO_2 reduction in the EU	- Weakness of the Iran's vehicle industry in meeting national fuel consumption regulations - Weak relation of Iran's vehicle industry to fuel conservation policy makers - Limited financial resources of Iran's vehicle industry - Driving old and over-consuming LDVs in Iran - Low fuel price in comparison with regional and European countries - Lack of a comprehensive fuel pricing mechanism - Weak fuel-efficiency of new local LDVs - Weak development of CNG stations across the whole country - Weak national regulations to reduce carbon in the transportation sector
Opportunities	**Threats**
- Availability of low-carbon vehicles technologies in the world (such as hybrid and electric vehicles) - Availability of technologies for fuel conservation in new vehicles (such as diesel and turbocharged vehicles) - Availability of new low-carbon fuels - Availability of huge hydrocarbon reserves in Iran (energy security) - Improvement of fuel quality produced in Iranian refineries - Learning from financial mechanisms in the EU - Monopole market for the local automakers - High tariffs for imported cars - Public awareness about fuels and low-carbon vehicles	- Limitations in fuel quality and fuel variety in Iran - Low cost-effectiveness of very low-carbon vehicles (such as hybrid and electric) - No reliable strategic foreign partners and investors to help Iranian automakers produce LCVs - Negative effect of sanctions and political situations - High energy intensity and increasing demand for energy in the segment - Inefficient fuel pricing mechanism in Iran - Fluctuation of the world oil price - Lack of CO_2 emissions reduction regulations in Iran - International CO_2 emissions regimes (post-Kyoto)

The questionnaire was distributed among experts and authorities in the field of fuel consumption and fuel standardization in the Iran's vehicle industry. Related organizations include the Ministry of Industry, Mining and Trade (MIMT), the Iranian Fuel Conservation Company (IFCO), the Iranian National Standard Organization (ISIRI), the Iranian Standards and Quality Inspection Company (ISQI), the Iranian Department of Environment (Iran DOE), and the Environmental Section of both main Iranian automakers (Iran Khodro Co. and SAIPA).

Over 39 of completed questionnaires were collected. According to EFE and IFE matrix calculations, there are several improving potentials for fuel consumption and CO_2 emissions reductions in Iran's transportation sector. Sectors' fuel efficiency targets are achievable through deploying proper strategies. Thus, related breakthroughs would be tangible for all of the stakeholders.

On the other hand, the gap between Iranian and EU emissions levels may grow wider if policymakers neglect these potentials. The present situation regarding available technologies for car and fuel production, fiscal mechanisms and public awareness have prepared a *window of opportunity* for policymakers to reduce energy consumption and CO_2 emissions in Iran's transportation sector. Table 4.8 shows the items that experts and audiences scored as most important in the survey.

Table 4.8. The items rated as most important in the questionnaire

Strengths	**Weaknesses**
Supportive policies for producing LCVs (q.4) Supportive policies for dismantling old cars (q.13) High potentials of fuel-efficiency in the LCVs segment (q.8)	Low quality of conventional fuels (q.9) Using old and high-consumption vehicles in the fleet (q.7) Weakness of the local vehicle industry in meeting national fuel standards (q.1)
Opportunities	**Threats**
Progress in technology of producing: - Low-carbon vehicles (q.1) - Conventional fuels (q.6) - Alternative fuels (q.3)	Low efficiency in local LDVs (q.4) Lack of related effective regulations (q.11) Lack of a reliable strategic partner for local automakers (q.10)

Developing the SWOT matrix

Matching external and internal factors leads to the development of proper strategies. Hence, I matched individual opportunities and threats (as external factors) with individual strengths and weaknesses (as internal factors). This way leads to four-fold strategies and this stage has a critical role in effective strategy formation. According to the nature of the study system and related internal and external factors, the strategies will be Aggressive (via matching internal strengths with external opportunities, and recording SO Strategies), Conservative (via matching internal weaknesses with external opportunities, and recording WO Strategies), Competitive (via matching internal strengths with external threats, and recording ST Strategies) and Defensive (via matching internal weaknesses with external threats, and recording WT Strategies) (Table 4.8). Table 4.9 includes a matrix of Strengths-Weaknesses-Opportunities-Threats (SWOT). This is a matching tool for developing four types of strategies.

For formulating appropriate strategies, we matched the external and internal factors individually and entered the strategies into the related quadrant. The purpose of this stage is not to specify the best strategy. The SWOT matrix looks for feasible alternative strategies.

Table 4.9. The SWOT matrix for fuel consumption and carbon dioxide emissions in the Iranian transportation sector, light-duty vehicles segment

	Strengths - … - …	Weaknesses - … - …
Opportunities - … - …	SO strategies: **Clean power alternative fuels**	WO strategies **Improving quality of conventional fuels for the LDV fleet**
Threats - … - …	ST strategies: **Low-carbon vehicles production act**	WT strategies: **Rationalizing fuel price policy for the LDV fleet** **Developing a national fuel economy policy**

4.3. Developing 25-year strategies for reducing carbon dioxide emissions from Iran's light-duty vehicles segment

I prioritize strategies according to their CO_2 emissions reduction potential:

Strategy number one

Low-carbon Vehicles Production Act

Our first strategy is ST. In an ST strategy, the system uses internal strengths to avoid or reduce the impacts of external threats (Conservative Strategy). This approach relies on the system's internal competencies. David discusses how ST strategies mostly include market penetration, market development, product development and related diversification.[365] Strategy number one is developed for:

Using strengths of

- Local automakers' abilities to produce new cars
- Supportive regulations for energy efficiency
- Political support of the government from the vehicle industry and

Avoiding threats of

- High energy intensity and increasing demand
- International CO_2 emissions regimes (post-Kyoto)
- Lack of a reliable international strategic partner for the vehicle industry

The European Union defined carbon dioxide as a fuel consumption index at the end of 1980s. According to Article 6 of the Directive 89/458/EC, the council of the European Communities called for measures to limit CO_2 emissions from motor vehicles to control the greenhouse effect. Both voluntary and mandatory European regulations were developed based on CO_2 criteria.

According to the voluntary agreement (ACEA Agreement), CO_2 emissions from new vehicles sold in the EU were to be improved from 170 grCO_2/kg in 2003 to 140 grCO_2/kg by 2008 and 130 grCO_2/kg by 2015. Despite partial success of the voluntary agreement, the Commission acknowledged its failure in February 2007.

Production of low-carbon vehicles accelerated after the ratification mandatory regulation in April 2009 (EC 443/2009). According to this regulation, the fleet average annual CO_2 emissions target

[365] Fred R. David, (2011), *Strategic Management: Concepts and Cases*, 13th edition, Prentice Hall Pub., New Jersey, USA, p.184.

for automakers is defined as 130 gr/kg by 2015 (compared with 161 gr/km in 2005) and 95 gr/kg by 2020. According to the EEA, the CO_2 rate of the segment hit 127.0 gr/km in 2013. That means the EU could hit the target 2 years earlier than 2015. The EEA reports that, despite increasing vehicle mass, dieselization and improved vehicle technology are two main reasons for greater fuel-efficiency in the EU (see figure 2.23).[366]

The mandatory regulation has been more effective than the voluntary agreement. The ICCT reports that the annual CO_2 reduction rate was about 1% until 2007 (the industry's voluntary reduction agreement). After ratifying the mandatory regulation, this rate increased significantly to approximately 4% per year from 2008 to 2013.[367]

The ICCT indicated that the top nine automakers, accounting for 87% of the EU-27 sales in 2013, met their 2015 target. Some of those manufacturers, such as PSA and Toyota, have achieved notable progress towards their 2020 target (the rates for both automakers were 116 grCO_2/kg in 2013).

Despite a 50% increase in the sale of hi-tech powertrain vehicles (HEVs, PHEVs, and BEVs)[368] from 2012 to 2013, the market share of these technologies accounts for just 1.9% in the EU. However, higher penetration rates in some European countries, such as the Netherlands (5.7%) and Norway (6.7%), are the result of aggressive fiscal incentives.

The EU clarifies the aim of Regulation No. 443 in creating incentives for the car industry to invest in new low-carbon technologies. This approach will result in the long-term competitiveness of the industry and promotes more high-quality jobs in the EU.

Regulation No. 443 did not focus on any specific technology and each manufacturer should ensure its average specific emissions target. The emissions target of each manufacturer is determined for a percentage of cars in each year (65% in 2012 to 100% in 2015 onward).

Super-credit is an incentive parameter for European automakers. Regarding Regulation No.443, vehicles emitting less than 50 grCO_2/km were to be counted as 3.5 cars in 2012 and 2013, 2.5 cars in 2014, 1.5 cars in 2015 and 1 car from 2016.

Standardizing fuel consumption of LDVs in Iran started in 2006 with the issuing of ISIRI No. 4241-2. This standard derived from the similar European standards, 80/1268/EEC, 93/116/EEC,

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[366] European Environment Agency (EEA), (April 2014), *Monitoring CO_2 emissions from new passenger cars in the EU: Summary of date for 2013*, Copenhagen, Denmark. Retrieved 25 February 2015 from: www.eea.europa.eu/

[367] The International Council for Clean Transport (ICCT), (JUNE 2014), *CO_2 emissions from new passenger cars in the EU: Car manufacturers' performance in 2013*.

[368] Hybrid-electric vehicles; plug-in-hybrid-electric-vehicles; battery-electric-vehicles.

and 99/100/EEC. According to ISIRI 4241-2, an Energy Consumption Label should be used for all local LDVs. This standard was developed based on fuel consumption, while European standards use carbon dioxide as the basic index. This standard, along with other national regulations, has not been completely successful in reducing fuel consumption (and carbon dioxide emissions) in the Iranian LDV fleet. According to the Vehicle Quality Enhancement Law, the average fuel consumption of passenger cars should have been reduced to 6.95 lit/100km in 2011. The rate hit 7.93 lit/100km and 7.4 lit/100km for gasoline and bi-fuel (CNG and gasoline) vehicles in 2011 respectively (see Figure 3.6). Factors such as lack of proper technologies, non-coordination among the players and economic factors (such as sanctions) are the key reasons for the issue.

There is not any comprehensive strategy for producing LDVs in Iran (similar to the EU). LDVs are limited to just gasoline and bi-fuel (CNG and gasoline) vehicles. Despite related regulations (e.g. Article 160 of the Fifth FYDP), other conventional and alternative-fueled vehicles (such as biodiesel and so forth) are not in the production plan. Mr. Nematzadeh, Minister of Industry, announced that the average CO_2 emissions of the new local Iranian LDVs should be reduced from 190 grCO_2/km (near 8 lit/100km) in 2012 to 100 grCO_2/km (near 4 lit/100km) in 2025. Introducing specific targets for CO_2 emissions plays a key role for both policymakers and local automakers.

Owing to the high potential of powerful vehicles in Iran (e.g. SUVs), more attention should be paid to producing more fuel-efficient passenger vehicles. Along with this approach, producing diesel LDVs is a proper strategy.

Some infrastructural limitations have prevented formulating proper fuel-efficient strategies in Iran. Lack of access to high-quality conventional fuels (light gasoline and diesel) along with accessibility to huge hydrocarbon reserves has led policymakers to short-term solutions.

Absence of reliable strategic partners and limited access to new technologies for energy-efficiency, along with the high potential the local LDV demand market, have resulted on Iranian local automakers focusing on production quantity rather than quality improvement.

Despite no explicit mention of the transportation sector in the Kyoto Protocol, and the complexity of policymaking in this field, the EU considered the energy efficiency of the sector for a number of reasons. First, transportation accounts for near one quarter of the GHGs in the region, and other sectors must compensate for all GHGs reductions if transportation failed to reach its target.

Second, fossil fuels account for over 93% of the consumed energy in transportation and the EU imports over 85% of this amount annually. Thus, in a growing economy, fuel-efficiency policies are not negligible in an energy security atmosphere.

However, the Protocol has not required Iran to commit to GHG reduction after the second period of commitment (2021 onward) when the international agreements may be changed. Having international commitments along with proper technical mechanisms will encourage policy makers to formulate related policies.

Strategy number two

Clean power alternative fuels

This strategy is in the SO quadrant. Through an SO Strategy, the system uses internal strengths to take advantage of external opportunities (Aggressive Strategy). David discusses how organizations generally pursue WO, ST, or WT strategies to get into a situation to apply SO Strategies.[369] Strategy number two is developed for:

Using strengths of

- Local automakers' abilities to produce new cars
- Supportive regulations for energy efficiency (such as the Targeted Subsidy Reform Plan and using the fuel smart card)
- Political support of the government for the vehicle industry and

Using opportunities of

- Available technologies for producing low-carbon vehicles
- Learning from financial mechanisms in the EU
- The isolated LDV market in Iran
- The availability of alternative fuels

Iran's vehicle industry experienced a huge growth at the beginning of the Fifth Five-Year Development Plan (2011-2015). Production hit over 1.6 million units (1.4 million of passenger cars) and the country 13th rank for vehicle producers in 2011. Local automakers invested in establishing modern production lines under license of some well-known global brands (such as Peugeot, Renault, KIA, and so on). Technology transfer for new vehicles has resulted in

[369] Fred R David, op. cit., p.178.

empowering local automakers to design and develop new engines, bi-fuel vehicles and mass-production of passenger vehicles.

Iran and the EU have the same reasons for approaching alternative fuels: environmental concern and energy security. Alternative fuels strategy for Iranian LDVs switched from LPG to CNG, owing to the availability of huge natural gas reserves and less polluting parameters. The IFCO reports that over 1.7 million bi-fueled LDVs (CNG and gasoline) were registered in Iran by 2011.[370] Owing to the International Association for Natural Gas Vehicles, 2268 natural gas refueling stations were established in the country by 2014.[371]

Launching rationing of gasoline, along with increasing the second quota to 0.43 USD in June 2007, decreased the gasoline demand in Iran. The IFCO reports that gasoline consumption in the Iranian transportation sector decreased from 146.8 MBOE in 2006 to 119.6 MBOE in 2011(-18.5%) (see section 3.5). Despite the decline for gasoline, total energy consumption of the LDV fleet continued to grow during the period. This means that CNG compensated for gasoline's share of total energy demand (see Figure 3.7).

According to these changes, total fuel consumption in the sector increased from 270 MBOE in 2006 to 297 MBOE in 2011 (+10% growth). Despite this increase, and because of the growing share of CNG, environmental costs of the sector increased from 45,322 bn Rls in the same period (-5.9% growth).

The share of bi-fuel (gasoline and CNG) locally produced passenger vehicles varied from 2005 to 2011 (Table 4.10). This rate should have reached 30% of total local car production, according to the Fourth FYDP (see section 3.6). The CNG passenger car fleet has played a key role in Iran's energy security in the sector. Despite economic sanctions in recent years, Iran could cope with limitations in importing gasoline with the help of a significant bi-fuel fleet and huge natural

[370] Iranian Fuel Conservation Company (IFCO), (2013), *Transportation Energy Data book 2011*, Tehran, Iran, p.151.

[371] The International Association for Natural Gas Vehicles, (2013), *Worldwide NGV statistics*. Retrieved 9 April 2015 from: www.ngvjournal.com/worldwide-ngv-statistics/

gas reserves. BP reports that Iran, with 18.2%, has the largest natural gas reserves in the world.[372]

Despite environmental benefits, CNG has not been a main alternative fuel in the EU on account of energy security. European countries import natural gas from limited sources and use the gas mainly for industries. Thus, European policymakers have relied on internal or more dependent energy sources for the transportation sector. However, the European Union has deployed some persuasive policies for developing gas-powered vehicles.

According to the International Association for Natural Gas Vehicles, Italy, with over 885,000 registered vehicles, has the largest CNG-fueled vehicle fleet in the EU. It should be noted that Iran, with over 4 million CNG-fueled vehicles, has the largest fleet in the world (see Table 3.13).

Table 4.10. Share of bi-fuel produced LDVs in Iran from 2005 to 2011 (percent)

2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
1.5	12.1	33.3	19.4	19.8	27.3	17.1

Source: IFCO 2013

The EU has set the target of increasing the share of biofuels and alternative fuels, including natural gas, to 10 and 20% respectively by 2020. To combat the refueling challenge faced by these vehicles, some European countries defined a project named GasHighWay.[373] GasHighWay is supported by the European Commission under the Intelligent Energy Europe Program. The target of the project is to develop a comprehensive network of filling stations for these fuels form Finland in the north to Italy in the south of the EU (Figure 4.3). The Natural & Bio Gas Vehicle Association reports that, among participating countries, Italy, Germany and Sweden are the most advanced in terms of their number of gas vehicles and gas filling stations.

[372] British Petroleum, (2014), *BP Statistical Review of World Energy,* (June 2014), p.20. Retrieved 31 December 2014, from www.bp.com/statisticalreview

[373] Natural & Bio Gas Vehicle Association, (2015), *The GasHighWay*.. Retrieved April 9, 2015, from: www.ngvaeurope.eu/the-gashighway

Figure 4.3. Schematic picture of the GasHighWay project in the EU

Source: Natural & Bio Gas Vehicle Association (picture designed by Martti Hänninen, Finland)

As we predicted in the BAU scenario, the fuel consumption of the Iran's LDV fleet will go from 140 MBOE in 2011 to 229 and 345 MBOE in 2025 and 2036 respectively (see Table 4.5). To increase alternative fuel penetration it requires the proper development of related infrastructures. There are some critical barriers for developing CNG as an alternative fuel in Iran. Weak supply of parts (especially CNG tanks) on the production side and higher maintenance costs of vehicles, along with a low number of CNG filling stations in the country, are the main issues.

Iran's Parliament required the Central Bank to prepare financial support for establishing CNG filling stations, according to the Public Transportation Development and Fuel Consumption Management Law. CNG policies have been deployed slowly because of economic sanctions in recent years. However, Iran can benchmark from European experiences, such as The GasHighWay, for improving CNG availability in the LDVs segment.

Following Article 22 of the Fourth FYDP is a proper strategy for Iran's vehicle industry. According to the Plan, Iranian local automakers should increase production of bi-fueled CNG vehicles to at least 30% of total productions.

Referring to our scenarios, the potential fuel consumption and CO_2 emissions reduction of Scenarios 5 and 6, compared to the BAU Scenario, are 8.3% for both moderate and high rates in 2025 and 9.3% and 17.4% for moderate and high rates, respectively, in 2036. In other words, approaching alternative fuels is necessary for gaining higher fuel efficiency in the LDV fleet in Iran.

Strategy number three

Improving fuel quality used for the LDV fleet

This is a WO Strategy that aims at improving internal weaknesses by taking advantage of external opportunities (Competitive Strategy). In such a situation, the system seeks integration, market penetration, market development and product development.[374] Strategy number three is developed for:

Improving weaknesses of

- Iran's vehicle industry in meeting national fuel consumption regulations
- Fue- efficiency in new local LDVs
- National regulations to reduce carbon in the transportation sector and

Using opportunities of

- Availability of huge hydrocarbon reserves in Iran
- Improvement of fuel quality produced in Iranian refineries
- Public awareness about fuel quality and low-carbon vehicles

Fuel quality, along with the technology of internal combustion engines (ICE) and emission-reducing parts, is the most significant factor in emissions reduction in vehicles. Related regulations and standards ensure that air quality emissions from vehicles will be significantly reduced.

Gasoline and diesel are the most consumed fuels in road transportation in the world. Conventional fossil fuels and petroleum products (i.e. gasoline and diesel) account for over 94% of energy consumed in road transportation in the European Union (EU-28) in 2012. Most of the remaining >5% belongs to renewables (e.g. biofuels) and nearly 0.5% belongs to gas.[375] For Iran, and according to the IFCO, conventional fuels (gasoline and diesel) and natural gas

[374] Fred R David, op. cit., p.184.
[375] European Union, (2014 edition), *Eurostat Energy Balance Sheets 2011-2012*, Luxembourg: Publications Office of the European Union, p.10.

accounted for over 85 and 14% of energy consumption of road transportation respectively in 2011.[376]

The fuels' quality is critical for any conservation program. Lean-burn gasoline engines increase the ratio of air to fuel, thus reducing fuel consumption by 15-20%. For getting the proper fuel economy of these engines, after-treatment technologies, such as catalysts, are required to control NO_x emissions. Higher sulfur levels reduce the effectiveness of the technologies and necessitate increasing fuel consumption (see section 3.4). The ACEA reports that fuel sulfur content dramatically reduces the efficiency, lifetime and durability of NO_x storage traps of catalysts.[377] Thus, desulfurization is a critical issue for meeting higher levels of both emissions and fuel consumption standards (Table 4.11; see Tables 2.8 and 3.10).[378]

Table 4.11. Sulfur content levels of different European emissions standards for the LDVs (ppm)

	EURO 1	**EURO 2 / EURO 3**	**EURO 4**	**EURO 5 / EURO 6**
Gasoline	1000	150	30	10
Diesel	2000	300	50	10

Source: ACEA et al, 2013

Desulfurization from gasoline and diesel has been a critical issue in Iranian refineries. The Air Quality Control Co. (Subsidiary of the Tehran Municipality) conducted a survey on the gasoline and diesel distributed in Tehran. Sampling from a number of gas stations randomly in different times showed that the sulfur content of most of the samples was over the standard limit (Figure 4.4).[379]

[376] IFCO, (2013), op. cit., p.55.
[377] Katherine O. Blumberg, Michael P. Walsh, Charlotte Pera, (2003), *Low-Sulfur Gasoline & Diesel: The Key to Lower Vehicle Emissions*, Prepared for the May 2003 meeting in Napa, California, of The International Council on Clean Transportation (ICCT), p.14.
[378] The European Automobile Manufacturers Association (ACEA), Alliance of Automobile Manufacturers, Truck and Engine Manufacturers Association (EMA), and Japan Automobile Manufacturers Association (JAMA), (2013), *The Worldwide Fuel Charter*, Fifth edition, September 2013, pp.3–7.
[379] Air Quality Control Co., (May 2013), *Gasoline and Diesel Quality Impacts on Light and Heavy Duty Vehicle's Pollution Emissions*, Technical Report No. QM92/03/02(U)/01, p.39.

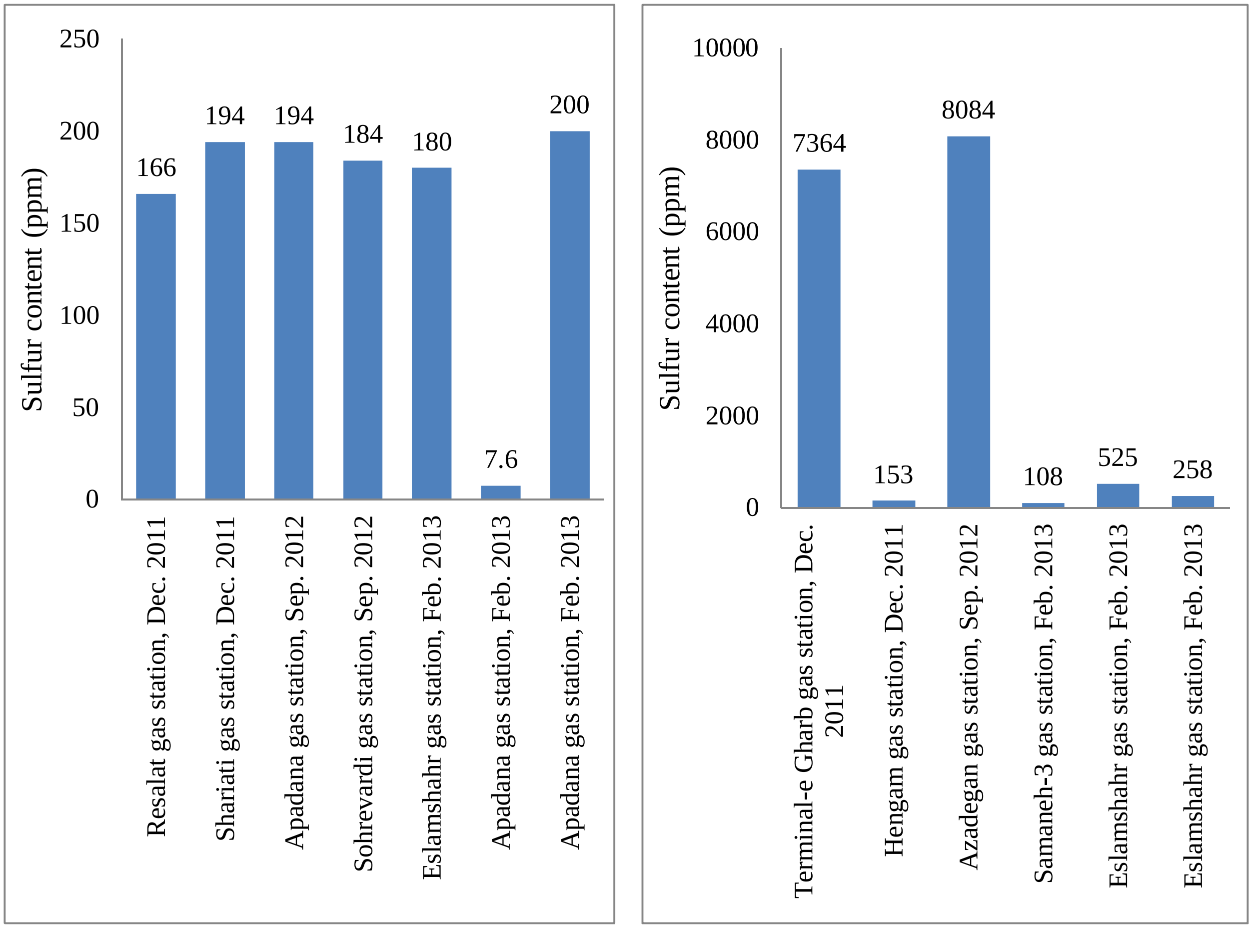

Figure 4.4. Sulfur content of gasoline (left) and diesel (right) samples taken random from gas stations in Tehran

Source: AQCC, 2013

Along with applying the EURO 4 standard to LDVs since May 2014, Iran's refineries have started gradually producing compatible gasoline. NIORDC[380] distributes the higher quality gasoline mainly in big cities.

The European Union has focused on CO_2 reduction over the whole life cycle of fuels used for transportation. Directive 2009/30/EC requires fuel suppliers to reduce greenhouse gas emissions in the sector to 10% per unit of energy by December 31, 2020. The share has been divided. 6% is for using of biofuels, alternative fuels and reductions in flaring and venting at production site. A further 2% reduction should be obtained through using carbon capture and storage (CCS)

[380] National Iranian Oil Refining & Distributing Company

technologies and electric vehicles. The remaining 2% reduction is to be obtained through purchasing credits under the clean development mechanism (CDM) of the Kyoto Protocol.

Old and inefficient fuel production technologies in Iran's refineries, along with wasting huge amounts of energy through flaring, show the high potential of designing CO_2 reduction programs on the production side.

Directive 2009/30/EC emphasizes sustainable biofuels standards. The EU's target is a 10% share of biofuels in transportation fuel consumption in 2020. The EEA reports that only a few countries are on track to meet the 2010 biofuel consumption targets (5.7% share) (see section 2.5). Despite several biofuels potentials in Iran, there is not any plan for producing these fuels in the country.

Referring to our scenarios, deploying any fuel-efficiency–improving program is not successful without proper fuel quality. It should be noted that preparing light fuel is necessary for diesel LDV penetration policy in Iran.

Strategy number four

Rationalizing fuel price policy for LDVs

This strategy appears in the WT quadrant. In a WT strategy, the system uses defensive tactics for reducing internal weaknesses and avoiding external threats (Defensive Strategy). In this situation, the system may have to fight for its survival by making retrenchment, divestiture, liquidation and related diversification decisions.[381] Strategy number four is developed for:

Reducing weaknesses of

- Iran's vehicle industry in meeting national fuel-consumption regulations
- Driving old and over consuming LDVs in Iran
- Low fuel prices in comparison with regional and European countries
- Lack of a comprehensive fuel pricing mechanism

Avoiding threats of

- High energy intensity and an increasing demand for energy in the segment
- Inefficient fuel pricing mechanisms in Iran

[381] Fred R. David, op. cit., p.184.

- Fluctuation of the world oil price
- Lack of CO_2 emissions reduction regulations in Iran

Fuel pricing mechanisms are completely different in Iran and the EU. Iran's economy has suffered from energy subsidizing for a long time. However, energy prices in the Europe have usually been calculated following market mechanisms. Fuel taxes usually account for over half of the retail price in the EU (see Section 2.6 and Table 2.11).

European countries have their own individual fuel pricing policies, but the mechanisms are very similar. For example, energy prices in Germany refer to the monthly average of the quarter and include taxes based on the type of energy carrier and end user. Gasoline and diesel price for non-commercial transportation in Germany include 19% for general tax (VAT) plus a special tax (eco tax) and excise tax (*Minaralölsteuer*), which are different for each fuel.[382] It should be added that the EU started internalizing external costs of transportation (such as air pollution, climate change and congestion costs) in 1998.[383] Developing biofuel production in the EU is has the support of direct and indirect subsidies.

The so-called eco tax in Germany increased fuel tax in total by about 15 €ct/l between 1999 and 2003. This measure reduced transport GHG emissions by more than 2 Mt CO_2 eq. annually after 2003.[384]

Fuel retail prices in Iran have been much lower than the real price because of subsidies. Paying subsidies for energy is an old policy in Iran, since increasing oil revenues and removing subsidies has always been a real challenge for decision makers (see Figure 3.9). Policymakers in Iran have preferred to solve economic problems with oil revenues rather than tax. Approaching this policy has led to high energy intensity and weak energy efficiency in all sectors such as transportation.

Removing subsidies is more complicated in Iran because of the close relation of the inflation rate and fuel (especially gasoline) prices. Iranian people look at gasoline prices as an index of public expenses, and increasing fuel prices have psychological effects on the society. For example,

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382 International Energy Agency (IEA), (2015), *Energy Prices and Taxes, Country Notes*, 1st Quarter 2015, pp.40-44.
383 Stef Proost, (2008), *Full Account of the Costs and Benefits of Reducing CO_2 Emissions in Transport*, OECD/ITF, JTRC Discussion Paper 2008-3, p.6.
384 Wolfgang Schade, (2011), *Transport in the Past and Current Climate Policy Regime*, Published in Rothengatter, W. et al., Transport Moving to Climate Intelligence, Springer, New York, p.30.

gasoline prices account for 10% of household expenses in the country. In the case of a 10% increase in gasoline prices, people expect transportation costs to be doubled and the price of all goods and services to be doubled as well. Increasing prices by removing subsidies in the short-term has caused serious social and political issues. Hence, the government has to use more conservative fuel policies in the long-term.

The Targeted Subsidy Reform Plan of Iran was ratified by the parliament in March 2010 and deployed with a strong political support. However, because of issues emerging from economic and political situations (such as sanctions), the Plan could not be implemented successfully (see Section 3.5).

However, the gasoline retail price in Iran reached the target (90% of the Persian Gulf F.O.B. price) because of decreasing world oil prices at the end of 2014 (see Table 4.4). This process had no effect (neither negative nor positive) on fuel consumption behavior (demand side) or energy-efficiency planning (supply side) in the country. This event shows that fuel-pricing mechanisms based on the oil market does not guaranty improving the energy intensity of transportation in Iran. In other words, using market mechanisms, such as carbon tax, helps the government to enhance fuel conservation and carbon emissions reduction.

Strategy number five

Developing a National Fuel Economy Policy

This strategy appears in the WT quadrant, like strategy number four. Strategy number five is developed for:

Reducing weaknesses of

- National regulation for reducing carbon in the transportation sector
- Fuel efficiency of new local LDVs
- Driving old and over-consuming LDVs in Iran and

Avoiding threats of

- Lack of CO_2 emission reduction regulations in Iran
- High energy intensity and increasing demand for energy in the segment
- Fluctuation of the world oil price.

As noted in Section 1.4.2, Iran's economy is highly energy intensive. According to the US Energy Information Administrative, Iran's energy intensity increased from nearly 5,000 quadrillion BTU after the Islamic Revolution (1980) reached to nearly 11,200 quadrillion BTU in 2011 (124% growth) (see Table 1.17). For transportation, use of individual energy consumers (here light-duty vehicles) has grown sharply during the period.

The passenger car market of the EU is nearly mature, whereas Iran has an emerging market. The number of cars per one thousands inhabitants (motorization rate) in the EU has grown more slowly than in Iran (Table 4.12). The motorization rate in Iran has increased dramatically by over 160% in ten years. Capros et al. predict this rate for the EU-27 to reach 710 in 2030.[385]

Table 4.12. Motorization rate in Iran and the EU in 1999 and 2009

	1999	**2009**
Iran	54	141
EU-27	412	473

Referring to our scenarios in Section 4.1.1, we expect the number of passenger vehicles to grow depending economic growth and Iran's population. Thus, LDVs' fuel demand will increase accordingly (see Table 4.6).

As mentioned in Section 3.3, Iranian authorities have ratified some regulations and technical standards for reducing energy consumption and CO_2 reduction in the sector. 'Iran's 20-Year Vision Plan', announced by the Supreme Leader of the I.R. of Iran on 22 January 2001, notes that *Energy Conservation* and *Energy Intensity Reduction* are the general energy policies in Iran.

Owing to this, and Article 121 of the Third FYDP, the first of Iran's national fuel consumption standards was born in 2006. ISIRI No. 4241-2, is derived from European fuel consumption standards. The National Organization for Standardization issues Energy Consumption Labels through an official procedure for each model annually (see Figure 3.5). Because of technical and financial limitations, Iranian automakers were not completely successful in implementing the

[385] P. Capros,L. Mantzos,V. Papandreou,N. Tasios, (2008), *European Energy and Transport: Trends to 2030 – Update 2007.* European Commission, Brussels, p.53.

standards (see Figure 3.6 and Table 3.7). Those standards are under revision according to a CO_2 emissions index like the EU's.

Despite growing demand for more powerful passenger vehicles in both the EU and Iran, various levels of downsizing engines are proper strategies for CO_2 reduction. Engine sizes of Iranian local vehicles are normally below 2000 cc. The government announced 'the prohibition for importing passenger vehicles over 2500 cc' on September 12, 2013. This regulation extended for the Persian Year 1394 (Mars 21, 2015 to March 19, 2016).[386] This strategy intends to slow down the emerging market for imported four-wheel-drive vehicles in recent years (Table 4.13). This strategy is more reactive than proactive. By the 19 March 2016, the government must decide on a new policy formulation, or extending the regulation for another year.

Table 4.13. Share of four-wheel-drive imported cars in the total cars imported to Iran 2006 – 2011 (percent)

2006	**2007**	**2008**	**2009**	**2010**	**2011**
18%	27%	27%	50%	44%	46%

Source: IFCO, 2013

Iran's vehicle industry benefits from a monopole and isolated local market. In a highly subsidized fuel price atmosphere, either consumers or producers do not prioritize fuel conservation.

Mr. Feyz-bakhs, Deputy of Transportation and Fuel Management, reports about over 2.5 million old vehicles in Iran. He adds that the official price of old cars is too low and that the owners do not prefer to replace their cars with new models.

In most European countries, old car owners can use monetary advantages (e.g. discount price, proper loans, etc.) to renovate their vehicles. Because of weak monetary policies in Iran (e.g. high discount rate), people do not prefer to engage with the national plans.

386 '*Raees-e Koll-e Gomrok Tashreeh Kard'* (September 19, 2014), The Islamic Republic of Iran Customs Administration (IRICA). Retrieved April 7, 2015, from: www.irica.gov.ir

Iran’s government can benchmark with the EU on tax mechanisms. Tax systems can encourage people to purchase more fuel-economic cars and encourage automakers to conform to market behavior.

Iran’s transportation sector suffers from a lack of national strategy for fuel consumption reduction. Iran’s automakers were nationalized after Islamic Revolution. Even after developing privatization policies, the government has controlled the key strategies of the vehicle industry, such as final pricing.

5. Discussion and conclusion

5.1. Analyzing European policies

The European Union implemented an integrated CO_2 emissions policy in the LDV segment successfully. Meeting its objectives has increased economic growth and improved environmental quality in the region. In this study, we conclude that the EU has stopped an increasing trend in the segment's CO_2 emissions since 2009 through implementing the three policy packages of *technology-base, fuel-base* and *fiscal-base* (Figure 5.1). In fact, the successful implementation of Regulation No. 443 is not because it is mandatory. However, consonant policies for all players (including supply and demand of both fuel and vehicles) have been the reasons.

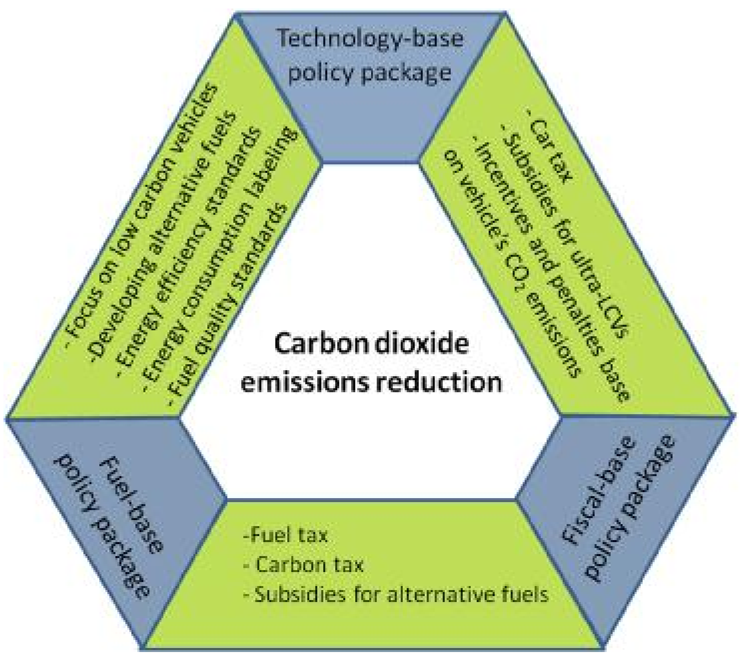

Figure 5.1 Conceptual model of CO_2 emissions reduction policies in the EU

The conceptual model shows the relations of the policy packages. These relations facilitate players in approaching CO_2 emissions targets. For example, new technology regulations push the automakers towards producing LCVs. Appropriate quality of conventional and alternative fuels facilitates the process.

5.1.1. Lessons learned from the EU

Mandatory regulations versus voluntary agreements

After the voluntary agreement from 2003 to 2007, mandatory regulation succeeded in reaching 2015 CO_2 emissions targets in 2013. It is expected that the EU will hit its 2020 targets on time. Since the transportation sector is responsible for a quarter of Europe's GHG emissions, reaching these targets will have a significant impact on meeting the EU's climate change commitments.

Developing more fuel-efficient cars bring enormous benefits, including:

- Lowering fuel expenses for drivers (in the case of the 2020 target, the average driver in Europe would save about 500 €/year and the EU benefits from savings of at least 36 billion EUR each year)
- Encouraging high-tech investments and improving more professional jobs (most of the European car manufacturers can reach targets through downsizing engines with turbo-charges, improved aerodynamics, stop-start systems, hybrid systems, electrification of drivetrains, etc.)
- Increasing energy security (Europe imports approximately €300 billion worth of oil every year. If the EU meets its 2020 target, it can benefit in energy security by nearly 20 billion EUR between 2020 and 2030 by lowering oil demand)
- Reducing environmental damage (e.g. pollution and climate change)

There are mandatory instructions for fuel consumption and energy labeling for vehicles in Iran. ISIRI 4241-2, ISIRI 8361 and ISIRI 6626-2 are national standards dealing with the issue in light-duty vehicles, heavy-duty vehicles and motorbikes, respectively. Despite improvement in the fuel consumption of local vehicles during the last ten years (see Figure 3.6), national standards need revision according to available technology innovations and environmental policy requirements. Iranian automakers have not been completely successful in deploying these standards. They have disputed the procedure of grade defining and fuel quality limitations as the basic difficulties of the issue. Revising procedure needs close relations among policymakers (i.e. Ministry of Industry, the Iranian Department of Environment, the Iranian Fuel Conservation Company, Headquarters of Transportation and Fuel Management and the Iranian National Organization for Standardization), fuel producers (National Iranian Oil Refining and Distributing Company) and automakers.

Deploying CO_2-base regulations

Defining carbon dioxide as the index of both environmental and fuel consumption performance has helped in harmonizing intersectoral policies of the transportation sector. CO_2 is the most important greenhouse gas with which all other similar chemicals are normalized. CO_2 emissions reflect the fuel consumption of vehicles and translate fuel economy calculating methods (e.g. European, American, etc.) into one language. In addition, environmental reporting helps manufacturers' performance meet their commitments. Finally, vehicle consumers can evaluate their own share in this procedure.

This approach in the EU (whether 120 gCO_2/km by 2010 under voluntary agreement or 130 g/km by 2015 and 95 g/km by 2020 under mandatory regulation) has clarified the tasks of each player in the policy packages (see Table 5.1). EU regulations do not emphasize any specific technology. European automakers have decreased CO_2 emissions of new vehicles through combined strategies (such as dieselization, hybrid vehicles, bio-fueled vehicles, etc.).

Number of liters per 100 kilometers is the only fuel efficiency index considered in the ISIRI 4241-2 Standard. Defining carbon dioxide as the fuel consumption performance index can facilitate deploying combined strategies from all policy packages. According to oral interviews with the Transportation Deputy of IFCO, a new national standard, ISIRI 4241-2, is under revision based on CO_2 calculations. Approaching CO_2 emissions helps the entities to meet national targets more precisely.

Approaching efficient fiscal policies

EU member countries manage market behavior through fiscal mechanisms such as taxes and subsidies. They also inform the cost-effectiveness preferences of new vehicles through unique signs and labels. On the other hand, consumers are propelled to choose less fuel-consuming vehicles through mechanisms such as car tax.

Incentives, such as super credit, lead automakers to produce LCVs. On the other hand, manufacturers exceeding limits have to pay defined fines (see Table 5.1). Along with these mechanisms, there are some fiscal incentives for the research and development of high-tech vehicles (such as hybrids).

Fuel pricing has been a strong policy instrument in the success of the EU's CO_2 emissions reduction policies. Fuel prices in each of the member countries are a combination of base price plus taxes (including value added tax, carbon tax, excise tax, etc.). Taxes nearly make up over half of retail price in the EU. The GIZ named the EU as a high tax region in its latest International Fuel Prices Report 2012/2013.

Table 5.1 Comparing Iranian and EU CO_2 policy parameters

	Iran	**European Union**	**Related strategy**
Availability of fossil fuels	Having 9.3% of oil and 18.2% of natural gas proven reserves in 2014	Importing over 85% of its fossil fuel consumption	2
Energy intensity	High	Low	1
International commitments	No	Kyoto Protocol	5
Developing fuel-consumption standards	Yes, but need upgrading (fuel consumption target for 2011 is 6.95 lit/100km)	Yes, (fuel consumption targets for 2015 are 5.6 lit/100km for gasoline and 4.9 lit/100km for diesel)	1
Defining CO_2 as a fuel consumption index	No, (but under planning)	Yes, (Directive 89/458/EC)	5
Defining CO_2 specific target	Yes, but informally	Yes, (130 grCO_2/km by 2015 and 95 grCO_2/km by 2020)	5
Using fuel-consumption labeling	Yes, (most of the local cars labeled *D* and lower)	Yes, (mostly *A* and *B* grades)	5
Diesel-fueled vehicle penetration	No, (but under planning)	Over 50% of LDV market share	1
Natural gas–fueled vehicle penetration	15.6% of LDVs' market share	A few in some countries, such as Italy and Germany (less than 1%)	2
Incentives and / or penalties	No, (just limitations, such as prohibition on importing over 2500 cc vehicles)	Yes, super credit as incentive (for $\leq$50 grCO_2/km) and excess emissions premium as penalty (for$\geq$130 grCO_2/km)	1
Alternative propulsion technologies (such as HEVs, PHEVs, and BEVs)	Limited (just CNG)	Yes	1
Fuel quality in terms of CO_2 reduction	Weak (e.g. high sulfur content)	Standard conventional and alternative fuels	3
Fuel pricing mechanism	High fuel subsidies; Subsidy Reform Plan based on the Persian Gulf F.O.B. price	High fuel taxation; Base price plus 19% VAT plus eco tax & excise tax (e.g. in Germany)	4
CO_2-based motor vehicle tax	No; Just base tax (equal to 1% of the car's price) and some municipality levies	Yes; Annual circulation tax for registered cars: base tax (2 €/100cc for gasoline and 9.5 €/100cc for diesel) plus CO_2 tax	4

Iran's economy suffers from high energy intensity. The final price of goods and services in Iran is strongly dependent on fuel prices (especially gasoline). Decision makers in the government are faced with a challenging situation for fuel pricing. They are taking a conservative procedure for rationalizing fuel price because of widespread and unexpected economic and social tensions. It should be added that fuel price goal-setting in the Fifth FYDP (i.e. 90% of Persian Gulf F.O.B) depends on the world price. Such a mechanism could not be reliable for fuel pricing policy formulation because of the absence of tax instruments.

Dieselization as a strategic policy

Despite more carbon content in diesel than gasoline, burning one liter of diesel produces more energy than the same amount of gasoline. Therefore, it is expected to emit 10-30% less CO_2 in comparison with gasoline. According to European Environment Agency, despite increasing vehicles mass in the EU, dieselization is one of the main reasons for meeting the 2015 target two years early. Introducing diesel LDVs to Iran's road fleet can help to diversify the fuel basket, on the one hand, and enhance outcomes for fuel efficiency strategies on the other.

5.1.2. EU challenges in CO_2 reduction procedures

5.1.2.1. New technological limitations

Technology improvements and dieselization are the main reasons for greater fuel efficiency in the EU. By meeting 2015 emissions targets, EU member countries are moving to the 2020 target and beyond. However, achieving more efficient performance is more complicated. Most of the easier and cheaper technologies, such as start-stop and smaller engines, have already been used. Automakers have to go through more expensive solutions, such as light materials (e.g. high-cost carbon fiber) and further electrification of the powertrain.

5.1.2.2. Alternative fuels challenges

EU member countries should increase their share of biofuels and alternative fuels to reach 2020 targets. In addition, targets have been set for developing alternative fuels and technologies. Technology suggestions for CO_2 reduction include electric vehicles for short distances,[387]

[387] Short journeys, mostly relating to urban areas, account for about 40% of all CO_2 emissions from road transportation.

hydrogen and methane for medium distances and biofuels/synthetic fuels, LNG and LPG for long-distance road transportation.[388] These alternatives are still too expensive to compete with conventional diesel and gasoline vehicles.

Paying subsidies for alternative fuels cannot be sustainable for a long time. Meanwhile, the exact amount of carbon dioxide emitted during the full life cycle of alternative fuels (from production to consumption) is not clear and needs more investigation. Reaching 2020 emission target needs more cost effective innovations in producing alternative fuels and developing the required infrastructure.

Lack of suitable refueling infrastructure is the other limiting factor for developing fuels in the EU. European countries have their own priorities for developing different fuels. This means that it is not easy for international travelers to refuel alternative technology vehicles across European borders.

The number of refueling CNG stations in Iran has not grown along with the number of CNG vehicles. The NIORDC reports that Iran needs at least 2550 CNG stations, rather than the existing 2075 in 2013. We should also consider the capital required to establish diesel stations, if introducing diesel LDVs is the plan of Iran's government.

5.1.2.3. Fuel efficiency testing method

European automakers test their products based on the New European Driving Cycle (NEDC) that was developed about 40 years ago. The European Commission plans to develop a new test cycle named the World Harmonized Light Vehicle Test Procedure (WLTP) by 2017. Some automakers believe that the WLTP is uncertain for tailpipe pollutants, particularly around particulates, real driving emissions and conformity factors.[389] However, most automakers want to postpone it until after 2021.

[388] European Commission, (2012), *Towards Low Carbon Transport in Europe*, EU's Transport Research and Innovation Portal,

[389] Nick Gibbs, (April 13, 2015), *Automakers defend diesels, call them key to meeting CO_2 goals*, Automotive News Products E-Magazine. Retrieved from: http://europe.autonews.com/article/20150413/ANE/150409988/automakers-defend-diesels-call-them-key-to-meeting-co2-goals

5.1.2.4. Penalty limitation

Regulation No. 443/2009 has planned some penalties for manufacturers whose average specific emissions of CO_2 exceed those permitted under the regulation. As mentioned before, meeting the target can be more difficult for the last grams of emissions. If automakers cannot meet the target, they should pay fines and the EU should focus on other incentives to motivate them.

5.1.2.5. Risk of losing leading position

Many automakers all around the world have adopted fuel-efficiency standards first introduced in the EU. However, remaining European automakers positioned at the forefront of clean vehicle technologies will be challenged by their overseas competitors.

The US President Obama restructured the US car industry in 2009, leading to emission standards for cars equivalent to 70-80 grCO_2/km by 2025. This is a challenge for European automakers, who could lose their leading position.

Energy intensity is a significant challenge for Iran, as the owner of the biggest car market in the Middle East and west of Asia. According to the 20-Year Perspective Document, Iran should be a developed country in the region in science and technology by 2025. Conserving fossil energy resources and decreasing CO_2 emissions is a challenge for policy makers, especially in the transportation sector.

5.1.2.6. Uncertain market behavior

Along with growing public opinion for environmental protection, people's behavior for choosing goods and services may change. Policymakers may affect the demand side through media, but socio-economic and cultural factors are keys. In the EU, despite introducing new hybrid and electric models to the market, consumers continue to demand fuel-powered models. To keep the market share, automakers are quickly adding plug-in hybrid variants to their midsize and SUV models. Automakers have to both invest in more fuel-efficient cars and to open new markets for new products.

Having more powerful vehicles in Iran may represent wealth. Demand for SUVs in the country has increased during the last decade along with GDP growth. The IFCO reports that the total number of SUVs has grown nearly sevenfold from 2005 to 2011 (see Table 3.6).

5.2. Defining a strategic roadmap for reducing CO_2 in Iran's transportation sector

Through deploying the five strategies mentioned in Section 4.4, average fuel consumption and CO_2 emissions of vehicles in Iran (especially LDVs) can be reduced in the future. We expect that LDV demand of the local market to continue to grow during the next 25 years (see Table 4.6). This growing market needs fuel efficiency for its sustainable development. Fuel efficiency in Iran's transportation sector has suffered from high energy intensity, high fuel subsidies and weak vehicle technology. Reducing CO_2 of the sector needs comprehensive strategies with cooperation from all players. Meeting targets in the EU is not possible without the harmonic functioning of the *technology-base, fiscal-base* and *fuel-base* policy packages.

Policymakers can only affect the trend until the motorization rate saturates. In the case of deploying strategies, we expect scenarios 5 and 11 from Section 4.1 more than the others. In scenario 5, fuel consumption of LDVs will be 8% and 9% less than scenario 4 (BAU) in 2025 and 2036 respectively. But, in case of high economic growth rate (scenario 11), fuel consumption will exceed the BAU by 5% and 10% in 2025 and 2036.

Reaching the more efficient fleet in the scenario and beyond it needs a phasing procedure to introduce lower carbon vehicles. We suggest the following steps to reach a more likely low-carbon fleet.

Phase 1: Setting a mandatory regulation based on CO_2 measures

As with the European experience, Iran needs a mandatory regulation for carbon dioxide emissions reduction. The regulation should be established based on CO_2 measures. Despite the reactive function of the Department of Environment in the current situation (see Table 5.2.), it should be a main governmental player. Policymakers should prepare an effective relationship with all the stakeholders, including automakers and fuel suppliers (such as the NIORDC). This regulation could be a part of the country's national policy for emission reduction. In this regulation, policymakers should consider technology implications (both local capabilities and technology transfer possibilities) to set rational targets.

Table 5.2. Current situation of Iranian entities relating to each strategy

	MIMT[390]	Iran-DOE[391]	IFCO[392]	HTFM[393]	ISIRI[394]	NIORDC[395]	Automakers
Strategy No. 1	Removing tariffs of hybrid vehicles	No long-term specific target	New fuel consumption standard is under development	Dismantling old LDVs (indirect)	New fuel consumption standard is under development	Producing standard fuels	Producing standard vehicles
Strategy No. 2	30% CNG of total LDV fleet	No long-term specific target	Suggesting 25% diesel-fueled cars by 2025	Developing CNG infrastructure	Developing fuel standards	Producing standard fuels	Producing standard vehicles
Strategy No. 3	Not related	No plan	Not related	Not related	Developing fuel standards	Producing standard fuels	Producing standard vehicles
Strategy No. 4	CNG price shouldn't exceed over 40% that of gasoline	Not related	Not related	Dismantling old LDVs (indirect)	Not related	More subsidy for CNG / following Subsidy Reform Plan	No plan

* We do not mention strategy number five in the table because it is a mix or the four strategies.

In some cases, an entity may oppose another while a strategy is being implemented. Emerging paradoxes diminish the strength of a strategy. In such a case, overestimation of the capacities and misevaluation of the potentials may cause paradoxes. For example, in the latest version of ISIRI 4241-2, the vehicle industry is required to reduce fuel consumption. Automakers considered low quality of fuels to be the main challenge for meeting regulation targets and the NIORDC rejected the statement and focused on the weak technology of vehicles.

Phase 2: Establishing an efficient fiscal context

Having a fuel-economic light-duty vehicle fleet is not possible unless a proper fiscal context is developed. Consumers tend to purchase more fuel-efficient cars when they believe in the economic and environmental advantages of low-carbon vehicles. Fiscal mechanisms, such as a CO_2-based car tax, encourage consumers to buy more fuel-economic vehicles and incentivize the vehicle industry to produce more fuel-efficient products. Auxiliary-adding policy instruments,

[390] Ministry of Industry, Mining and Trade.
[391] Iran Department of Environment.
[392] Iranian Fuel Conservation Company (IFCO).
[393] Headquarter of Transportation and Fuel Management.
[394] Iranian National Organization for Standardization (ISIRI).
[395] National Iranian Oil Refining and Distributing Company (NIORDC).

such as super credits, emphasize competition among automakers for developing their own market.

Rationalizing fuel prices will guide both fuel producers and consumers to lower-carbon options. Policies such as carbon tax perform effectively without being deployed on an international scale, such as Persian Gulf F.O.B. Iran's Subsidy Reform Plan should gradually be followed with a tax-base mechanism. This approach makes the policy context more stable.

Social and economic consequences are the probable issues of the fiscal reforms relating to strategies four and five (see Table 5.3).

Phase 3: Establishing strategic relations with well-known automakers

Iran's automotive industry is the second-largest industrial sector after oil and gas. This sector produced 16% of the total value-added in the country's industrial sector, amounting to 3.7 billion USD in 2010.

The two main Iranian automakers, Iran Khodro Industrial Group (IKCO) and SAIPA Automotive Manufacturing Group, had close relations with PSA and Renault (France), Nissan (Japan) and KIA Motors (South Korea) by 2012. The European origin of the Iran's vehicle manufacturing standards, proper infrastructure (from iron and steel to spare parts production) and high potentials in the local and regional markets convinced both sides to renew relations after economic sanctions.

This plan helped local automakers to enhance the fuel efficiency of new vehicles. Meeting low CO_2 emissions standard limits is mandatory for exporting cars to regional and global markets. Ongoing fuel consumption European standards count as a priority for local consumers who are familiar with the quality of products. Low-carbon vehicles can contribute to the air pollution that most mega cities are facing.
Costly investment in technology transfer may be a concern for strategy one. Policymakers can cope with the issue through fiscal mechanisms (see Table 5.3).

Phase 4: Public awareness enhancement and low-carbon transportation

People are one the main players of all five strategies. They demand transportation for their daily activities, whether public or private. Educating people about the advantages and disadvantages of alternative transport technologies is a key European policy for combating CO_2 emissions. Low-carbon options, such as cycling, walking, distance working, etc., are available in most urban areas.

In addition, we need people's contribution for any socially-oriented activity. People in Iran do not trust the government unless informed transparently about the benefits of costly policies (such as the Subsidy Reform Plan, carbon tax, etc.). As mentioned above, Iran's government has experienced serious social issues after deploying some phases of the Fuel Subsidy Reform Plan. Paying for CO_2 emissions requires that deep cultural and social understandings be established through long-term transparent communication with the people. Training consumers to use low-carbon transportation modes is critical for any strategy in this field (see Table 5.3).

Table 5.3. Limits and solutions of deploying the strategies in Iran

	Limit	**Description**	**Solution**
Strategy No. 1	High expenditures for investment	Costly investment for technology transfer and producing LCVs	Improving subsidies mechanisms (shift from fuel to producing LCVs)
Strategy No. 2	Weak infrastructures	Costly capital investment	- Long term loans - Supporting private sector
Strategy No. 3	Improving quality against cost-effectiveness of fuels' final price	Improving fuel quality requires technology transfer and investing in old refineries	- Rationalizing fuel price - Increasing public awareness - FDIs to improve local refineries
Strategy No. 4	Social and economic consequences	- Inflation - Political resistance	- Communication - Increasing public awareness - Strong political support
Strategy No. 5	Public likely oppose	- Inflation - Economic concerns	- Communication - Increasing public awareness - Strong political support

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Annex A

Questionnaire

Please score the importance of each issue from 1-4 as follows: 1 (very low importance), 2 (low importance), 3 (important) and 4 (very important).

Opportunities:

1. Significant progress in low-carbon vehicle (LCV) technologies in the world (such as development of gasoline and diesel-fueled LCVs, hybrid vehicles, electric vehicles and fuel cells)
2. Accessibility of the complementary technologies that can reduce fuel consumption as a side benefit (such as electric wheels, new tires, etc.)
3. Availability of various fuel technologies in new vehicles (such as biofuels, methanol, ethanol, etc.)
4. Availability of modern energy-conservation technologies for new vehicles (such as new gearboxes, double clutches, new power transmission systems, etc.)
5. Availability of significant hydrocarbon resources for supplying fuel the LDV fleet in Iran (including CNG, gasoline and diesel)
6. Progress in high-quality conventional fuel production (e.g. low sulfur content) and proper accessibility to good quality fuels in the country.
7. Sound European experience of financial mechanisms in controlling energy consumption (such as carbon tax, excise duty, VAT, etc.)
8. Monopole market for local light-duty vehicles
9. High tariffs for the foreign light-duty vehicles
10. Enhancement of public awareness of fuel conservation and CO_2 emissions reductions

Threats:

1. Low cost-effectiveness, high final price and high maintenance costs of low-carbon vehicles (such as hybrid and electric) in comparison with conventional vehicles

2. Fluctuations in world oil price and negative effects on the effective implementation of the ‘Targeted Subsidy Reform Plan’ in Iran
3. Not calculating social and environmental costs of production and consumption on the retail price of fossil fuels
4. High energy-intensity and low energy conservation in the Iranian light-duty vehicle fleet
5. Limited choice for the LDV fleet’s fuel basket in Iran (only gasoline and CNG)
6. Limitations for production of conventional fuels (gasoline and diesel) with proper quality in Iran
7. More emphasis of Iranian policymakers on CNG development and bi-fuel vehicle production, rather than supporting the development of low-carbon vehicles
8. Consumers’ tendency to prefer more powerful vehicles and larger engine volumes (such as SUVs) in Iran
9. Lack of foreign direct investment for fuel conservation in the Iranian vehicle industry
10. Lack of a reliable and strategic partner for local automakers for strategic goal-setting for fuel conservation in new vehicles
11. Lack of national requirements for CO_2 emissions reduction in Iran’s transportation sector (as in the European Union)
12. Lack of competitive advantage among local automakers
13. Lack of a strategic plan for Iran’s vehicle industry
14. Negative effect of economic sanctions on the Iran’s vehicle industry
15. Progression trends of vehicle pricing in Iran
16. Limited choices of Iranian customers purchasing vehicles (especially local products)
17. Limited and depleting hydrocarbon reserves
18. Increasing trend of petroleum product consumption in the country and limitation effect on exporting

Strengths:

1. Technology and experienced manpower in the Iran’s vehicle industry
2. Design and development infrastructure for producing LDV engine power in Iran
3. Producing CNG-based engines in Iran

4. Legal support for producing low-carbon and hybrid vehicles
5. Experience of producing diesel light-duty vehicles for export
6. Increasing conventional fuels' quality in Iran
7. High demand market for LDVs
8. Vast potential of fuel conservation in Iran
9. Experience of producing low-consumption vehicles (such as Peugeot 206, Renault Logan and Pride) in Iran
10. Relative development of CNG infrastructures in the vehicle industry
11. Experience of developing and implementing national standards of fuel consumption for LDVs
12. Producing bi-fuel vehicles (vehicles that use conventional fuels plus CNG)
13. National regulations for dismantling old vehicles
14. Regulation support for energy conservation in Iran (such as the 'Targeted Subsidy Reform Plan')
15. Encouraging regulations for importing new low-carbon vehicles (such as hybrid and electric vehicles)
16. Policies for reducing and removing fuel quotas on high-consumption vehicles
17. Notifying consumers of the fuel consumption of vehicles they want to purchase
18. Fuel consumption management system through deploying fuel cards for all vehicles
19. Proper equipment along with experienced and knowledgeable manpower for the research and development of low-consumption vehicle production
20. Governmental support for local vehicle industry
21. Proper technology of automakers (such as Iran Khodro, SAIPA and etc.)
22. Systematic relations of local automakers with their international partners (such as Peugeot, Renault, KIA and etc.)
23. Using financial instruments (such as the 'Targeted Subsidy Reform Plan') for controlling fuel price

Weaknesses:

1. Weakness of the Iran's vehicle industry in meeting national fuel consumption standards

2. Weak relation of the vehicle industry (as producer) with policymakers in the government and parliament
3. Limited financial sources of the vehicle industry for investing in low-consumption vehicles
4. Weak development of the ‘Gasoline vehicles – Criteria for fuel consumption; ISIRI 4241-2’ national standard
5. Lack of a comprehensive fuel consumption standard, owing to Iran’s climate and socio-economic conditions
6. Low fuel-efficiency of the LDV fleet and also new local vehicles
7. Driving high-consumption and old vehicles
8. Lack of renewable and bio-fuel infrastructure
9. Low quality of conventional fuels (gasoline and diesel)
10. Weak development of CNG stations in the country
11. Lack of diesel-fueled vehicles in the light passenger vehicles fleet
12. Weak variety of LDV classes in Iran
13. Very low fuel price in Iran in comparison with regional and global prices
14. Lack of legal requirements regarding CO_2 reduction in the transportation sector in the European Union (including threshold and time bound)
15. Lack of a national comprehensive pricing policy regarding all variables (including energy taxes, oil price, socio-economic conditions, etc.)
16. Early depreciation of bi-fuel vehicles
17. Fuels’ high wasting potential, according to huge numbers of high-consumption local LDVs
18. Weak official forces for preventing the registration new high-consumption local LDVs
19. Increasing CNG price
20. Distant legal limit on old vehicles in Iran (20 years), in contrast to the European Union (10 years)