1. Introduction

Scope of the report

This report has been developed in the framework of the United Nations Development Account (UNDA) project "***Development and implementation of a monitoring and assessment tool for CO_2 emissions in inland transport to facilitate climate change mitigation***". One of the main tasks of the project consisted in the development of the ForFITS (as acronym for Future Inland Transport Systems) model, an instrument intended to asses transport CO_2 emissions and to evaluate potential policies to mitigate them.

The report builds on the results of model runs applied to seven pilot cases. The preparation of these pilots followed the development of the ForFITS model and contributes to its validation, allowing to test its response in several world regions with differing socio-economic characteristics and under the influence of a wide variety of hypotheses. Key parameters discussed in this report include in particular transport activity, energy use and CO_2 emissions.

The report concludes with the formulation of a set of suggestions for the definition of transport policies having implications for climate change mitigation, leveraging on the results of the pilot runs.

Pilot cases

The pilots were developed in parallel with the organization of awareness-raising events and capacity building/technical workshops on the ForFITS model. Such meetings were organized by the United Nation Economic Commission for Europe (UNECE) and the other Regional Commissions of the United Nations.

Awareness-raising events included the presentation of the ForFITS tool, framing it in a broader discussion on the analysis of transport and climate related issues. The technical workshops focused on hands-on experience on the ForFITS model. The pilot cases were used as a basis for the training activities undertaken in this framework.

The pilot country tested in each technical workshop was selected by the UN Regional Commission organizing the event. With the exception of UNECE, the other UN agencies chose the country where they are based and where the event took place: Chile for ECLAC, Ethiopia for UNECA, Thailand for UNESCAP and Tunisia for UNESCWA. The main reasons for that were mainly administrative concerning the easy organization of the workshop in the UN premises, the fluent conversations with national administrations, the simplicity to contact local experts and the rapid access to sources providing national data.

As leading agency UNECE extended the pilot to three different countries, each of them tested separately. These countries are France, Montenegro and Hungary. The first was picked due to the good availability of data and was especially important for the model development. The pilot cases of Montenegro and Hungary were developed at a later stage, in conjunction with national administrations or academic experts.

Table 1.1 contains a summary of the date and location of the technical workshops in which pilot cases were discussed. These events gave the opportunity to discuss preliminary results with local technical experts and researchers. In some occasions (Chile, Hungary, Montenegro, and Tunisia), the development of pilot analyses benefited from the contribution of local consultants, primarily for the data gathering process.

Table 1.1

Date of the capacity bulding/technical workshop where the pilot was presented	*Location where the meeting took place*	*Pilot country selected*	*Corresponding United Nations Regional Commission*
5–28 August 2013	Santiago	Chile	Latin America and the Caribbean
23–24 September 2013	Bangkok	Thailand	East Asia and Pacific
8–10 October 2013	Geneva	France	Europe
1–2 November 2013	Addis Ababa	Ethiopia	Africa
19–20 November 2013	Pogdorica	Montenegro	Europe
4–5 December 2013	Hammamet	Tunisia	West Asia
No workshop	*No workshop*	Hungary	Europe

Structure

The data in the ForFITS input file are divided into four different categories depending on the importance of user involvement:

- "M": data absolutely required.
- "A": inputs expected to be introduced by the user.

  The current value in the ForFITS Inputs file is for guidance only. This category includes policy inputs that allow exploring different scenarios.
- "B": inputs containing a (often technical) default value that may remain unchanged, depending on data availability.

  Defaults are set on the basis of research activities involving literature reviews and statistical analyses.
- "C": inputs capable to modify the structural characteristics of the model.

  Unless the user acquires sufficient experience, modification of these inputs is not recommended.

"M" inputs were considered as a priority in the development of the pilot analyses. These inputs are necessary to characterize the transport system under scrutiny and to define key parameters that allow performing model runs. Chapter 2 aims to provide information on the sources used and the assumptions/estimations that have been necessary to characterize "M" inputs in the base year.

"A" inputs are related to the definition of scenarios and transport policies to be simulated in the model run. "B" inputs are mainly related with technical information (such as fuel saving potentials of different powertrain options and related costs). Their evaluation results from analytical work, literature reviews and research activities. The characterization of both "A" and "B" inputs will be addressed in Chapter 3 of this report. The same chapter will also discuss the definition of "M" inputs that include projections over time.

"C" inputs refer mainly to elasticities and data maps used for the characterization of the ForFITS model. They result from literature review and an iterative process of calibration that benefited from several pilot runs. The values of "C" inputs currently available in the model shall be considered as one of the results of the modeling exercise that led to the release of ForFITS. A discussion on these values is provided in the methodological sections of the ForFITS user manual.

Chapter 4 builds on the results stemming from the information described in earlier Chapters to present a comparative analysis of the pilot runs.

Chapter 5 summarizes the messages resulting from the results described in Chapter 4 to synthesize policy recommendations resulting from the use of the ForFITS model.

2. Data gathering

The discussion of "M" inputs in the base year has been classified here in a way that corresponds to the structure adopted in the ForFITS input file (sheet " Table of contents"), as follows:

- time period;
- GDP and population;
- vehicle stock:
  - number of vehicles;
  - annual travel and load per vehicle;
  - fuel consumption;
- new vehicle registrations:
  - number of vehicles;
  - fuel consumption;
- transport system characteristics:
  - passenger;
  - freight;
- fuels:
  - prices and taxes;
  - emission factors;
- powertrains;
- modal and vehicle shares;
- pipelines.

The lack of data availability and the poor quality of the information led to the exclusion, in some pilot regions, of selected transport vehicles and modes. This is the case for bicycles, road modes, vessels, rail, air and pipelines. Table 2.1 provides a summary of the transport modes taken into account in each pilot region.

Table 2.1 Transport modes taken into account for each pilot country

	BICYCLES	ROAD	VESSELS	RAIL	AIR	PIPELINES
Chile	Yes	Yes	No	Yes	Yes	No
Ethiopia	No	Yes	No	Yes	Yes	No
France	Yes	Yes	Yes	Yes	Yes	Yes
Hungary	Yes	Yes	Yes	Yes	No	No
Montenegro	Yes	Yes	No	Yes	No	No
Thailand	No	Yes	Yes	Yes	Yes	No
Tunisia	No	Yes	No	Yes	Yes	Yes

Time period

Table 2.2 provides a summary of the base year chosen in each pilot region. This choice depended mainly on data availability.

Table 2.2 Initial year for each pilot country

Chile	Ethiopia	France	Hungary	Montenegro	Thailand	Tunisia
2010	2010	2010	2010	2010	2012	2010

The last year of the projections was 2040 in all pilot regions.

GDP and population

Population and GDP data were obtained from international databases that contain information for each country.

The sources of the population figures used for the characterization of the pilots were the World Bank (WB, 2012) and the United Nations (UN DESA PD, 2012).

The GDP in current USD and the GDP deflator were taken respectively from OECD Statistics (OECD, 2012) and the World Bank (WB, 2012b and 2012c).

The distinction between urban and non-urban areas is only applicable in the French case. The urban share of the total population is taken from the UN (UN DESA PD, 2011). The distribution of the GDP between urban and non-urban areas builds on the assumption that the GDP per capita in urban areas is 15% higher than in non-urban areas.

Information concerning the projections of the GDP and population parameters is provided in Chapter 3.

Vehicle stock

Number of vehicles

The number of vehicles in the stock at the base year is generally available from institutions collecting taxes from vehicles in operation, agencies managing vehicle registrations and statistical offices. Country level data on the number of vehicles in circulation can be also found in publications from the industry or in reports from international organizations that look at the transport sector at the international level.

In some occasions, the data available from official sources may overestimate the rolling vehicle fleet. This happens when registration data do not take into account vehicles that have been scrapped (see for instance Boughedaoui, 2013, on Algerian data).

The discussion held during the national workshops highlighted that this is likely to be the case for two of the pilot regions: Thailand and Tunisia. In such cases, the number of vehicles retained for the pilot runs was reassessed. This correction followed discussions with local administrations and local experts. In Thailand, the number of active passenger two wheelers and light passenger vehicles (passenger LDVs) was estimated as 65% of the value contained in published information on vehicle registrations (DLT, 2013). Similar ratios were applied to other modes (55 % in case of passenger three wheelers, and 70% for road freight vehicles).

In Tunisia, the estimated number of vehicles is 20% to 30% lower than the data of the Agence Technique des Transports Terrestres (ATTT, 2014).

Table 2.3 provides detailed information on the sources of information used to estimate the number of active vehicles in each pilot region.

Table 2.3 Vehicle stock by mode, vehicle class and powertrain for each pilot country

Chile	Asociación Nacional Automotriz de Chile (ANAC, 2012) Instituto Nacional de Estadísticas (INE, 2012) Ministerio de Transportes y Telecomunicacones (SECTRA, 2010) Local consultant
Ethiopia	Presentation under the Global Fuel Economy Initiative framework on Ethiopia as pilot country (Daniel Redda, 2012) Central Statistical Agency of Ethiopia (CSA of Ethiopia, 2012)
France	Comité des Constructeurs Français d'Automobiles (CCFA, 2013) European Commission (EC, 2009) International Energy Agency (IEA, 2011)
Hungary	EU statistical pocketbook (EC, 2013) Local consultant
Montenegro	Statistical Office of Montenegro (MONSTAT, 2012) Local consultant
Thailand	Department of Land Transport (DLT, 2013)
Tunisia	Agence Technique des Transports Terrestres (ATTT, 2014) Institut National des Statisticques(INS, 2012) Local consultant

Where possible, the sources listed in Table 2.3 were also used to assess the shares of vehicles in the stock by powertrain technology, in combination with the data resulting from a detailed report on the fuel consumption of light passenger vehicles by the International Energy Agency (IEA, 2011). All trucks and buses were considered to be diesel when data on powertrain shares could not be found. Rail in Chile was assumed to be 100% electric, while local and intercity trains in France were estimated to be half diesel and half electric.

Concerning non-motorized transport modes, it was assumed that 90% of the total population walked. For cycling, simplifying assumptions on the number of people actively using bicycles were introduced in Chile, France and Hungary[1].

Annual travel and load per vehicle

Information on the average annual travel per vehicle can be obtained through household/travel surveys. However, these data are not frequently available. For the pilot exercise, the average travel per vehicles was primarily estimated on the basis of the following considerations:

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[1] These estimations were mainly aimed to assure the correct methodological functioning of ForFITS. They would require a much deeper investigation to provide informative results on the role of non-motorized transport.

1. Using available information from household/travel surveys in developed countries as a reference (see UNECE, 2012 for information on the availability of these data).
2. By means of assuming a certain speed (km/h) and vehicle usage (hours/day and days/week), taking into account that the average speed of vehicles is influenced by the characteristics of the vehicles and the level of development of the infrastructure (for instance: i) a highly developed motorway network is associated with higher average speeds for long haul trucks; ii) buses have a similar usage profile to long haul trucks, but lower average speeds due to the higher frequency of stops).
3. By making sure that the assumptions and the statistics on the number of vehicles in the stock, their average travel and their average fuel consumption are consistent with the total energy use by fuel blend in each mode at the base year (data on the total energy use by fuel blend in each mode at the base year are regularly published by the International Energy Agency: IEA, 2013).

These considerations lead to ranges of annual travel per vehicle that is between 50000 km/year and 60000 km/year for buses, 20000-30000 km/year for light commercial/freight vehicles, 60000-90000 km/year for medium duty trucks and 80000-130000 km/year for heavy duty trucks. The annual travel per vehicle of passenger LDVs is estimated to be close to 20000 km/year in areas with relatively low fuel taxation and low population density. In densely populated areas with high fuel taxation, the annual vehicle travel is expected to be closer to 10000 km/year.

The average load per vehicle is estimated on the basis of the share of total km driven empty and the average load on laden trips, taking into account the carrying capacity of different vehicle classes.

Information on vehicle, passenger and freight activity, expressed in vkm, pkm and tkm, respectively, may be published by statistical offices, transport agencies, some insustry associations (e.g. dealing with a specific mode, like rail), international organizations such as the International Transport Forum and other sources. These data are used in combination with the data on the number of vehicles to confirm the assessments made on the average travel and to estimate average vehicle loads. The average annual travel and load per vehicle are calibrated to hit published information on transport activity according to the following equations:

$$vkm = number\ of\ vehicles\ in\ the\ stock \times average\ annual\ travel\ per\ vehicle$$

$$pkm/tkm = vkm \times average\ vehicle\ load$$

Table 2.4 provides a summary of the method used to calibrate the annual travel and load per vehicle at the base year for each of the pilots:

Table 2.4 Average annual travel and load per vehicle for each pilot country

Chile	Travel	Number of vehicles as estimated earlier and vkm provided by a local consultant
	Load	Default values based on European estimates (capacity according to the definition of the vehicle classes and application of load factors)
Ethiopia	Travel	Number of vehicles as estimated earlier and vkm published in the Central Statistical Agency of Ethiopia (CSA of Ethiopia, 2012) Information for public transport by UITP (UITP, 2010)
	Load	Vkm as mentioned earlier and pkm/tkm published in the Central Statistical Agency of Ethiopia (CSA of Ethiopia, 2012) Information for public transport by UITP (UITP, 2010)
France	Travel	Based on assumptions on vehicle speed and vehicle usage Minstére du développement durable (MDD, 2012)
	Load	Based on the capacity according to the definition of the vehicle classes and the application of estimated load factors
Hungary	Travel	Based on assumptions on vehicle speed and vehicle usage
	Load	Based on the French case, but adjusted according to the lower average personal income Number of vehicles as estimated earlier, average vehicle travel as mentioned, and pkm/tkm published in the EU statistical pocketbook (EC, 2013)
Montenegro	Travel	Based on assumption on vehicle speed and vehicle usage In case of rail, checked against the pkm/tkm available from the International Union of Railways (UIC, 2008)
	Load	Based on the French case, but adjusted according to the lower average personal income In case of rail, checked against the pkm/tkm available from the International Union of Railways (UIC, 2008)
Thailand	Travel	Based on assumption on vehicle speed and vehicle usage
	Load	Analogies with other countries at the same income level Number of vehicles as estimated earlier, average vehicle travel as mentioned, and pkm/tkm as published by ASEAN-Japan Transport Partnership (AJTP, 2012) and the Ministry of Transport (MOT, 2012)
Tunisia	Travel	Based on assumption on vehicle speed and vehicle usage Analogies with estimates in other countries and expert judgment from local consultant In case of rail, information checked against data from Statistiques Tunisie (INS, 2012)
	Load	Analogies with other countries at the same income level and expert judgment from local consultant In case of rail, information checked against data from Institut National de la Statistique (INS, 2012)

Fuel consumption

The estimation of the average vehicle fuel consumption is derived from two main approaches:

1. Bottom-up

   This builds on information on the number of new vehicles registered in past years, the associated average fuel consumption, and relevant scrappage assumptions (depending on the vehicle age).

   The vehicle fuel consumption of newly registered light passenger vehicles can be estimated for selected countries from detailed reports such as the one issued by the International Energy Agency (IEA, 2011).

   Information on the fuel consumption of public transport modes, available from specific studies (such as Kenworthy, 2003), was used as comparative reference for the estimation of the consumption in other modes. In addition, the bottom-up assessment benefited from technical considerations on the mass, the frontal surfaces and the speed profiles of vehicles, as well as the varying needs to overcome inertial forces, rolling resistance and aerodynamic drag in a varying range of transport missions (i.e. on motorways, in congested urban areas, and in conditions located in between these extremes).

   The data calculated with the bottom-up approach were also compared for consistency with estimates made by local consultants for specific pilot regions.

2. Top-down

   This approach relies on the use of historical values of total energy use in combination with information on vehicle activity:

   $$energy\ use = vehicle\ activity\ (vkm) \times vehicle\ fuel\ consumption\ (lge/vkm)$$

   This method was used to validate the bottom-up calculations for the estimates of the average fuel consumption of the vehicle stock. When bottom-up estimations were not feasible due to the lack of information, the top-down method was extended to new vehicle registrations before the base year, assuming that there were no changes in the average fuel consumption of vehicles registered in the decades preceding the base year.

   As already mentioned, statistics on the total energy use by fuel blend in each mode at the base year, necessary for the use of the top-down approach, are regularly released by the International Energy Agency (IEA, 2013).

New vehicle registrations

Number of vehicles

The number of new vehicles registered in the past for Hungary and France was obtained from the data published by the European Automobile Manufacturers Association (ACEA, 2012), the European Environment Agency (EEA, 2012), Eurostat (Eurostat, 2011) and the EU statistical pocketbook (EC, 2013).

The historical vehicle registrations in Chile are available from automobile industry association (ANAC, 2012). In case of rail, the assumptions are based on stock and new registration/stock ratio estimated for Europe.

In Tunisia, the data were collected by local consultant having access to a national database (ATTT, 2014).

The historical vehicle registrations, the number of vehicles in the stock and assumption on vehicle scrappage curves allowed evaluating the maximum scrappage age and the average vehicle life. Checking these variables against reasonable average vehicle lifetimes may help calibrating information on new vehicle registrations in the past when published data are not available. This was the method used for Ethiopia, Montenegro and Thailand, where the calibration was performed ensuring coherence with the available data on stock disaggregated by age.

Data on the number of vehicles by vehicle age was used to determine reasonable average vehicle lifetimes. Such information was collected from the following sources:

- Ethiopia: presentation given in the Global Fuel Economy Initiative framework (Redda, 2012) and presentation on the final draft report on pilot Global Fuel Economy Initiative Study in Ethiopia (Alemu Amibe, 2012);
- Montenegro: presentation of the transport sector research environment in Montenegro (Nikolic, 2009);
- Thailand: statistics from the Department of Land Transport (DLT, 2012).

Fuel consumption

In developed countries, information on the fuel consumption of newly registered light passenger vehicles is available from energy efficiency databases (e.g. Odyssee, 2010), analyses of environmental NGOs dealing with transport, such as the International Council on Clean Transportation (ICCT, 2013) and Transport and Environment (T&E, 2013), and international organizations like the IEA (e.g. IEA, 2011 and IEA, 2004). In Europe, fleet averages are also published by the European Environment Agency (EEA). The same information for other modes and services is much less frequently available.

The estimates worked out for the pilots were based on available data when available from the sources mentioned earlier, or assumed to be equal to the average value evaluated for the vehicle stock when historical data were not available. The information for the French case was also checked against national sources such as the "Minstére du développement" durable (MDD, 2012) and the "Agence de l'Environnement et de la Maîtrise de l'Energie" (ADEME, 2013).

The fuel consumption of the vehicles registered within the last ten years is combined by ForFITS with the average fuel consumption of the vehicle stock to estimate the fuel consumption per km of vehicles older than ten years. The reasonable value of these estimates was also ensured while developing pilot datasets.

Transport system characteristics

Passenger

France is the only pilot country where the information concerning all passenger transport data required a differentiation between urban and non-urban areas. All other pilots were evaluated considering non-specified inputs.

Freight

The shares of tonnes lifted by good type were obtained from Eurostat (Eurostat, 2011) in the case of France and Hungary. The information for Montenegro and Tunisia data from the World Trade Organization (WTO, 2012) that were elaborated adding estimates on unit costs of different traded commodities. Rail data were the only information found in Ethiopia (CSA of Ethiopia, 2012). For all other large freight sub-modes, the shares of tonnes lifted by good type were allocated to the category "other". This was also the case for all freight modes in the Chilean pilot. In the case of Thailand, the source of these data is the Ministry of Transport of Thailand (MOT, 2012).

Fuels

Prices and taxes

The fuel cost before taxes is calculated on the basis of technical estimates based on average primary energy prices, assumptions on margins and published information on the prices of transport fuels. The fuel taxation is distinguished between passenger and freight, excluding the value added tax component from freight tax rates. This was the case of Chile, France, Hungary and Montenegro.

Data on fuel prices and taxes were taken from publications of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, 2009 and 2013) and statistics released by the International Energy Agency (IEA, 2013b). For the European countries, these data were also checked against a report by the World Bank (WB, 2013). In Chile, the Comisión Nacional de Energía (CNE, 2014) releases information on fuel prices. In Thailand, the data leveraged on the information on fuel subsidies published by the International Institute for Sustainable Development (IISD, 2013).

Projections of fuel prices and taxes depend on the definition of the pilot scenarios and are discussed in Chapter 3 of this report.

Emission factors

Emission factors were obtained in the same source for all the pilot regions.

The Tank-To-Wheel (TTW) emission factors depend on the combustion of fuels and were derived from the guidelines published by the Intergovernmental Panel on Cimate Change (IPCC, 2006).

The Well-To-Tank (WTT) factors refer to upstream emissions. They vary for different fuels. The data used for all pilots refer to blends not containing any biofuel and were relying on the specific technical estimates of Edwards et al. (JRC, 2011).

The evolution of the fuel characteristics over time is discussed in Chapter 3 of this report.

Powertrains

The ForFITS model enables the user to decide running the model with endogenous or exogenous powertrain selection. All the pilots were performed with exogenous technology choice according to different scenarios detailed in Chapter 3 of this report.

The powertrain shares concerning the new vehicle registrations at the base year are determined on the basis of the number of vehicles registered, disaggregated by technology. This is an input already discussed in the section concerning new vehicle registrations.

The powertrain availability is an input that only matters when the endogenous technology choice is selected by the user. Since the powertrain selection was always treated exogenously, this input is not relevant for any pilot.

Modal and vehicle shares

The evolution of the modal shares depends on the definition of the scenarios and is discussed in Chapter 3. As in the case of powertrains, modal and vehicle shares in the base year are determined on the basis of the information on the number of vehicle, the average travel and the average loads discussed earlier.

Pipelines

This input is only relevant for France and Tunisia, the only pilot regions containing inputs on pipelines. The average distance travelled by each volume unit is estimated to be 200 km in case of oil pipelines and 1000 km for natural gas pipelines. The extension of the network is assumed not to vary over time and therefore the average distance travelled remains always constant at the base year value.

3. Definition of the scenarios

All pilot cases were run on the basis of a consistent set of hypotheses, defining five sets of scenarios in each pilot:

A. Reference;

B. Oil up;

C. Oil up and shift;

D. Oil up, shift and tech;

E. Oil up, shift, tech and biofuels.

The key elements characterizing each of these sets of scenarios, including details on how they are applied to each specific pilot case, are provided in the following sections of this Chapter. The Chapter also provides an overview of the elements that are common to all scenarios.

Common elements for all scenarios

GDP and Population projections

All scenarios were developed taking into account the same population and GDP projections in each pilot region.

Population projections relied on information published by the World Bank (WB, 2011) and the United Nations Population Division (UN DESA PD, 2012).

GDP projections were taken from publications issued by the Organization for Economic Cooperation and Development (OECD, 2011), HSBC (HSBC, 2012) and PWC (PWC, 2013).

Fuel consumption characteristics and associated costs

Fuel consumption characteristics by powertrain were defined according to the same set of assumptions, reflecting a general improvement of powertrain technologies in the period from 2010 to 2040 to mimic the progressive introduction of improvements in vehicle technology. Table 3.1 provides a summary of the improvement taken into account for all powertrain technologies in the case of passenger light duty vehicles.

Assumptions on the costs associated with the introduction of these improvements on representative vehicles of the same mode and service are shown in Table 3.2[2].

Both the assumptions on fuel consumption improvements and costs are based on information collected from literature sources. References to relevant assessments have already been provided in the review on statistics, mitigation polices, and modelling tools published by the UNECE in 2012 under the project development framework that also

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[2] Similar assumptions were used for all other services, modes and vehicle classes. The full detail of the fuel consumption improvement and the costs associated with it is available in the input files of each pilot case.

included the development of the ForFITS model (UNECE, 2012). They are all primarily focused on developed vehicle markets (namely Europe and North America).

Table 3.1 Fuel consumption improvement for passenger light vehicles (cars) over time with respect to a conventional gasoline PI ICE at the base year

	FUEL CONSUMPTION IMPROVEMENT		
PASSENGER LDVS: POWERTRAIN GROUP	BASE YEAR	2025	2040
GASOLINE PI ICE	0%	23%	28%
GASOLINE PI ICE-HYDRAULIC HYBRID	24%	31%	35%
GASOLINE PI ICE-ELECTRIC HYBRID	33%	39%	43%
METHANE PI ICE	3%	25%	30%
METHANE PI ICE-HYDRAULIC HYBRID	26%	33%	37%
METHANE PI ICE-ELECTRIC HYBRID	35%	41%	45%
LPG PI ICE	0%	23%	28%
LPG PI ICE-HYDRAULIC HYBRID	24%	31%	35%
LPG PI ICE-ELECTRIC HYBRID	33%	39%	43%
DIESEL CI ICE	21%	33%	36%
DIESEL CI ICE-HYDRAULIC HYBRID	38%	37%	38%
DIESEL CI ICE-ELECTRIC HYBRID	46%	43%	44%
DME CI ICE	21%	33%	36%
DME CI ICE-HYDRAULIC HYBRID	38%	37%	38%
DME CI ICE-ELECTRIC HYBRID	46%	43%	44%
HYDROGEN ICE	3%	25%	30%
HYDROGEN ICE-HYDRAULIC HYBRID	26%	33%	37%
HYDROGEN ICE-ELECTRIC HYBRID	35%	41%	45%
FC	49%	49%	59%
FC-ELECTRIC HYBRID	69%	69%	73%
ELECTRIC	72%	72%	75%
GASOLINE PI ICE-ELECTRIC HYBRID PLUG-IN	41%	46%	50%
METHANE PI ICE-ELECTRIC HYBRID PLUG-IN	43%	47%	51%
LPG PI ICE-ELECTRIC HYBRID PLUG-IN	41%	46%	50%
DIESEL CI ICE-ELECTRIC HYBRID PLUG-IN	51%	49%	50%
DME CI ICE-ELECTRIC HYBRID PLUG-IN	51%	49%	50%
HYDROGEN ICE-ELECTRIC HYBRID PLUG-IN	43%	47%	51%
FC-ELECTRIC PLUG-IN HYBRID	69%	69%	73%

The use of these figures for all pilot regions is therefore a simplification of the reality that was required by the limited time available for the development of the pilot cases. Improvements and costs may indeed differ significantly in pilot regions characterized by very different economic and regulatory conditions. Emerging markets may be characterized by larger fuel consumption improvements for the same cost assumed in the pilot scenarios. First, the possibility to transfer powertrain technologies already developed for the main vehicle markets may allow improving the characteristics of vehicles sold on emerging markets while benefiting from the cost reductions due to technology learning that have already taken place in developed markets. Second, the regulatory requirements in emerging markets are generally less stringent than those characterizing developed markets, reducing the unit cost of vehicles.

Should in-depth analyses be carried out on the same pilot regions, this aspect of the modelling assumptions will require a refinement. Such refinement should also take into account the frequent practice of distributing, in emerging markets, reconditioned vehicles and second hand vehicles removed from developed markets. This does allow introducing vehicles with a much lower unit cost in new markets, but it also limits the transfer of advanced fuel saving technologies, influencing the fuel consumption reduction potential[3].

Table 3.2. Incremental costs of powertrain technologies for passenger light vehicles (cars) over time with respect to a conventional gasoline PI ICE at the base year

	INCREMENTAL COST	
PASSENGER LDVS: POWERTRAIN GROUP	BASE YEAR	2040
GASOLINE PI ICE	0	1800
GASOLINE PI ICE-HYDRAULIC HYBRID	1700	2500
GASOLINE PI ICE-ELECTRIC HYBRID	2300	3100
GASOLINE PI ICE-ELECTRIC HYBRID PLUG-IN	7500	8100
METHANE PI ICE	1700	3500
METHANE PI ICE-HYDRAULIC HYBRID	3400	4200
METHANE PI ICE-ELECTRIC HYBRID	4000	4800
METHANE PI ICE-ELECTRIC HYBRID PLUG-IN	9200	9800
LPG PI ICE	1400	3100
LPG PI ICE-HYDRAULIC HYBRID	3100	3900
LPG PI ICE-ELECTRIC HYBRID	3600	4400
LPG PI ICE-ELECTRIC HYBRID PLUG-IN	8800	9500
DIESEL CI ICE	1300	2800
DIESEL CI ICE-HYDRAULIC HYBRID	3000	3500
DIESEL CI ICE-ELECTRIC HYBRID	3600	4200
DIESEL CI ICE-ELECTRIC HYBRID PLUG-IN	8800	9200
DME CI ICE	2700	4200
DME CI ICE-HYDRAULIC HYBRID	4400	4900
DME CI ICE-ELECTRIC HYBRID	5000	5500
DME CI ICE-ELECTRIC HYBRID PLUG-IN	10200	10600
HYDROGEN ICE	8200	10000
HYDROGEN ICE-HYDRAULIC HYBRID	9900	10700
HYDROGEN ICE-ELECTRIC HYBRID	10500	11300
HYDROGEN ICE-ELECTRIC HYBRID PLUG-IN	15700	16300
FC	82300	83100
FC-ELECTRIC HYBRID	44800	44900
FC-ELECTRIC PLUG-IN HYBRID	4500	49300
ELECTRIC	16500	16500

The same reasons explaining the choice of the simplifications introduced in the definition of fuel consumption improvements and costs in the different pilot regions also explain the choice to use the model in its "exogenous mode". Using ForFITS with the endogenous selection of powertrains to produce informative results is only feasible when the datasets on fuel consumption and powertrain technology costs are adequately developed. The use of data developed only for established markets led to the choice to use the "what-if" features

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[3] The second hand vehicle market is not modeled separately in ForFITS. Changes related with second hand imports need to be reflected by the modeler in other modelling assumptions.

of ForFITS, allowing the calculation of the impacts of switching across powertrain technology via the definition of specific technology penetration scenarios (the *tech* scenarios) rather than evaluating the technology penetration associated with fuel consumption characteristics and costs (endogenous approach).

Freight transport system characteristics

Projections on the parameters defining the freight transport system characteristics have been maintained constant in all scenarios.

This means that, for all pilot regions, no changes were assumed for the shares of tonnes lifted by transport zone, the shares of tonnes lifted by haul distance, the shares of tonnes lifted by good type and the shares of tonnes lifted by large-freight sub-mode (medium trucks, heavy trucks, rail, inland waterways, short sea shipping and other maritime transport). On the other hand, freight transport projections do take into account for the change of the total amount of tonnes lifted, since this is assumed to be proportional to the growth of the GDP.

This assumption is a simplification due to the limited information available on the structure of the economy associated with GDP projections, but also to the limited data available in some pilot regions for what concerns the vehicles, the average travel and the average loads in some of the freight modes (namely navigation). Should in-depth analyses be carried out on the same pilot regions, more work will be needed to characterize the freight transport system at the base year (this is important for the initial allocation of tonnes lifted across the different modes) and to understand whether the GDP projections taken into account shall be associated with structural changes of the economic system under consideration.

Modal and vehicle shares

Projections on modal and vehicle shares have been maintained constant in all scenarios.

In the case of model shares, this excludes the effect of structural changes in the passenger transport system (accounted for in the *shift* scenarios) and is limited to the distribution of shares within the ForFITS "driving passenger modes" (i.e. modes related with personal vehicles, modes related with public transport modes, and the air mode).

In the case of vehicle shares, vehicles were nearly always categorized in the class representing each mode as a whole. In such a situation, there is no interest in exploring a migration towards other classes. In the few cases where information on different vehicle classes have been estimated (such as France), maintaining constant projections for the different classes means that the scenarios consider that the relative importance of the vehicles belonging to the different classes, without considering switches between a certain vehicle class and another.

Should in-depth analyses be carried out on the same pilot regions, this aspect of the modelling assumptions may also require a refinement, especially for modes where the difference amongst classes is reflected not only in a change of the number of vehicles, but also in variations of the average vehicle travel and load. This is particularly relevant for passenger public transport modes (e.g. for different kinds of buses and coaches and across rail vehicles such as tramways, metros, suburban trains, intercity trains and high speed trains).

Other inputs

Other inputs, including those defining road pricing, the network extension of pipelines and the crew cost per day were also maintained constant in all pilot runs.

Parameters that change across scenarios

Table 3.3 summarizes the parameters that are subject to a variation across the different scenarios considered for the pilot runs and provides details on the set of hypotheses that defines each of the scenarios under consideration. Shaded cells highlight the key changes from a scenario to another.

Table 3.3. Changes in the parameters defining the scenarios of the pilot runs

	Fuel prices and taxes	Passenger transport system index	Powertrain technology shares	CO_2 emission factors
Reference	Constant	Constant	Constant	Constant
Oil up	Oil price doubles by 2040	Constant	Constant	Constant
Oil up and shift	Oil price doubles by 2040	Closing the gap with high-density areas by 20%	Constant	Constant
Oil up, shift and tech	Oil price doubles by 2040	Closing the gap with high-density areas by 20%	Growing market share of fuel saving and switching technologies	Constant
Oil up, shift, tech and biofuels	Oil price doubles by 2040	Closing the gap with high-density areas by 20%	Growing market share of fuel saving and switching technologies	Growing share of biofuels in all fuel blends

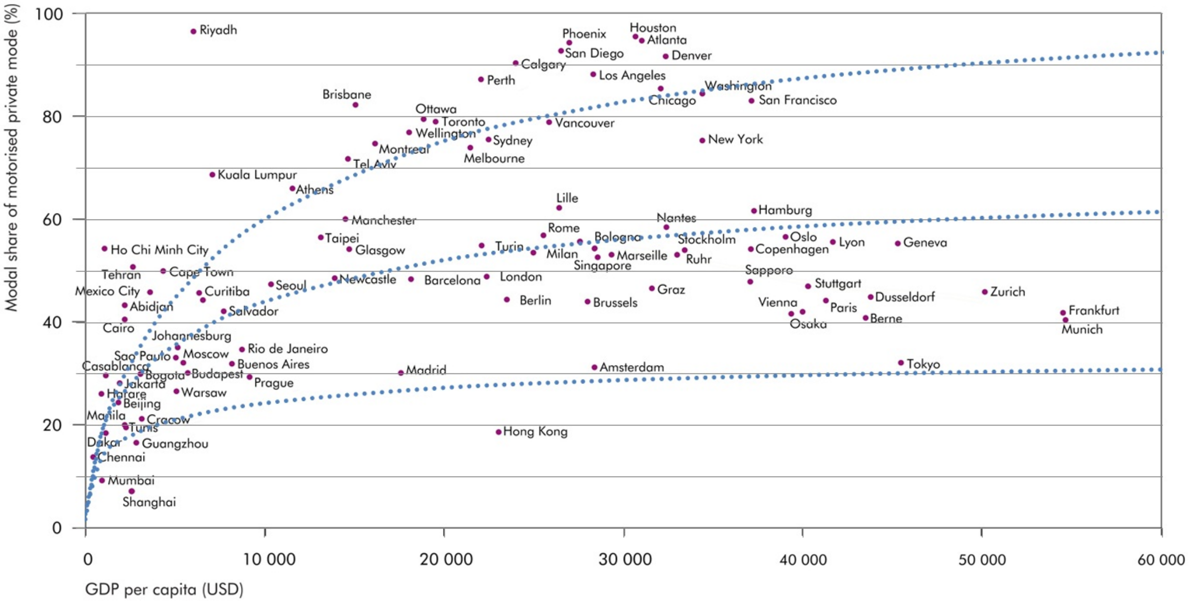
Reference

The Reference scenario considers:

- constant fuel prices and taxes, maintaining the levels identified for the base year;
- a constant passenger transport system index, reflecting a development of the share of transport on personal motorised passenger vehicles (as opposed to public transport, excluding air) that follows the driving curves of Figure 3.1 (further information on this aspect is extensively discussed in the ForFITS user manual);

- constant powertrain technology shares for all vehicles and all modes, maintaining the levels identified for the base year (but also taking into account the improvement of the fuel consumption characteristics of each powertrain technology described earlier);
- constant CO_2 emission factors, reflecting no changes in fuel blends with respect to well-to-tank and tank-to-wheel emission characteristics (and therefore excluding a switches towards more or less energy-and carbon-intensive fuel options).

Figure 3.1 **Pkm share of transport on personal motorised passenger vehicles in total pkm of personal motorised passenger vehicles and public passenger transport (excluding air transport)**



Sources: elaboration of UITP, 2006 (cited by IEA, 2008)

Oil up

The *oil up* scenario considers a doubling of the oil price from the base year to 2040. In between the base year and 2040, the evolution of the average oil price is assumed linear for simplicity. The changes in the oil price are assumed to influence directly the fuel cost of the gasoline and diesel fuel blends. The change in the oil price is not reflected in changes of the percentages of fuel taxation and subsidies: these percentages are maintained equal to those used in the Reference scenario.

The passenger transport system index, powertrain technology shares and CO_2 emission factors are the same of the Reference scenario.

The aim of the assumptions made in the *oil up* scenario is to test the response of the ForFITS model to changes in the fuel price. The choice to double the price of conventional fuels is not only a simplification, but it also does not take into account the impact of oil prices on other fuels, nor on possible changes in the fuel taxation profiles. This is why eventual in-depth studies performed on the pilot regions will require adequate complements to the inputs selected in this case.

Oil up and shift

The *oil up and shift* scenario considers an evolution of the passenger transport system index towards a condition where a significant fraction of the passenger transport task is performed by public transport modes. The practical implementation of this input relies on the possibility to modify the ForFITS "passenger transport system index", an instrument that was specifically developed to help understand the changes in the passenger transport system associated with shifts to/from private vehicles from/to public transport (see the ForFITS user manual for further details on this index)[4].

In the *oil up and shift* scenario, the gap between the value of the passenger transport system index calculated in the base year and the 0.7 value characterizing high density and public transport oriented regions is assumed to be progressively reduced by 20% between the base year and 2040. The evolution of the passenger transport system index between the base year and 2040 is assumed to be linear, for simplicity. In practice, this assumption represents the implementation of a wide number of policies favouring public transport over personal vehicles, such as parking and access restrictions for personal vehicles, land use policies that encourage the vertical development of the city and mixed use areas, and support for the provision of appealing, widely available and high-quality public transport services.

Table 3.4. Changes of the passenger transport system index in the *shift* scenarios

		Passenger transport system index		
		Base year	2040 (shift scenarios)	% change
Chile		0.59	0.61	4%
Ethiopia		0.67	0.68	1%
France	Urban	0.47	0.52	10%
	Non-urban	0.07	0.08	10%
Hungary		0.13	0.24	87%
Montenegro		0.03	0.16	457%
Thailand		0.26	0.34	35%
Tunisia		0.39	0.45	16%

The importance of this assumption differs in the pilot areas taken into consideration. Table 3.4 summarizes the changes of the passenger transport system index in the *oil up and shift* scenario, as well as all other scenarios including a *shift* component. The changes are larger in situations where the passenger transport system index at the base year is farther from the 0.7 target. This is the condition of regions where the information available at the base year

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[4] An index of 0 is associated with a share of pkm on personal vehicles that tends to 1 (100%) when GDP per capita increases, reflecting high shares of the average vehicle travel of personal vehicles. An index of 1 is associated with an evolution of the share of pkm on collective passenger transport vehicles of 100%, while pkm on personal vehicles is reduced to 0% (below the bottom blue dotted line of **Error! Reference source not found.**). This is an extreme case where the transport system fully operates on public transport. According to historical data, a high value of the passenger transport system index is close to 0.7, as in the case of the bottom blue dotted line of **Error! Reference source not found.**.

identifies a development of the mobility that is more oriented towards personal vehicles rather than public transport in comparison with other historical data.

Larger changes in the passenger transport system index are likely to be associated with larger emission reductions. Larger changes in the passenger transport system index also highlight the need for more policy interventions in comparison with cases characterized by lower variations in the passenger transport system index. On the other hand, it is also important to bear in mind that the development pattern assumed in the *reference* scenario for pilot regions already having a high passenger transport system index in the base year reflects a more optimistic outlook on policy interventions aimed to the promotion of public transport, rather than a development that does not require new actions.

The changes calculated for France, where the historical data and the assumptions used allowed an estimation of effects in urban and non-urban areas, are calibrated to a 20% reduction (in the period from the base year to 2040) of the gap between the base year passenger transport system index and the 0.7 target that is calculated for urban areas. This reflects limited changes in the passenger transport system index, even if its initial value is relatively low, and takes into account that promoting public transport can leverage on a much wider set of policy interventions in urban agglomeration than in non-urban areas, building on the higher potential for public transport supply that is associated with higher average densities of population. Looking at the national average, this means also that the reduction of the gap between the base year passenger transport system index and the 0.7 target is lower, in the assumptions concerning France, than in the assumptions made for other pilot regions.

As in previous scenarios, it is important to bear in mind that the primary aim of the assumptions made in the *shift* scenarios is to test the response of the ForFITS model to changes of input parameters. The considerations mentioned for the case of France, where urban and non-urban passenger transport were considered separately, may indeed be enlarged to other regions. Eventual in-depth studies will need to consider the data availability, possibly attempting to differentiate urban from non-urban passenger transport, and investigate which specific policy interventions could actually be hidden behind a change of an aggregated parameter as the passenger transport system index. Depending on the information available and considerations that are specific to each case considered, the indicative assumptions made here may then require modifications.

Oil up, shift and tech

The *oil up, shift and tech* scenario takes into account of a higher market penetration of advanced fuel saving and fuel switching technologies. This represents an important difference gap with the constant powertrain technology shares assumed in the *reference*, *oil up*, and *oil up and shift* scenarios.

In order to take into account of the diverse base year characteristics of the pilot regions, as well as the different economic and regulatory situations, the inputs characterizing the *tech* scenarios differ amongst pilots.

Developed regions are characterized by a quicker switch towards fuel saving and fuel switching technologies, while the transition is assumed to be delayed by 5 to 10 years in developing regions.

Table 3.5 provides an overview of the powertrain technology penetrations in developed regions by 2040. Table 3.6 illustrates the specific assumptions of the *tech* scenario for each pilot region. The values for the time period between the base year and 2040 are obtained with a linear interpolation, for simplicity. For rail, electrification rates exceeding the values reported in Table 3.5 are maintained across the projection period.

Table 3.5. Powertrain technology penetrations in developed regions by 2040

		POWERTRAIN TECHNOLOGY				ICE FUEL	
		ICE	ICE-ELECTRIC HYBRID	ICE-ELECTRIC PLUG-IN HYBRID	ELECTRIC	GASOLINE & DIESEL	METHANE
PASSENGER	TWO WHEELERS	25%	0%	0%	75%	100%	0%
	THREE WHEELERS	25%	0%	0%	75%	100%	0%
	LDVS	50%	40%	10%	0%	100%	0%
	VESSELS	100%	0%	0%	0%	100%	0%
	LARGE ROAD	0%	100%	0%	0%	67%	33%
	RAIL	0%	10%	0%	90%	100%	0%
FREIGHT	TWO WHEELERS	25%	0%	0%	75%	100%	0%
	THREE WHEELERS	25%	0%	0%	75%	100%	0%
	LDVS	50%	40%	10%	0%	100%	0%
	VESSELS	100%	0%	0%	0%	100%	0%
	MEDIUM TRUCKS	80%	20%	0%	0%	83%	17%
	HEAVY TRUCKS	100%	0%	0%	0%	67%	33%
	RAIL	0%	10%	0%	90%	100%	0%

Table 3.6. Assumptions on delays of the tech scenario for each pilot region

Chile	Ethiopia	France	Hungary	Montenegro	Thailand	Tunisia
No delay	10 years	No delay	No delay	5 years	5 years	5 years

Technologies are always assumed to enter the market through new vehicle registrations. The effect of this input is therefore mediated by the need to replace existing vehicles, especially in developed pilot regions, where the amount of vehicles per capita is already high. This effect is partly compensated by the lower market shares taken into account for less developed regions, where the importance of new registrations is larger due to the faster growth of the vehicle stock.

The *tech* scenarios have been developed using the "what-if" features of ForFITS. Eventual in-depth studies may build on this approach, refining it with specific regional information, or consider the use of the "endogenous" technology selection module available in ForFITS. As mentioned earlier, this would require a revision of the information concerning fuel consumption improvements and associated costs for the different powertrain options. Additional investigations may also contemplate the use of differentiated assumptions for the evolution of the costs of the powertrain technology options at different points in time across the projections.

Oil up, shift and tech and biofuels

The *oil up, shift, tech and biofuels* scenario considers the introduction of biofuels in all liquid and gaseous fuel blends taken into account by the *tech* scenario assumptions: gasoline, diesel, and methane. In addition, it considers a reduction by 20% of the well-to-tank emission factor of electricity generation.

In the *oil up, shift, tech and biofuels* scenario, biofuels are assumed to provide 20% of the energy content of liquid and gaseous fuel blends by 2040 in all pilot regions.

The switch to biofuels is implemented in the model by modifying exclusively the well-to-tank emission characteristics of the fuel blends. This is a simplification, since introducing biofuels in the energy mix is also likely to lead to changes in fuel costs and, eventually, on fuel taxation.

The variation of emission factors is calculated using the estimations of well-to-tank (WTT) emission factors published in Edwards et al. (2011), combining them with the tank-to-wheel (TTW) emission factors of the Intergovernmental Panel on Climate Change (IPCC, 2006) to obtain well-to-wheel (WTW) emission estimates, and considering the results of this calculation on the basis of the importance of the different components of the fuel mix. As TTW emission factors remain constant for each fuel blend, the WTT emission factor components resulting from the introduction of biofuels may be negative (i.e. including the absorption of carbon in the biomass). WTW emissions are always positive.

Table 3.7 provides a summary of the region specific characteristics that are taken into account to define the WTT factors used in different pilot cases. Table 3.8 summarizes the resulting emission factors.

Table 3.7. Powertrain technology penetrations in developed regions by 2040

Fuel blend	Pilot region	Biofuel composition
GASOLINE	All but Thailand	wheat (75%) and woody biomass (25%)
	Thailand	sugar cane
METHANE	All	biogas (woody biomass)
LPG	All	-
DIESEL	All but Thailand	rapeseed/sunflower (75%) and woody biomass (25%)
	Thailand	palm (75%) and woody biomass (25%)
DME	All	coal (CCS) (75%) and woody biomass (25%)
HYDROGEN	All	coal (CCS) (33%) and natural gas (67%)
ELECTRICITY	All	20% lower emission factor
KEROSENE	All	biokerosene (average of rapeseed/sunflower, palm and soybean (75%) and woody biomass (25%)

Table 3.8. Powertrain technology penetrations in developed regions by 2040

	Emission factors (kg CO_2/Lge)				
	TTW	WTT		WTW	
	All pilots	All pilots but Thailand	Thailand	All pilots but Thailand	Thailand
GASOLINE (BIO 20% OF ENERGY CONTENT)	2.28	0.09	-0.06	2.37	2.22
METHANE (BIO 20% OF ENERGY CONTENT)	1.84	0.11	0.11	1.95	1.95
LPG	2.07	0.55	0.55	2.62	2.62
DIESEL (BIO 20% OF ENERGY CONTENT)	2.43	0.01	0.10	2.44	2.54
DME (BIO 20% OF ENERGY CONTENT)	2.21	0.55	0.55	2.76	2.76
HYDROGEN (BIO 20% OF ENERGY CONTENT)	0.00	2.75	2.75	2.75	2.75
KEROSENE (BIO 20% OF ENERGY CONTENT)	2.36	0.10	0.10	2.46	2.46

4. Results

This Chapter introduces the model results for all pilot regions and each scenario described in Chapter 3. It includes several Figures, taken directly from the Vensim model, and Tables with data extracted from model variables.

It includes information on the evolution of key outputs over time (graphs with all the scenario results), tables with numerical information on the results, figures with information by service and mode, and analytical considerations explaining the main trends.

It provides elements allowing a comparative assessment of the impacts determined by the changes introduced in the scenarios described in Chapter 3, highlighting the reasons between the differences across pilot runs.

Chile

Scenario results

Figure 4.1 to Figure 4.8 show the evolution of passenger /freight activity (pkm/tkm), energy use (toe) and kg of CO_2 emissions (TTW and WTW) for the Chilean case in the five scenarios described in Chapter 3 (A, B, C, D, E).

Figure 4.1 Chile: total pkm

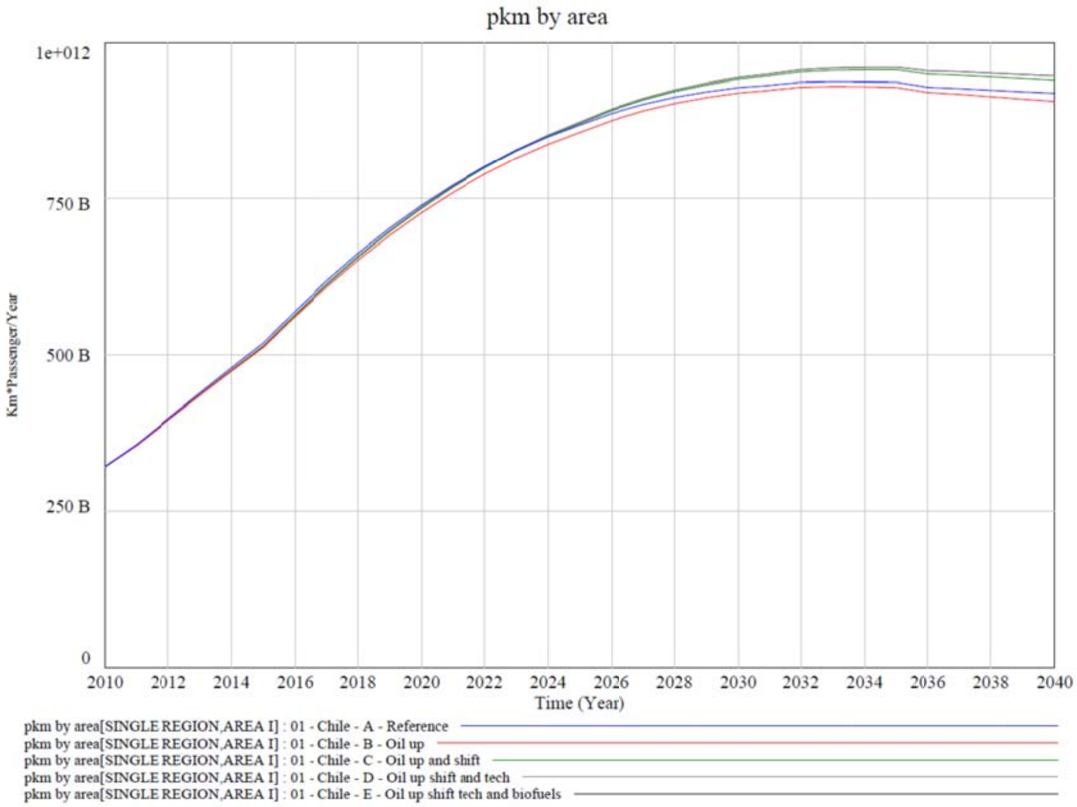


Figure 4.2 Chile: total tkm

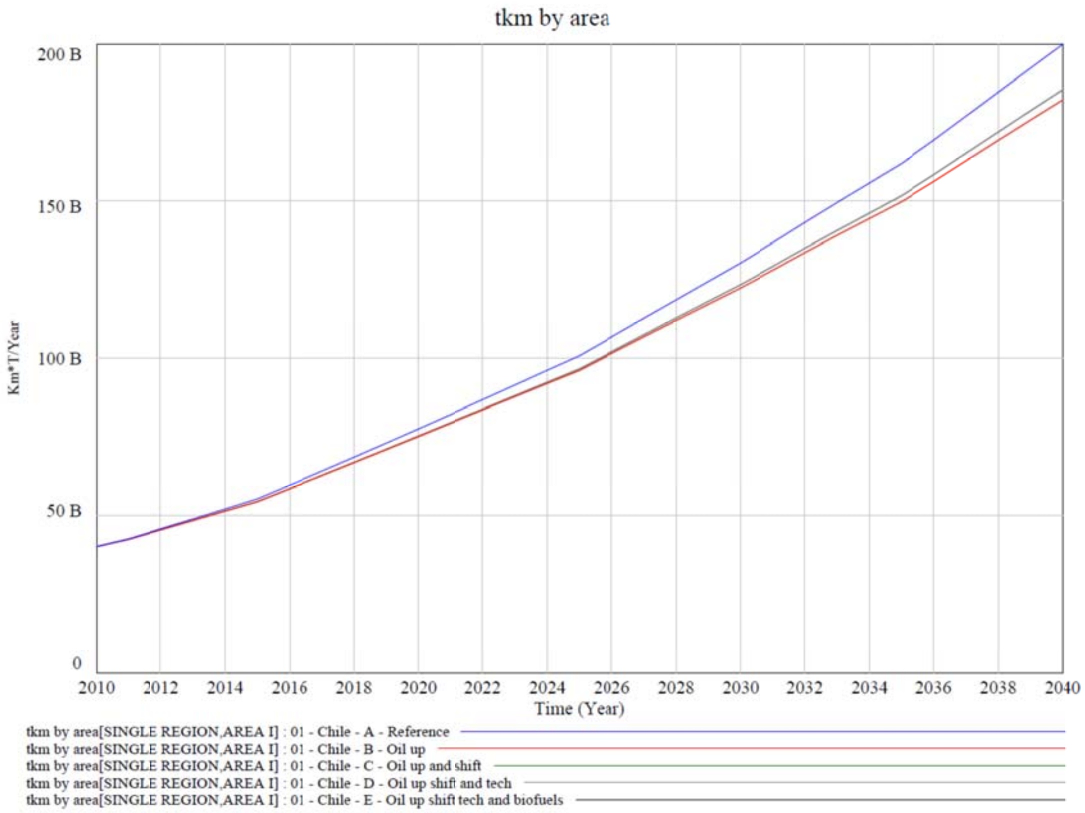


Figure 4.3 Chile: energy use in passenger transport (toe: tonnes of oil equivalent)

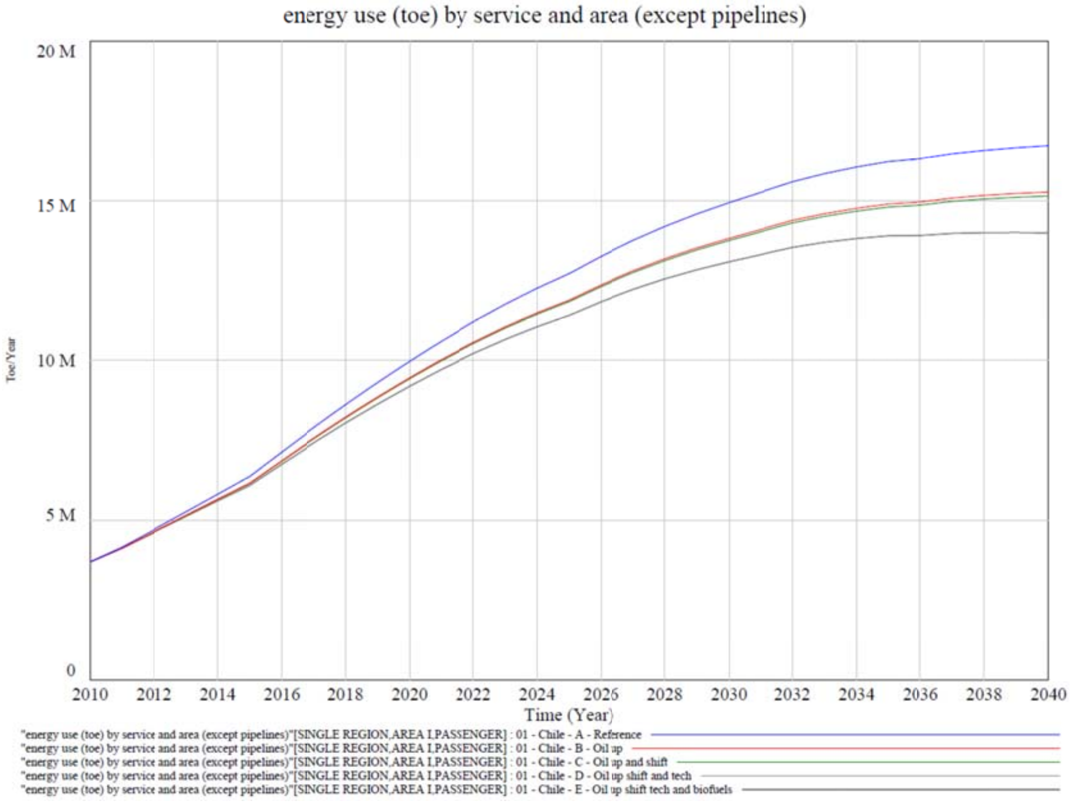


Figure 4.4 Chile: energy use in freight transport (toe)

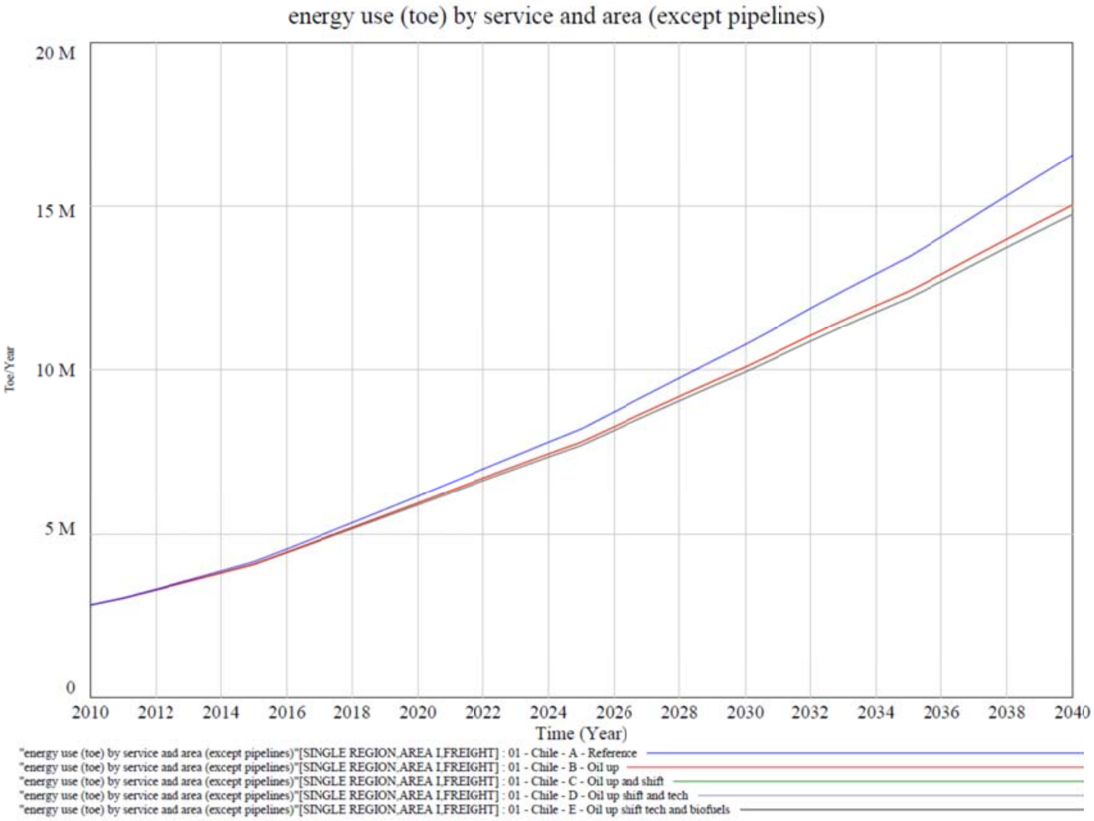


Figure 4.5 Chile: Tank-To-Wheel (TTW) CO_2 emissions in passenger transport (kg CO_2)

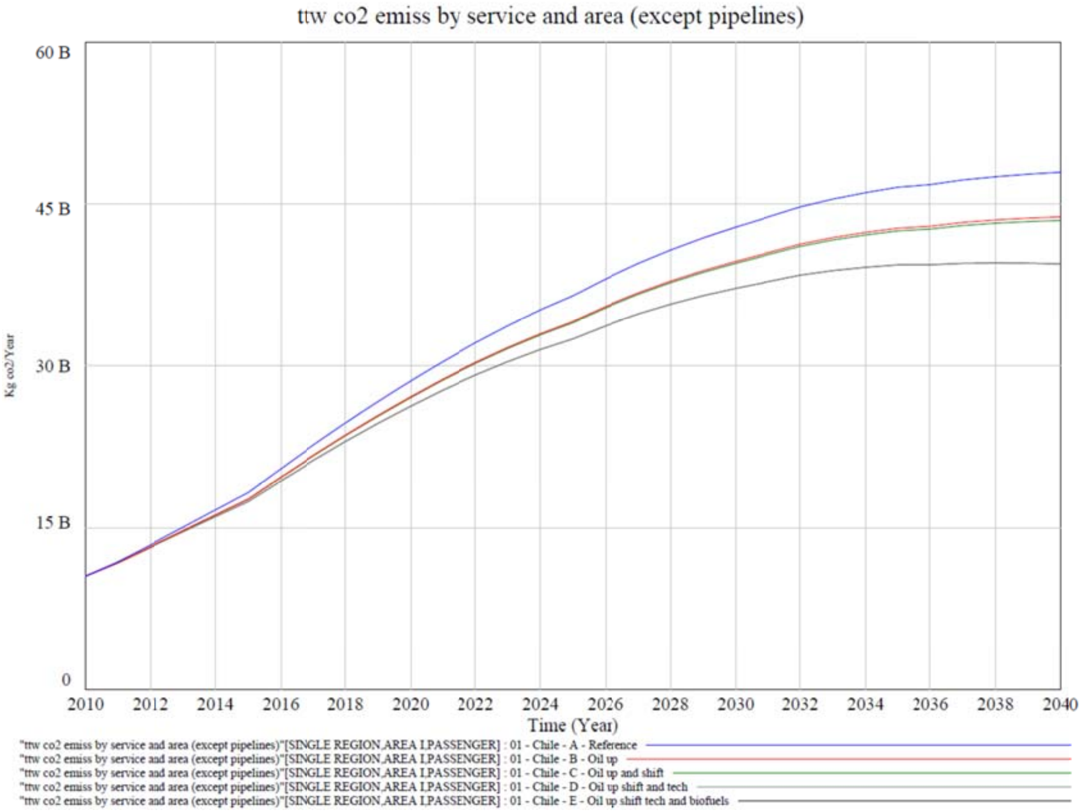


Figure 4.6 **Chile: TTW CO_2 emissions in freight transport (kg CO_2)**

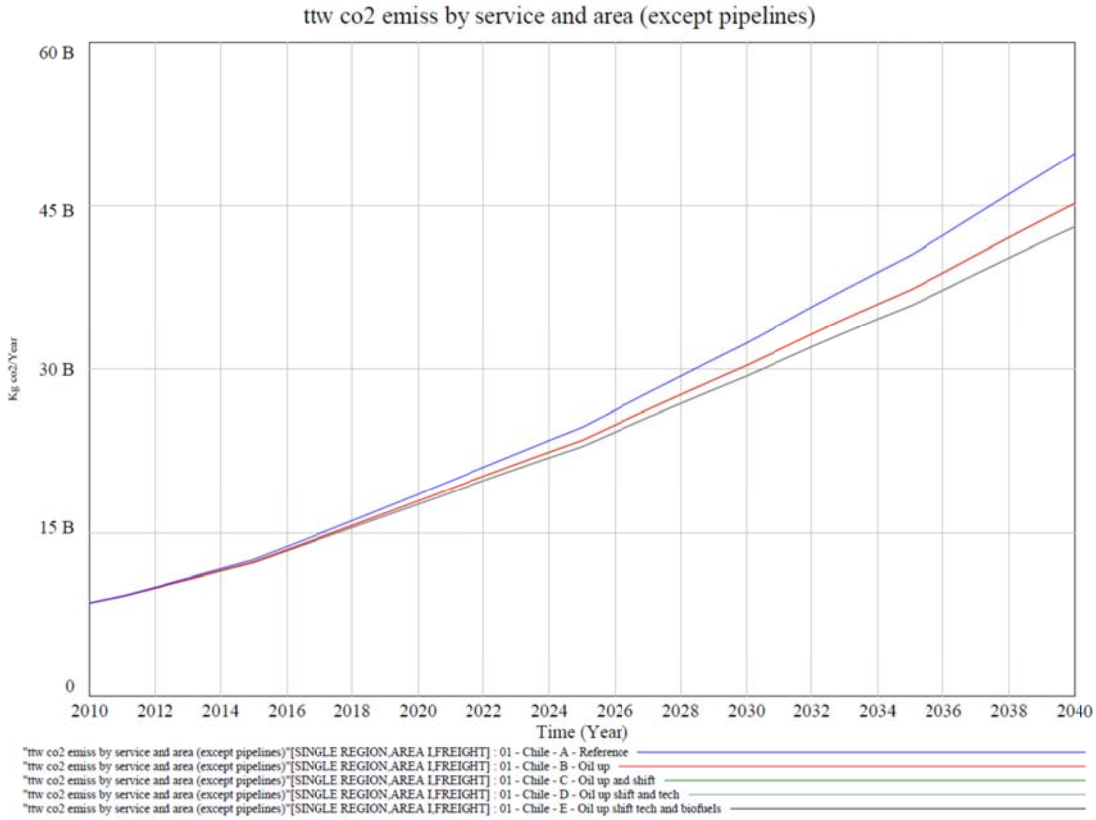


Figure 4.7 **Chile: Well-To-Wheel (WTW) CO_2 emissions in passenger transport (kg CO_2)**

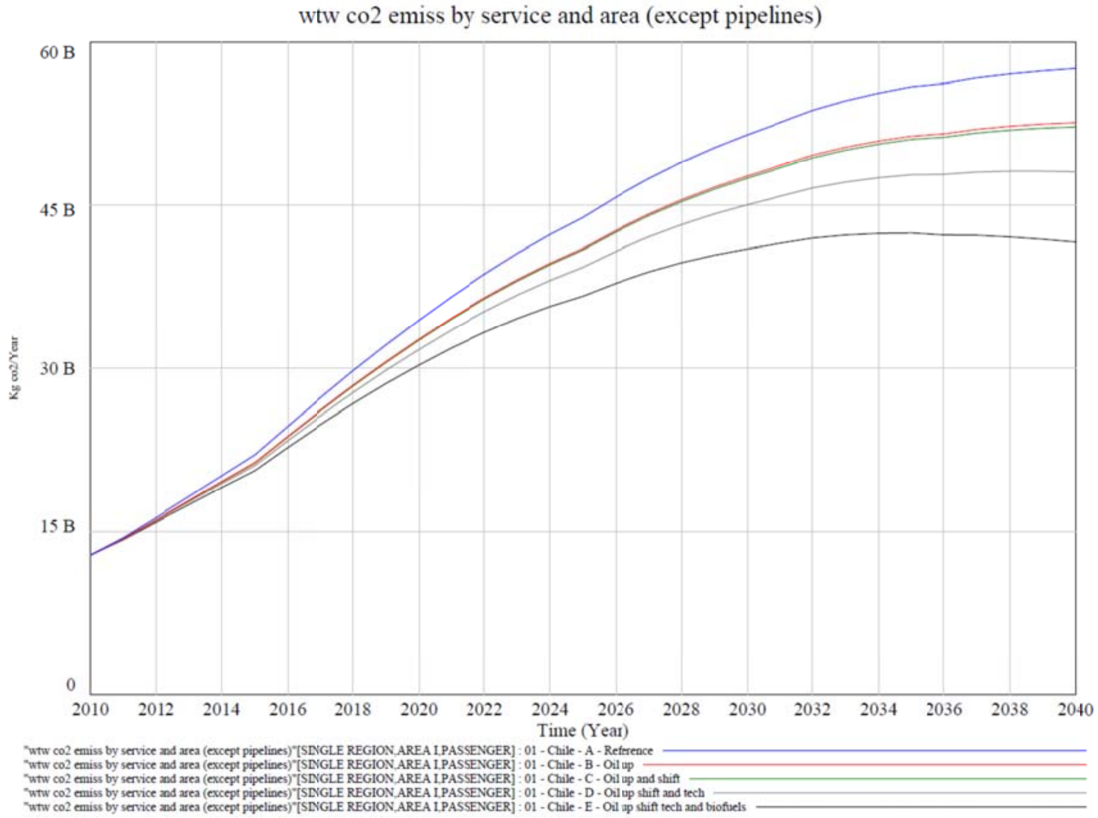
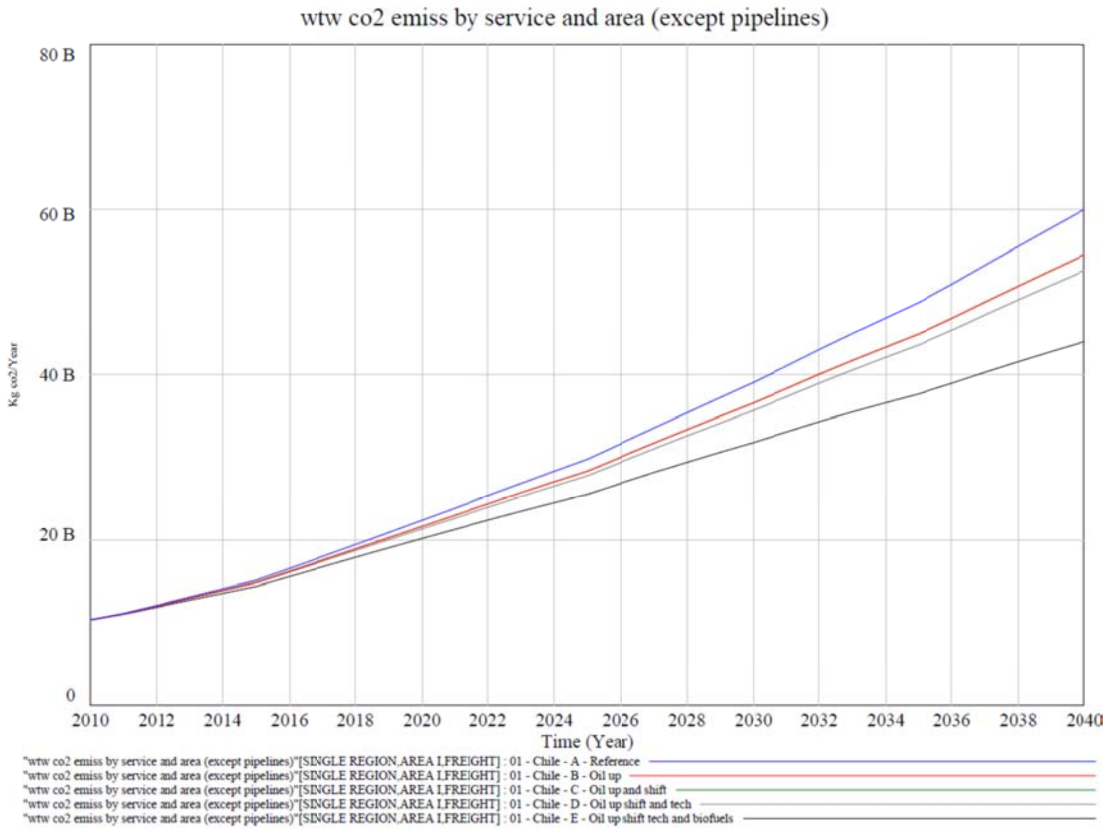


Figure 4.8 Chile: WTW CO_2 emissions in freight transport (kg CO_2)



Scenario A – Reference

Table 4.1 shows the values of the main outputs in the *reference* scenario for Chile, at the first and last year of the projections, as well as the rate of change between the base year (2010) and 2040.

Table 4.1 Main outputs: Chile, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	321.5	918.79	2.86
Total tkm	billion tkm	40.05	199.94	4.99
Total energy use	million toe	6.514	33.28	5.11
Total TTW CO_2 emissions	billion kg CO_2	19.067	97.72	5.13
Total WTW CO_2 emissions	billion kg CO_2	23.13	117.58	5.08

The passenger and freight activity increase substantially compared to the base year. This is mainly due to the sharp economic growth assumed in the projections concerning Chile up to 2040. The growth of passenger activity is mitigated in the second part of the projection period by the fact that the average GDP per capita exceeds 40000 constant 2000 USD, entering in a range of values that are associated with the progressive saturation of the vehicle stock. Freight activity grows proportionally to the economic output.

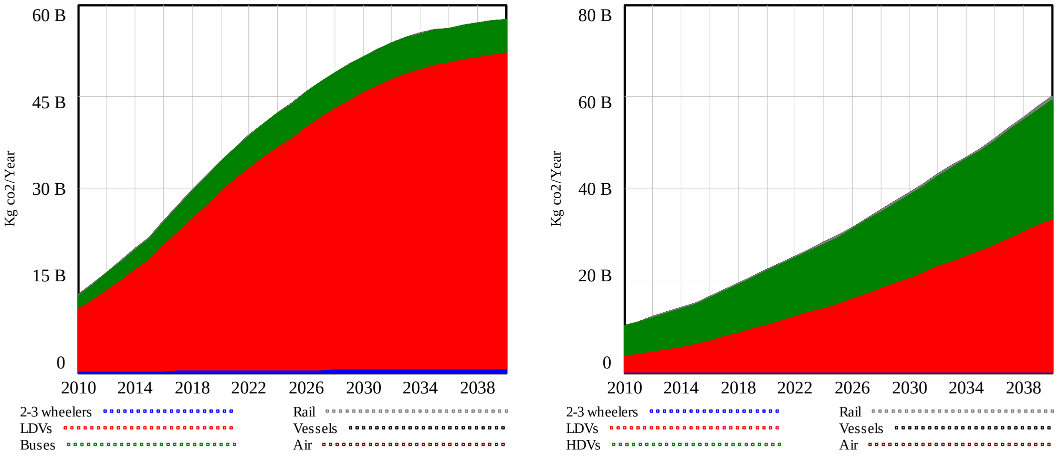
The increment of the transport activity is the main driver behind the growth of energy use in transport. Energy demand increases more than transport activity due to the increased importance of energy intensive modes, such as personal passenger vehicles in passenger transport and light commercial vehicles in freight transport. In passenger transport, the economic growth triggers an increment of the number of personal passenger cars and their average annual travel, while the share of pkm on public transport modes decreases, even if the absolute value of the transport activity on public transport vehicle increases. Fuel savings associated with the improving evolution of the powertrain technologies in terms of fuel consumption only partly offset the upward influence of the growing activity[5].

The growth of TTW and WTW CO_2 emissions follows closely the trend of the energy demand increase, since the emission factors remain constant.

Results for Chile are affected by the lack of adequate data, since this limits the information considered in the pilot runs to rail and road modes, excluding air and vessels amongst the motorized transport modes.

In passenger transport, the number of trains at the base year is almost zero, reflecting a limited development of the rail sector. The share of rail in public passenger and freight transport does not increase in the *reference* and other scenarios. This, combined with the low energy and CO_2 intensity of rail, translates in a large contribution to the development of CO_2 emissions over time from two wheelers, LDVs and large road vehicles (see the left side of Figure 4.9, showing WTW CO_2 emissions by mode in Passenger transport).

Figure 4.9 **Chile, *reference* scenario: WTW CO_2 emissions by mode in passenger and freight transport**



In Chile, statistics show that the contribution of rail to the total transport activity is also limited in freight transport. The low energy and CO_2 intensity of rail, combined with its marginal role, is such that most of the WTW CO_2 emissions estimated for freight transport in Chile are due to road vehicles (right side of Figure 4.9). ForFITS calculates the number of light commercial vehicles (freight LDVs) on the basis of projections of the large road freight vehicles through a function of the GDP per capita. Overall, this results in an increasing portion of the road freight transport being performed by smaller and more energy intensive

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[5] The limited information on the fuel consumption of vehicles registered in the past decades, which led to an estimation of fuel consumption values that equal those of the average of the stock in all years preceding the base year, weakens this effect. The use of estimations associated with a progressive reduction of the average fuel consumption of vehicles registered between 1990 and 2010 would lead to a lower estimate of fuel consumption growth.

vehicles. This aspect of the projections, however, needs to be handled with care because the share of freight LDVs in the base year may be very sensitive to the classification. In addition, Chile is also characterized by a significant importance of the extractive industry in its economy (i.e. by a sector that is not associated with freight LDVs). Further improvement of the model concerning the characterization of projections for light freight duty vehicles may be required in the future.

Scenario B – Oil up

The increase of fuel price considered in the *oil up* scenario has an impact of the transport activity that corresponds to the combined effects of the fuel price on the ownership levels of personal passenger vehicles, the average annual personal passenger and freight vehicle travel, the total passenger km on public transport and air passenger vehicles, and the total tonne km of large freight transport vehicles.

Table 4.2 contains a summary of the changes induced by the variation of the oil price in the same variables included in Table 4.1. The total energy demand and CO_2 emissions in the *oil up* scenario falls by roughly one tenth of the consumption estimated for 2040 in the *reference* scenario. This follows a similar contraction of the freight transport activity and a shift towards more efficient passenger transport modes (such as public transport) that does not result in very significant changes of the total passenger km travelled (1% reduction).

Table 4.2 Main outputs: Chile, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	321.5	905.72	2.82
Total tkm	billion tkm	40.05	182.3	4.55
Total energy use	million toe	6.514	30.31	4.65
Total TTW CO_2 emissions	billion kg CO_2	19.067	89.02	4.67
Total WTW CO_2 emissions	billion kg CO_2	23.13	107.12	4.63

Scenario C – Oil up and shift

The *oil up and shift* scenario takes into account a change of the passenger transport characteristic index in addition to the oil price increase. In Chile, the passenger transport characteristic index at the base year is 0.59 in the base year. This highlights a good comparative performance of public transport modes in comparison with other global regions. In Chile, filling the gap of the passenger transport characteristic index to 0.7 by 20% translates in relatively small changes taking place in the *oil up and shift scenario* with respect to the *oil up* case.

The *shift* considered in this new scenario results in a rise of the total passenger transport activity on public transport modes and a decline of the passenger km on personal passenger vehicles. The large importance of public transport in the total passenger transport activity of Chile is such that the growth of the pkm in collective modes exceeds the decline taking place for personal vehicles, leading to a slight overall increase of the passenger transport activity in the *oil up and shift scenario* with respect to the *oil up* case. However, the shift towards more energy efficient modes also triggers a reduction (very minor in the Chilean case) in the total energy use and CO_2 emissions (Table 4.3).

Table 4.3 **Main outputs: Chile, *oil up and shift* scenario**

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	321.5	939.12	2.92
Total tkm	billion tkm	40.05	182.3	4.55
Total energy use	million toe	6.514	30.18	4.63
Total TTW CO_2 emissions	billion kg CO_2	19.067	88.69	4.65
Total WTW CO_2 emissions	billion kg CO_2	23.13	106.72	4.61

Moving towards a higher passenger transport characteristic index does not affect freight transport.

Scenario D – Oil up, shift and tech

The oil up, shift and tech scenario considers the introduction of advanced vehicle powertrain technology options in addition to the progressive increase of oil prices and the evolution of the passenger transport characteristic index.

Table 4.4 summarizes the results for the main model output in the oil up, shift and tech scenario. In comparison with the oil up and shift scenario, the table shows higher activity estimates for passenger and freight transport (1 to 2%), as well as lower energy consumption and emission figures (5% to 6%).

Table 4.4 **Main outputs: Chile, oil up, shift and tech scenario**

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	321.5	946.42	2.94
Total tkm	billion tkm	40.05	185.56	4.63
Total energy use	million toe	6.514	28.73	4.41
Total TTW CO2 emissions	billion kg CO2	19.067	82.52	4.33
Total WTW CO2 emissions	billion kg CO2	23.13	100.67	4.35

The assumptions used in the tech scenarios reflect important changes in the powertrain technologies of newly registered vehicles. Total fuel and emission reduction are due to the stronger fuel savings of the advanced powertrain options. Nevertheless, Figure 3.1 to Figure 3.8 and Table 3.4 show that the tech component has a relatively small impact on the total energy consumption and emissions.

This is due to the combination of the "stock effect" (i.e. the need to progressively replace and renew the vehicles already in the stock) and the "rebound effect" (i.e. the increase in the average travel per vehicle – in comparison with a scenario without technology switch – due to the lower cost of travel due to fuel savings, as shown in Table 3.10 for light passenger vehicles). Another aspect that mitigates the contribution delivered by the higher penetration of advanced powertrain options is the improvement of conventional powertrain technologies already embedded in the results of all scenarios (including reference, oil up and oil up and shift), since this reduced the contributions of additional fuel savings given by competing powertrains.

Figure 4.10 Chile, average annual vehicle travel: *oil up, shift and tech* vs. *oil up, shift*

The comparatively small impact on the total energy consumption and emissions of the measures taken into account in the *tech* scenario shall not diminish the importance of the contribution powertrain technologies to reduce energy use and CO_2 emissions. On the other hand, this result should warn about the importance to set ambitious targets and the need for a rapid evolution of the automotive market towards more energy efficient solutions to deliver effective results in terms of increased energy efficiency and reduced CO_2 emissions from the transport sector.

Scenario E – Oil up, shift, tech and biofuels

The *oil up, shift, tech and biofuels* takes into account for the change of emission factors resulting from the introduction of biofuels in most of the fuel blends.

The characteristics of the assumption behind this variation (only limited to a modification of the emission factors), as well as methodological aspects allocating the variation of emission factors only to the well-to-tank (WTT) component, are such that the effect of the introduction of biofuels on the main model outputs (Table 4.5) is limited to the well-to-wheel (WTW) emission estimates. If the introduction of biofuels had been associated with changes in fuel cost and taxation, changes would also be reflected on activity and energy consumption estimates.

In Chile, the introduction of biofuels assumed in the *oil up, shift, tech and biofuels* scenario results in a WTW emission reduction of 15%.

Table 4.5 Main outputs: Chile, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	321.5	946.42	2.94
Total tkm	billion tkm	40.05	185.56	4.63
Total energy use	million toe	6.514	28.73	4.41
Total TTW CO_2 emissions	billion kg CO_2	19.067	82.52	4.33
Total WTW CO_2 emissions	billion kg CO_2	23.13	85.6	3.7

Ethiopia

Scenario results

As in the case of Chile, the passenger and freight activity in Ethiopia increase substantially compared to the base year. This is driven by the increase of the GDP (nearly seven fold from 2010 to 2040), also associated with a rapid population growth (60% in 30 years).

Freight activity (the information considered in the pilot runs for Ethiopia excludes vessels) grows proportionally to the economic output.

Changes in passenger activity are due to the increased population and the rising average income per capita. The exponential nature of the GDP growth is the main reason behind the stronger growth of passenger activity towards the end of the projection period. Public transport remains the main mobility option in 2040 in all scenarios, even if income levels progressively approach (but do not yet reach) values that are historically associated with very strong increases in personal vehicle ownership.

The growth of the total energy demand (both for passenger and freight) is comparable to the increase in transport activity. This shows that the increased importance of energy intensive modes (such as personal passenger vehicles and light commercial vehicles) compensates the fuel savings due to the improving fuel consumption[6].

The growth of TTW and WTW CO_2 emissions follows closely the trend of the energy demand, since the emission factors remain constant.

The *oil up* scenario is associated with the largest impact on transport activity and energy use. This reflects the high elasticities of travel with respect to the cost of driving assumed for regions with low incomes per capita. The *shift* scenario leads to the lowest variation in terms of WTW CO_2 emissions. This is due to the orientation, according to the data gathered for Ethiopia, of the passenger transport system towards public transport and the limited change taking place in the *shift* scenarios with respect to the *reference* and *oil up* conditions. In Ethiopia, the *tech* scenario also leads to limited results because of the slower implementation pace with respect to other pilot regions. In freight transport, the switch to methane does not lead to significant energy savings (gaseous fuelled vehicles are not assumed to be more efficient than diesels), but it does lead to CO_2 emission reduction.

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[6] The estimation of fuel consumption values equal to those of the average of the stock in all years preceding the base year weakens the fuel savings in the first decades also in Ethiopia. Progressively reducing average fuel consumption would lead to lower fuel consumption estimates.

Figure 4.11 Ethiopia: total pkm

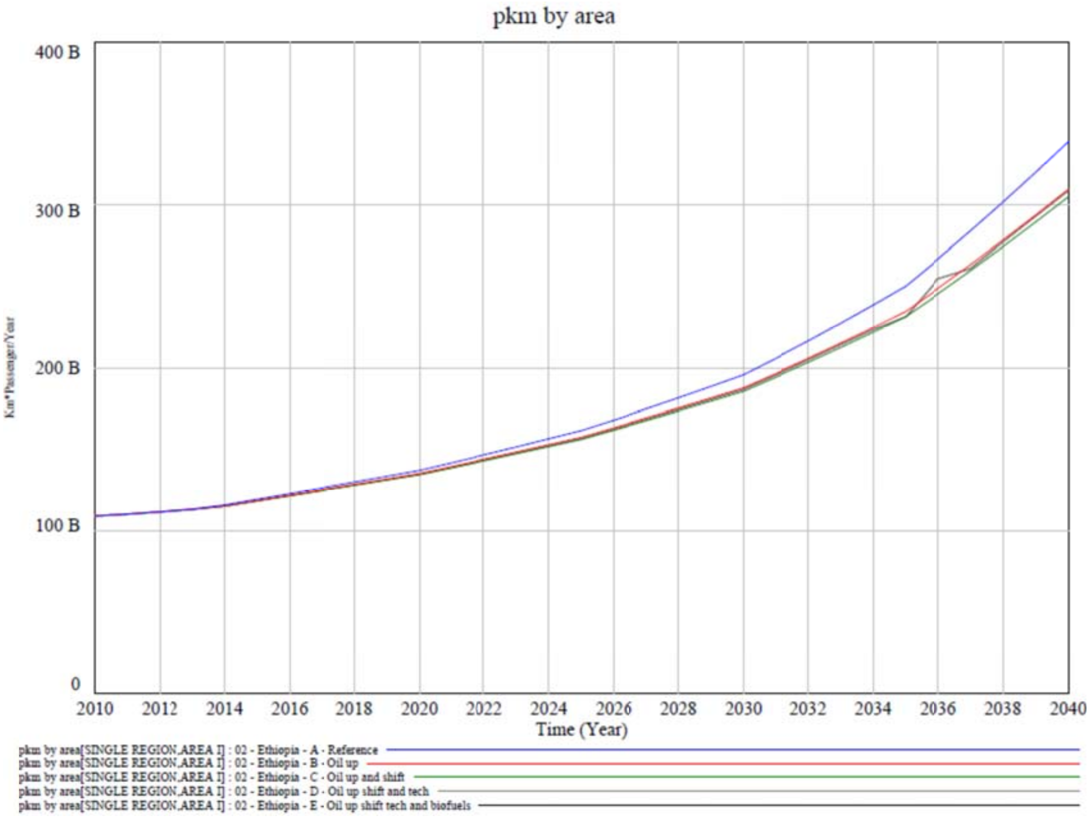


Figure 4.12 Ethiopia: total tkm

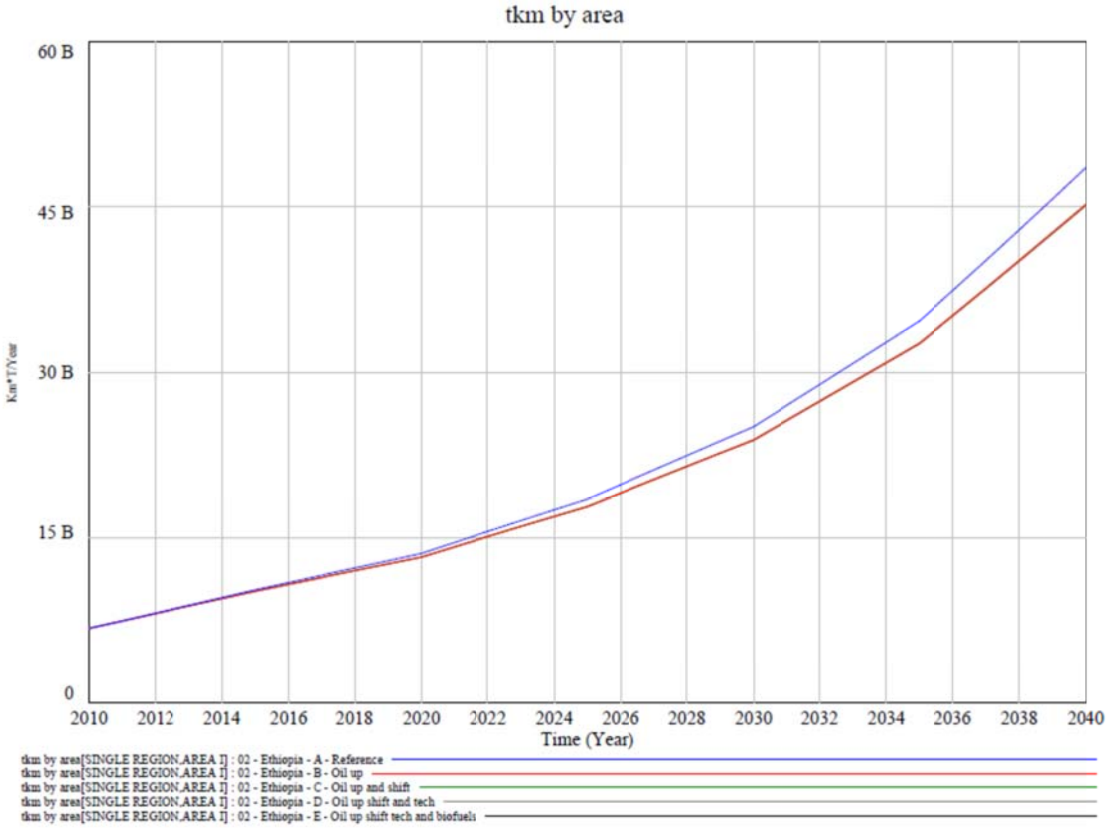


Figure 4.13 Ethiopia: energy use in passenger transport (toe)

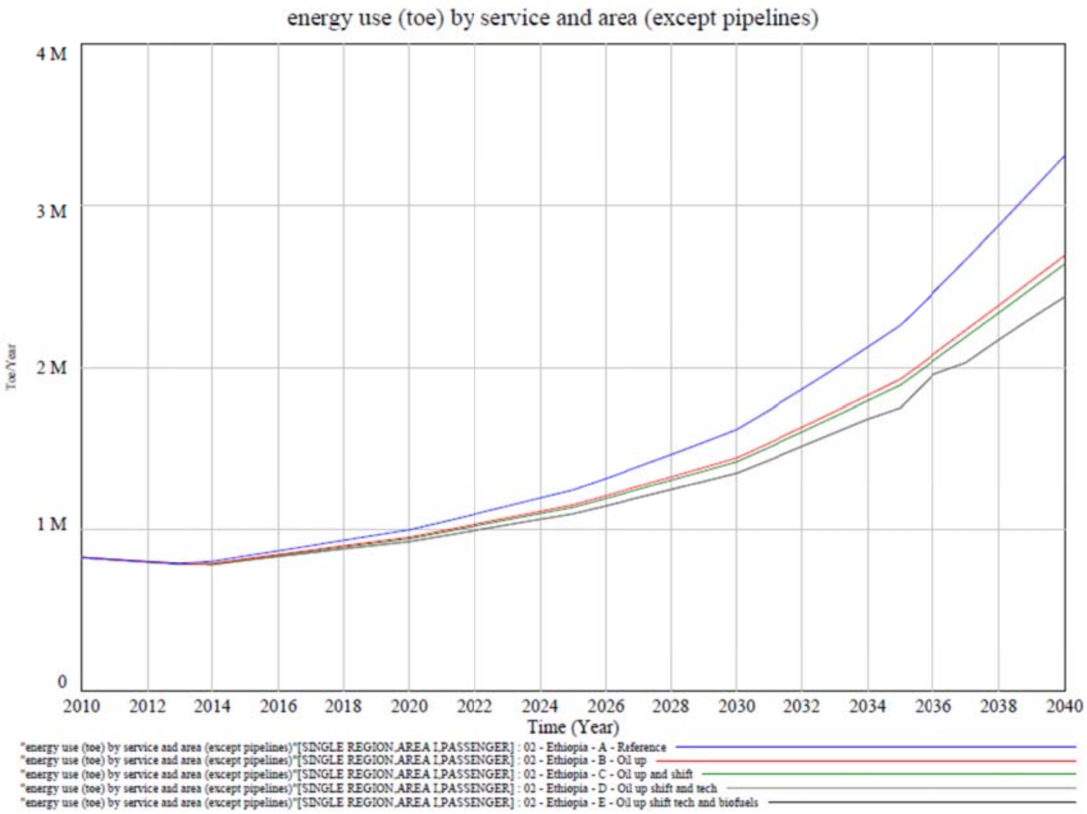


Figure 4.14 Ethiopia: energy use in freight transport (toe)

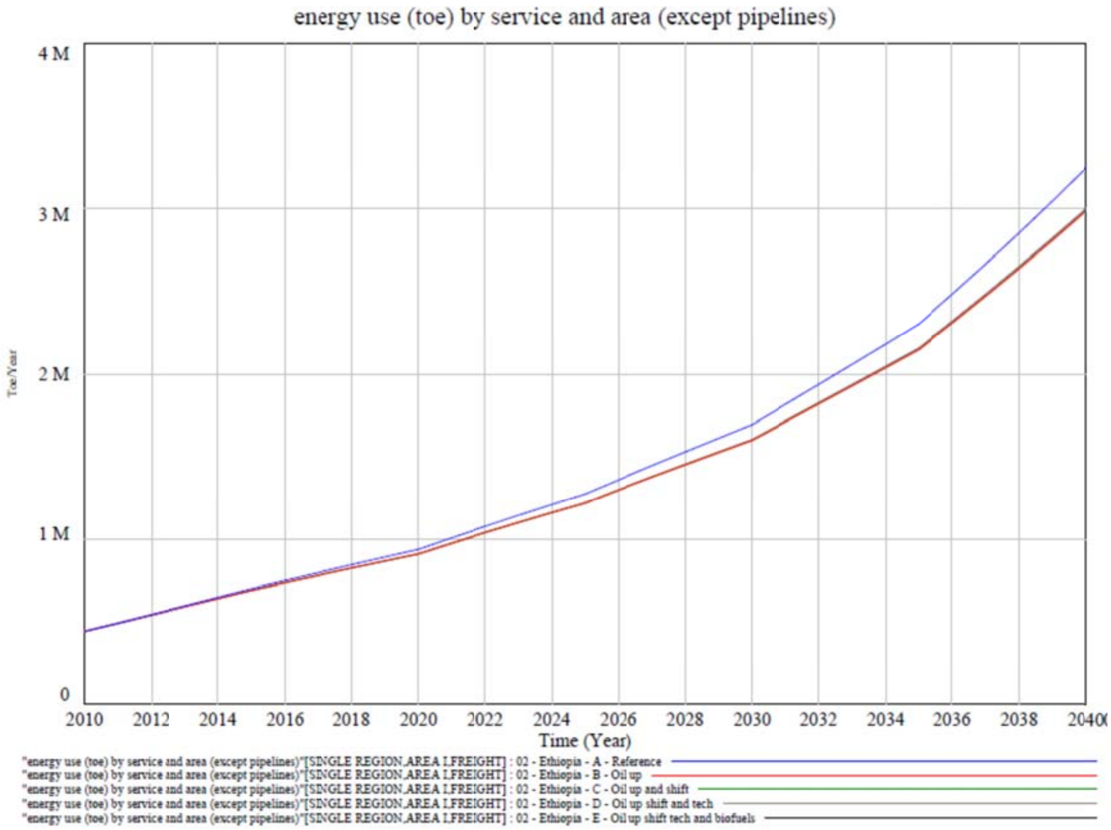


Figure 4.15 Ethiopia: TTW CO_2 emissions in passenger transport (kg CO_2)

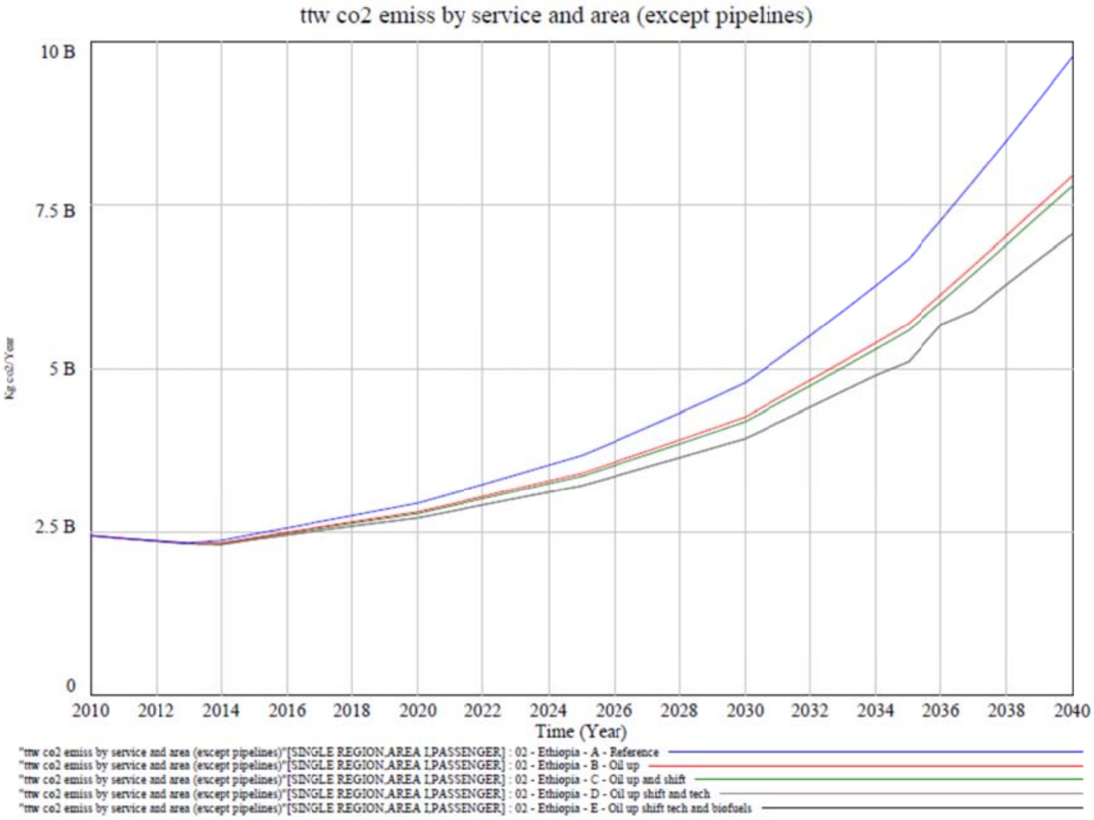


Figure 4.16 Ethiopia: TTW CO_2 emissions in freight transport (kg CO_2)

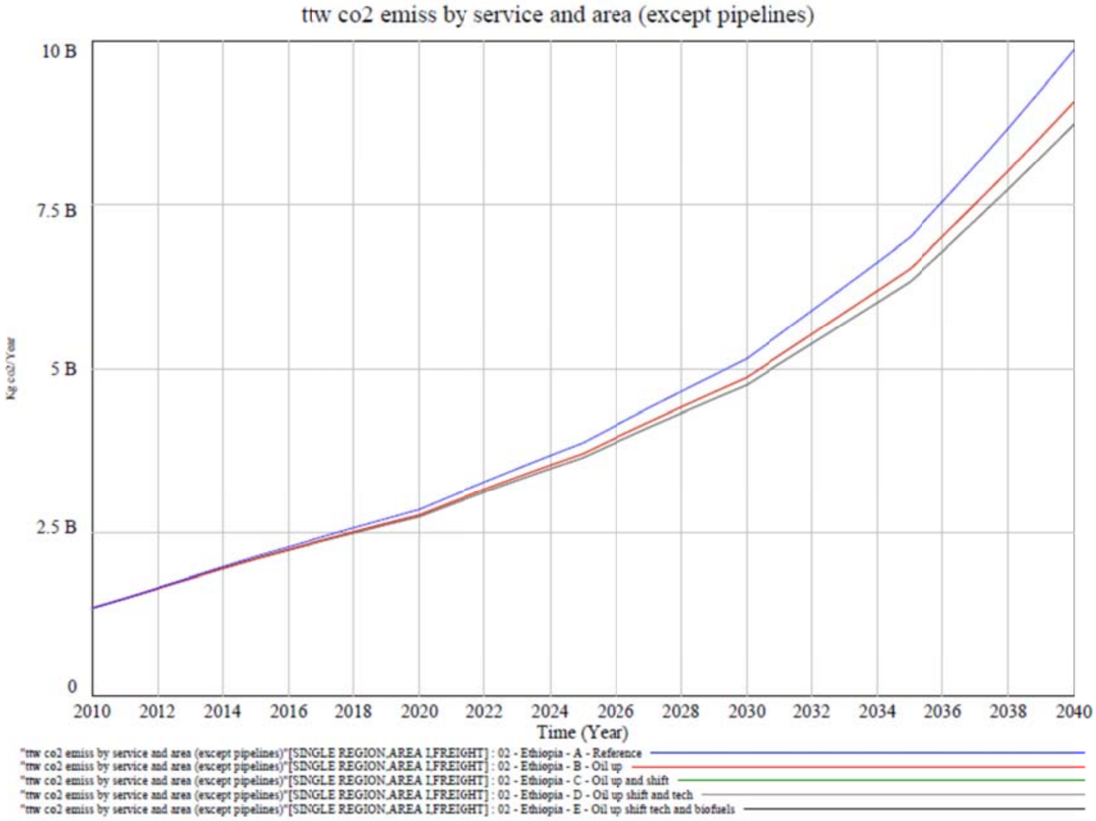


Figure 4.17 Ethiopia: WTW CO_2 emissions in passenger transport (kg CO_2)

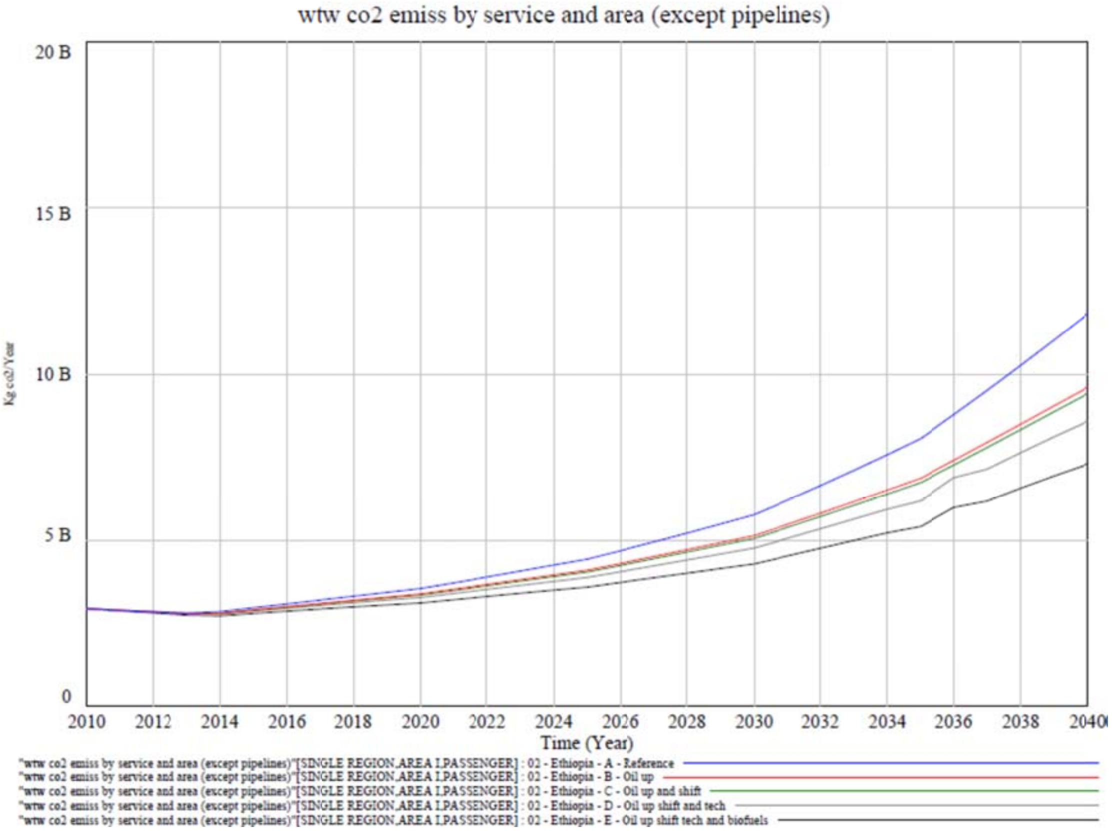
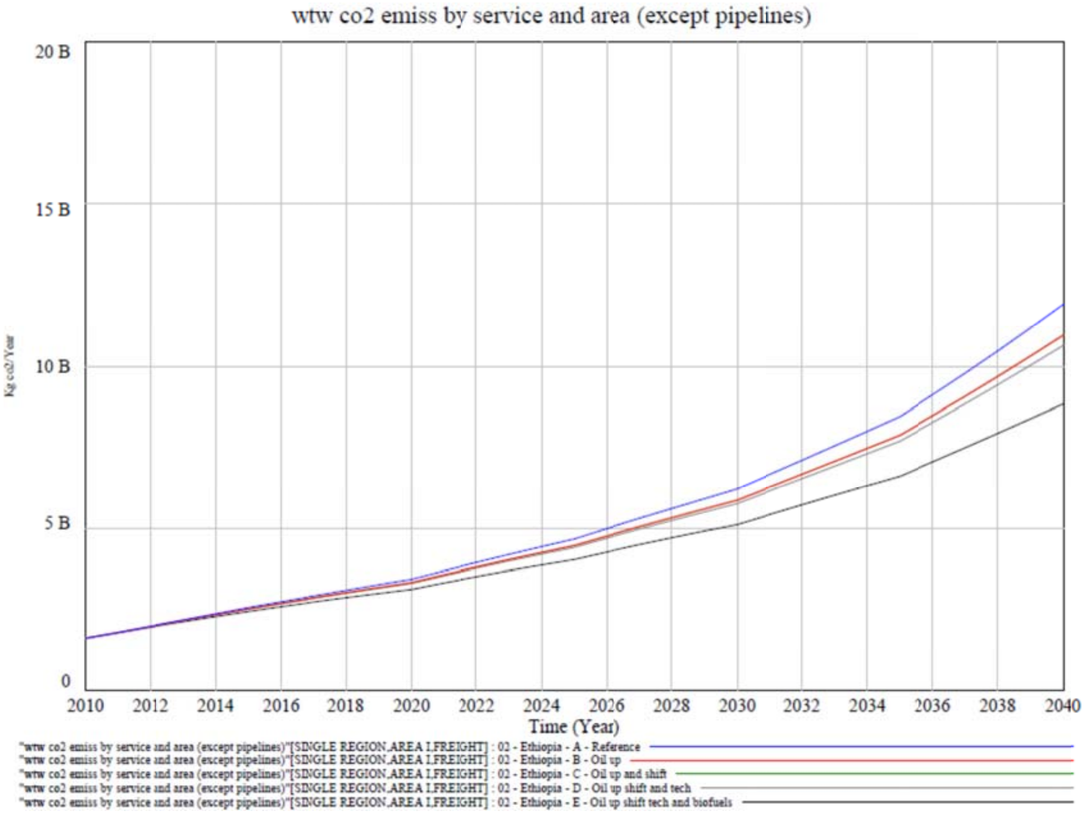


Figure 4.18 Ethiopia: WTW CO_2 emissions in freight transport (kg CO_2)



Scenario A – Reference

Table 4.6 Main outputs: Ethiopia, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	109.14	339.17	3.11
Total tkm	billion tkm	6.786	48.59	7.16
Total energy use	million toe	1.27	6.56	5.16
Total TTW CO_2 emissions	billion kg CO_2	3.796	19.653	5.18
Total WTW CO_2 emissions	billion kg CO_2	4.583	23.73	5.18

Scenario B – Oil up

Table 4.7 Main outputs: Ethiopia, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	109.14	309.7	2.84
Total tkm	billion tkm	6.786	45.25	6.67
Total energy use	million toe	1.27	5.683	4.47
Total TTW CO_2 emissions	billion kg CO_2	3.796	17.042	4.49
Total WTW CO_2 emissions	billion kg CO_2	4.583	20.574	4.49

Scenario C – Oil up and shift

Table 4.8 Main outputs: Ethiopia, *oil up and shift* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	109.14	305.1	2.8
Total tkm	billion tkm	6.786	45.25	6.67
Total energy use	million toe	1.27	5.63	4.43
Total TTW CO_2 emissions	billion kg CO_2	3.796	16.886	4.45
Total WTW CO_2 emissions	billion kg CO_2	4.583	20.386	4.45

Scenario D – Oil up, shift and tech

Table 4.9 Main outputs: Ethiopia, *oil up, shift and tech* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	109.14	308.9	2.83
Total tkm	billion tkm	6.786	45.16	6.65
Total energy use	million toe	1.27	5.438	4.28
Total TTW CO_2 emissions	billion kg CO_2	3.796	15.81	4.16
Total WTW CO_2 emissions	billion kg CO_2	4.583	19.232	4.2

Scenario E – Oil up, shift, tech and biofuels

Table 4.10 Main outputs: Ethiopia, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	109.14	308.9	2.83
Total tkm	billion tkm	6.786	45.16	6.65
Total energy use	million toe	1.27	5.438	4.28
Total TTW CO_2 emissions	billion kg CO_2	3.796	15.81	4.16
Total WTW CO_2 emissions	billion kg CO_2	4.583	16.139	3.52

France

Scenario results

Passenger transport in France experience a limited growth (24% in the *reference* scenario) between 2010 and 2040. Separate projections were developed for urban and non-urban environments. The growing passenger transport activity in urban areas is driven by the increasing urbanization rate and a growing income per capita. Pkm decrease over time in non-urban areas, since changes in urbanization overcome the effect of income.

The energy demand and CO_2 emissions of passenger transport decline in the first years of the projections, benefitting from the improvement, over time, of the average fuel consumption of vehicles registered between 1990 and 2010. The stabilization and growth of energy demand for passenger transport observed in *reference* projections is primarily explained by the reduced fuel consumption improvement rates after 2025, by a contained growth of the average vehicle travel and a limited increase of the personal passenger vehicle ownership, both linked with the increasing average income. Measures and assumptions taken into account for other scenarios, including the rising oil price, the slight *shift* towards public transport options, the larger market share of advanced powertrain technology (*tech*), and the growth of *biofuel* use, contribute to an evolution of WTW CO_2 emission that, in the *oil up, shift, tech and biofuels* scenario can actually decline over time.

Public transport represents a relevant mobility option in urban areas, where the larger availability of alternatives to personal vehicles explain the comparatively higher impact of the oil price increase with respect to what happens in the non-urban context. As in the case of Ethiopia (but with significant differences for vehicle ownership because of the much higher average incomes of France), the public transport orientation of the French urban transport systems also explains the limited variation in terms of energy use and CO_2 emissions in the *shift* scenarios.

Freight transport projections are evaluated at the national level. Freight activity is affected by the increase of the economic output and partly modulated by changes of freight transport costs (as shown by the variation between the *reference* and *oil up* scenarios). This, combined with improving fuel consumption characteristic for each powertrain technology and limited variations in the relative importance of different freight transport modes and vehicles, always translates in a comparatively lower growth of energy demand from freight transport.

The growth of TTW and WTW CO_2 emissions follows closely the trend of the energy demand increase in most scenarios, except when *biofuels* modify WTW emission factors.

Figure 4.19 France: pkm by area

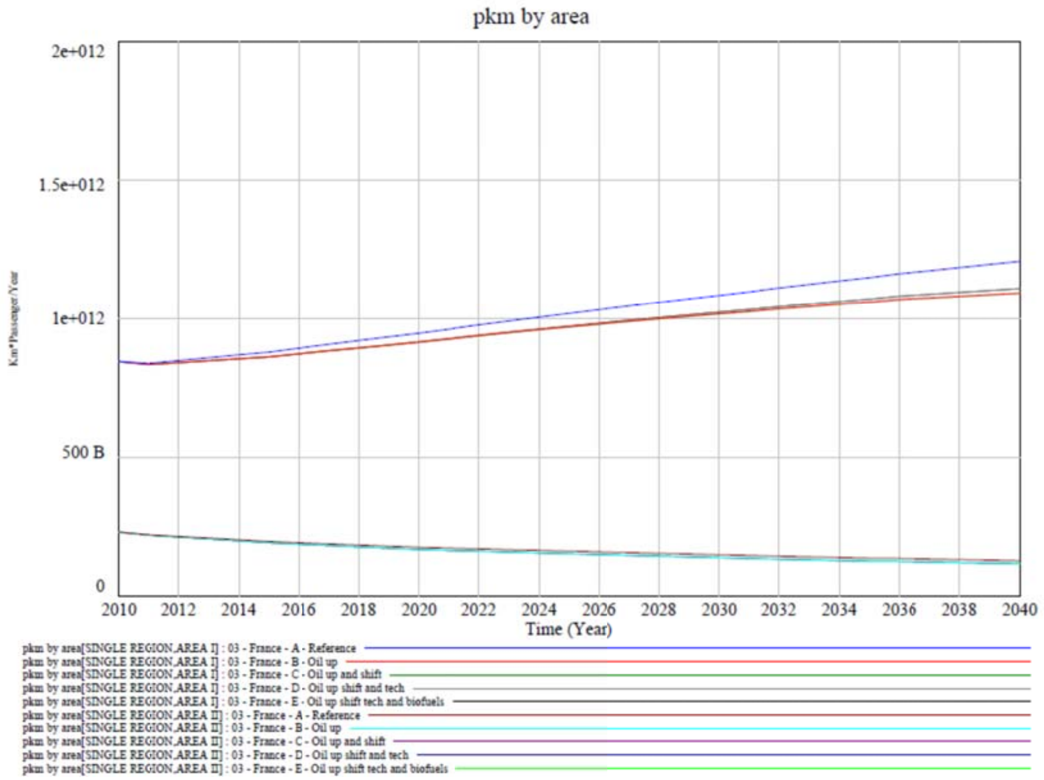


Figure 4.20 France: total tkm

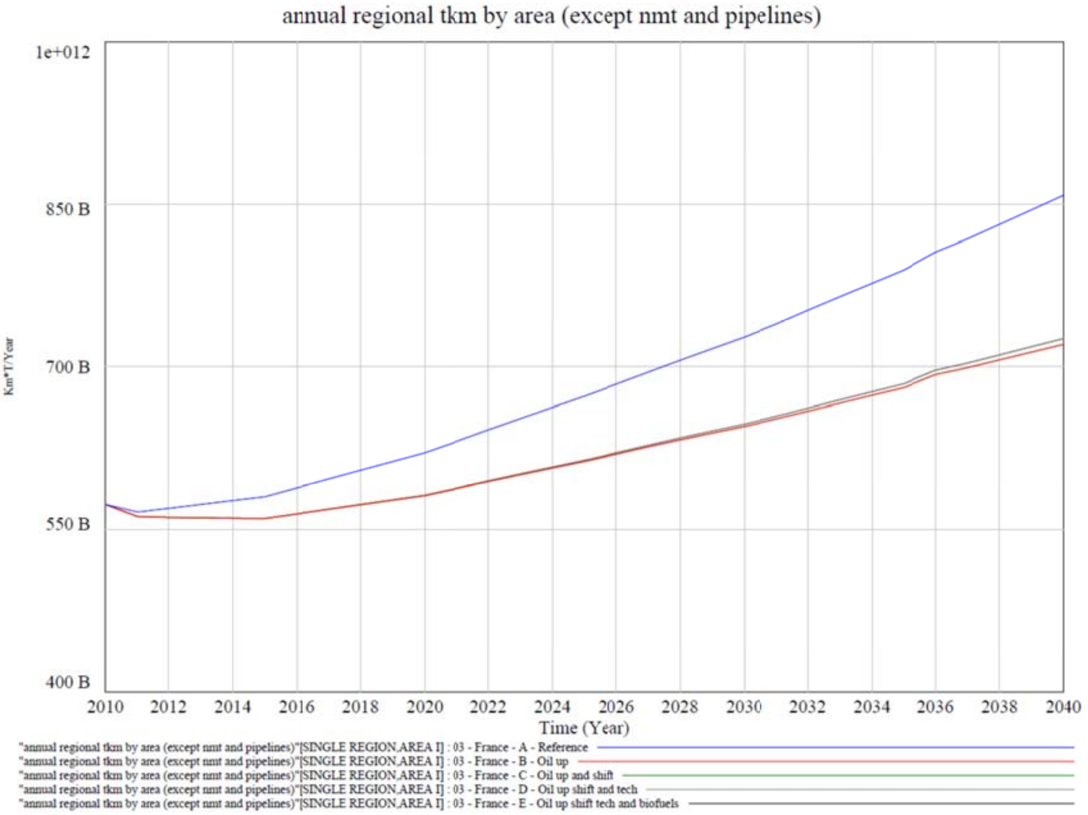


Figure 4.21 France: energy use in passenger transport (toe)

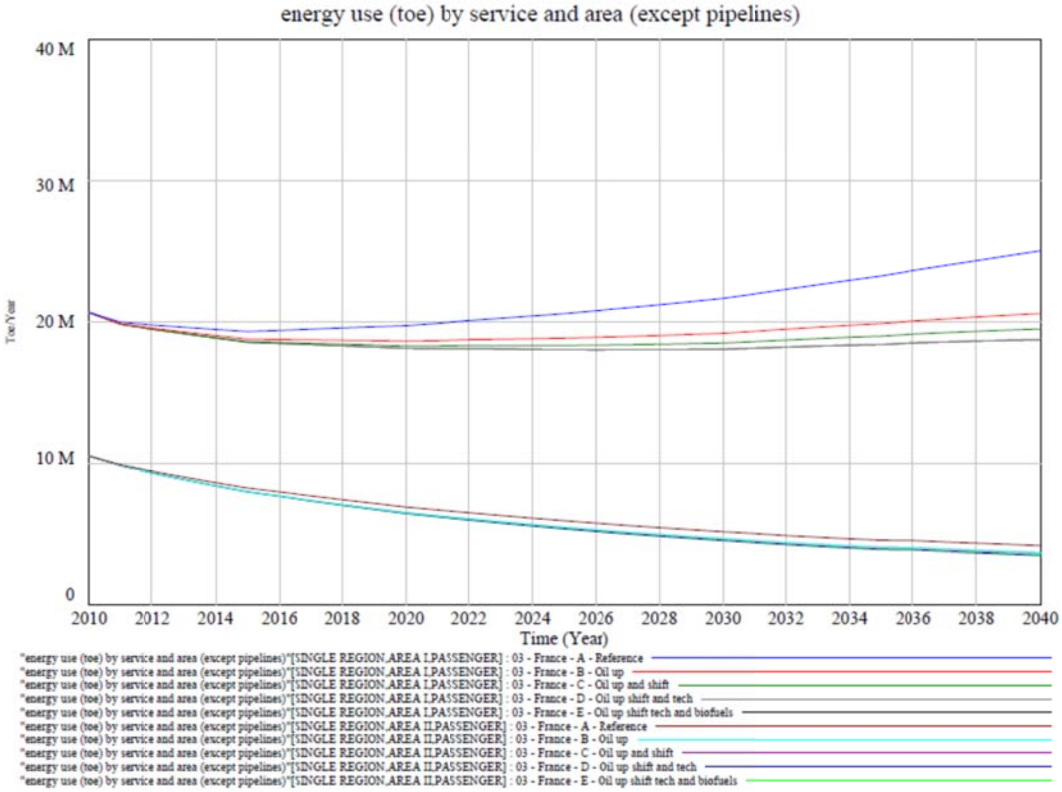


Figure 4.22 France: energy use in freight transport (toe)

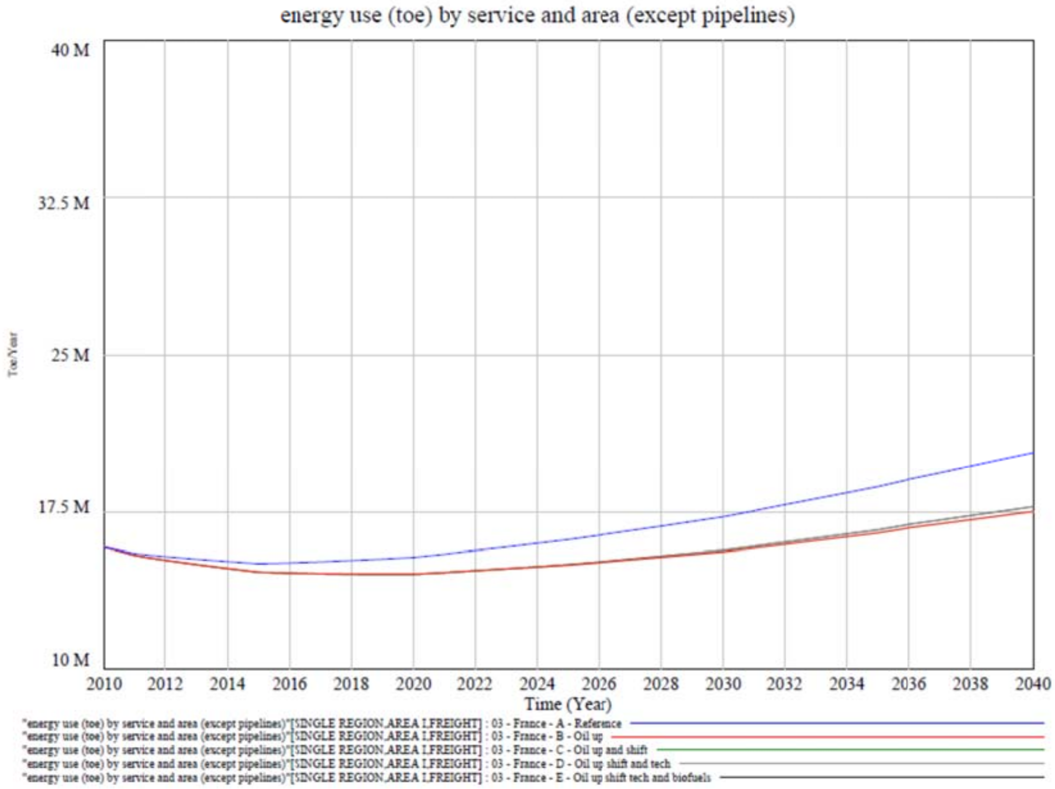


Figure 4.23 France: TTW CO_2 emissions in passenger transport (kg CO_2)

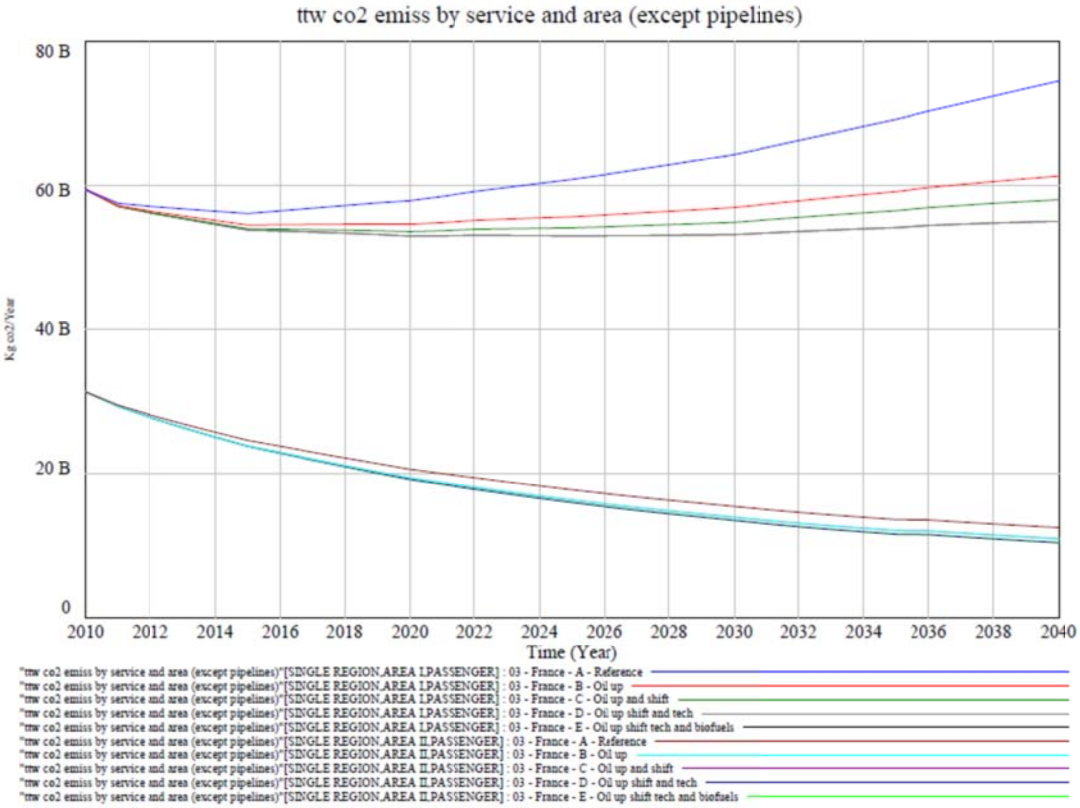


Figure 4.24 France: TTW CO_2 emissions in freight transport (kg CO_2)

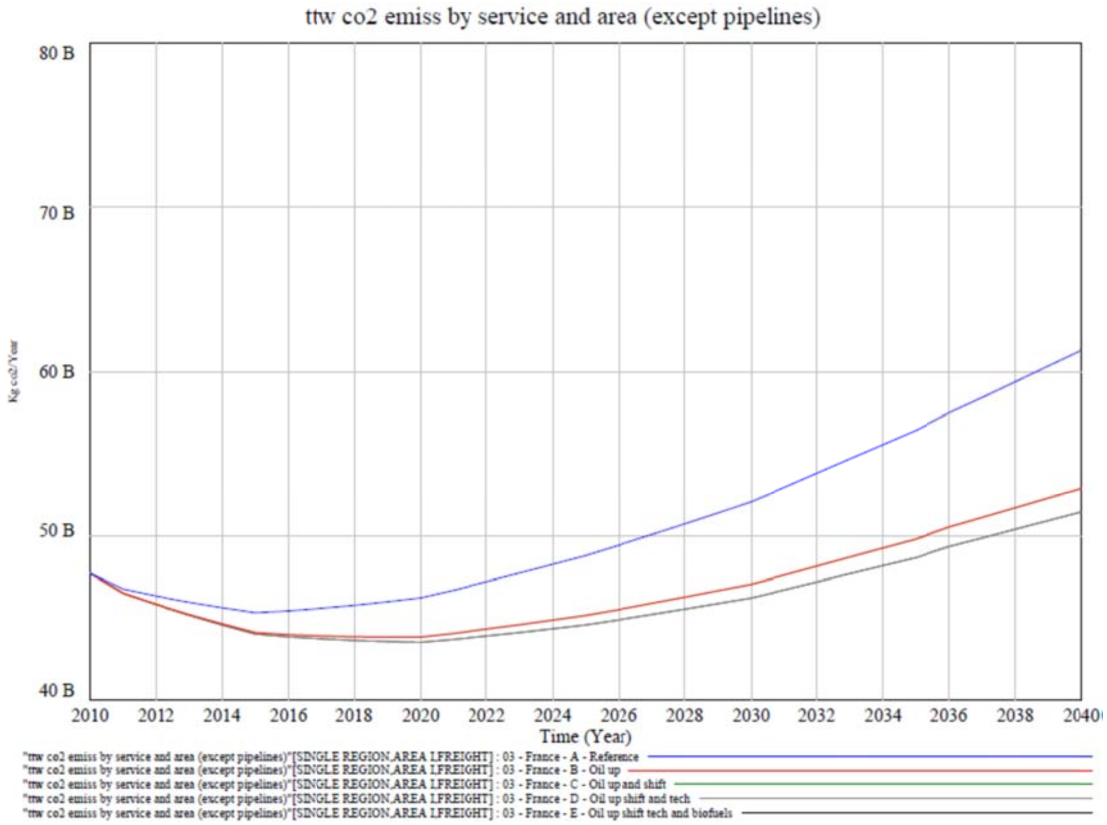


Figure 4.25 France: WTW CO_2 emissions in passenger transport (kg CO_2)

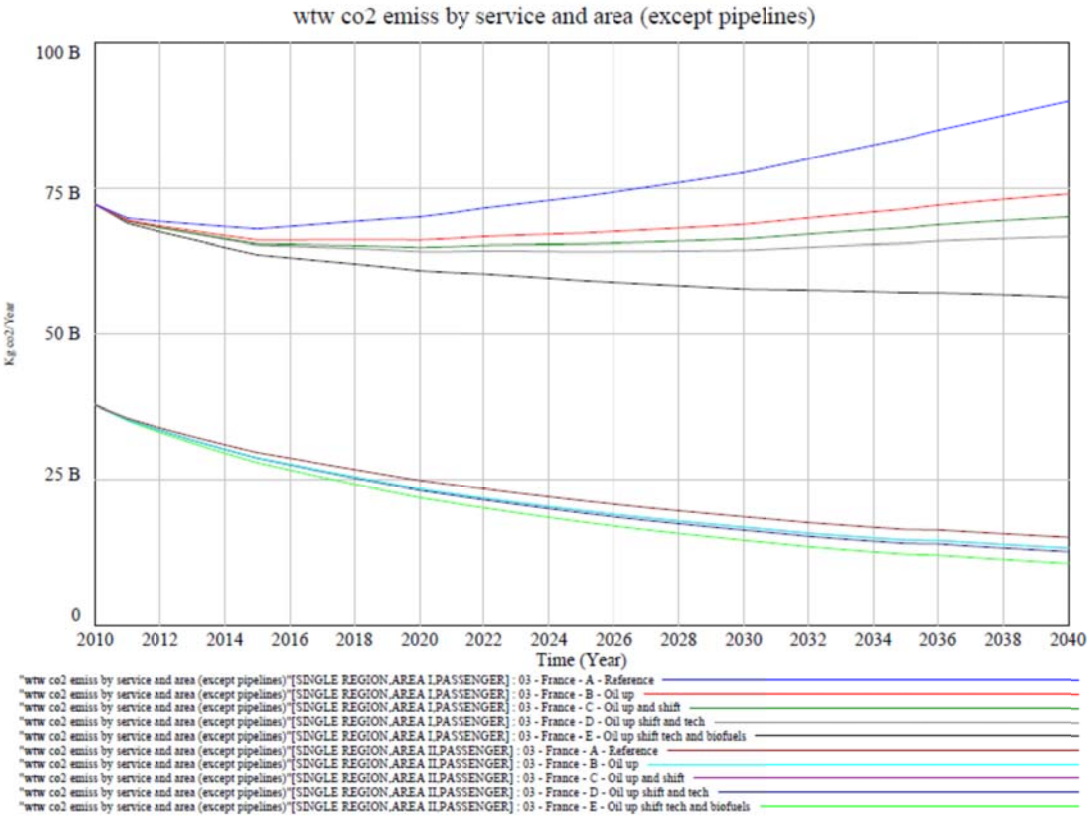
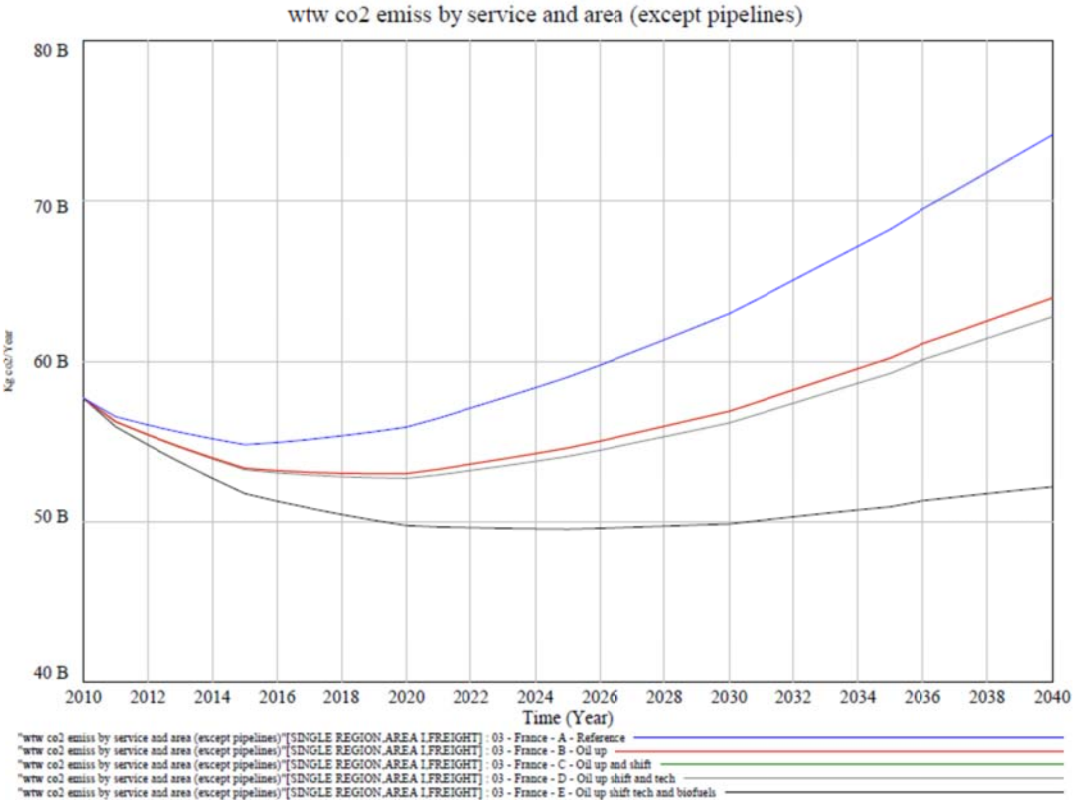


Figure 4.26 France: WTW CO_2 emissions in freight transport (kg CO_2)



Scenario A – Reference

Table 4.11 Main outputs: France, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	1072.36	1332.65	1.24
Total tkm	billion tkm	572.92	858.35	1.5
Total energy use	million toe	46.98	49.519	1.05
Total TTW CO_2 emissions	billion kg CO_2	138.43	148.26	1.07
Total WTW CO_2 emissions	billion kg CO_2	167.62	179.16	1.07

Scenario B – Oil up

Table 4.12 Main outputs: France, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	1072.36	1205.75	1.12
Total tkm	billion tkm	572.92	720.66	1.26
Total energy use	million toe	46.98	41.736	0.89
Total TTW CO_2 emissions	billion kg CO_2	138.43	125.07	0.9
Total WTW CO_2 emissions	billion kg CO_2	167.62	151.09	0.9

Scenario C – Oil up and shift

Table 4.13 Main outputs: France, *oil up and shift* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	1072.36	1205.25	1.12
Total tkm	billion tkm	572.92	720.66	1.26
Total energy use	million toe	46.98	40.635	0.86
Total TTW CO_2 emissions	billion kg CO_2	138.43	121.78	0.88
Total WTW CO_2 emissions	billion kg CO_2	167.62	147.12	0.88

Scenario D – Oil up, shift and tech

Table 4.14 Main outputs: France, *oil up, shift and tech* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	1072.36	1223.25	1.14
Total tkm	billion tkm	572.92	726.08	1.27
Total energy use	million toe	46.98	39.962	0.85
Total TTW CO_2 emissions	billion kg CO_2	138.43	116.81	0.84
Total WTW CO_2 emissions	billion kg CO_2	167.62	141.93	0.85

Scenario E – Oil up, shift, tech and biofuels

Table 4.15 Main outputs: France, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	1072.36	1223.25	1.14
Total tkm	billion tkm	572.92	726.08	1.27
Total energy use	million toe	46.98	39.962	0.85
Total TTW CO_2 emissions	billion kg CO_2	138.43	116.81	0.84
Total WTW CO_2 emissions	billion kg CO_2	167.62	118.98	0.71

Hungary

Passenger transport activity in Hungary is projected to witness a relatively growth that is comparable to the one seen for France. This is justified by projections that include expectations for a contracting population in Hungary, coupled with a higher growth of the GDP with respect to France. Hungarian projections on passenger transport activity are also affected by lower average incomes than in France, and therefore subject to a steeper increase of vehicle ownership curve across the projection period.

Freight activity grows in a way that is slightly exceeding the increase of GDP because of the increasing share of light commercial/freight vehicles across the period 2010-2040.

The data available for the definition of the Hungarian transport system show that there is limited flexibility with respect to mobility options in comparison with regions having a similar level of income. Numerically, this translates in a passenger transport index in the base year that is relatively low: 0.13. The changes following the introduction of *shift* inputs, where the passenger transport index move towards 0.7, are therefore significant for all passenger related outputs, from activity to energy use and CO_2 emissions.

In the *reference* scenario, the growth of energy demand in Hungary is comparable to the increase in transport activity, both for passenger and freight transport. Also in this case, fuel savings assumed for each powertrain technology are compensated by shifts towards more energy intensive modes and the income-driven growth of travel of personal passenger vehicles.

The *tech* scenario is coupled with a slight increase of passenger transport activity (rebound effect) and a corresponding decrease of energy demand.

Measures and assumptions characterizing the *oil up*, *shift*, *tech* and *biofuels* scenarios contribute to an evolution of passenger WTW CO_2 emissions that, when all contributions are combined, can actually decline. The assumptions considered are not sufficient for the stabilization of freight-related energy demand in Hungary.

The *biofuel* scenario results in important WTW CO_2 emission savings, as in all other pilot regions. These savings, however, need to be taken with caution, since land-use change has not been included in the elements leading to the characterization of WTT emission factors.

Figure 4.27 Hungary: total pkm

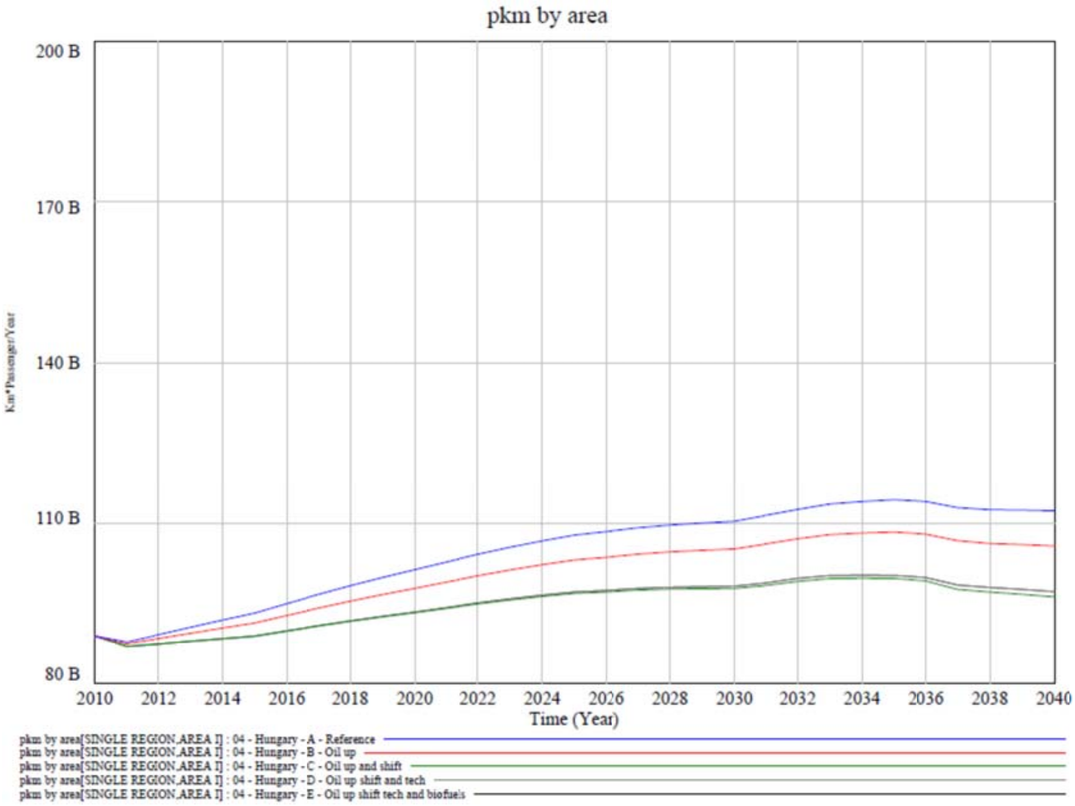


Figure 4.28 Hungary: total tkm

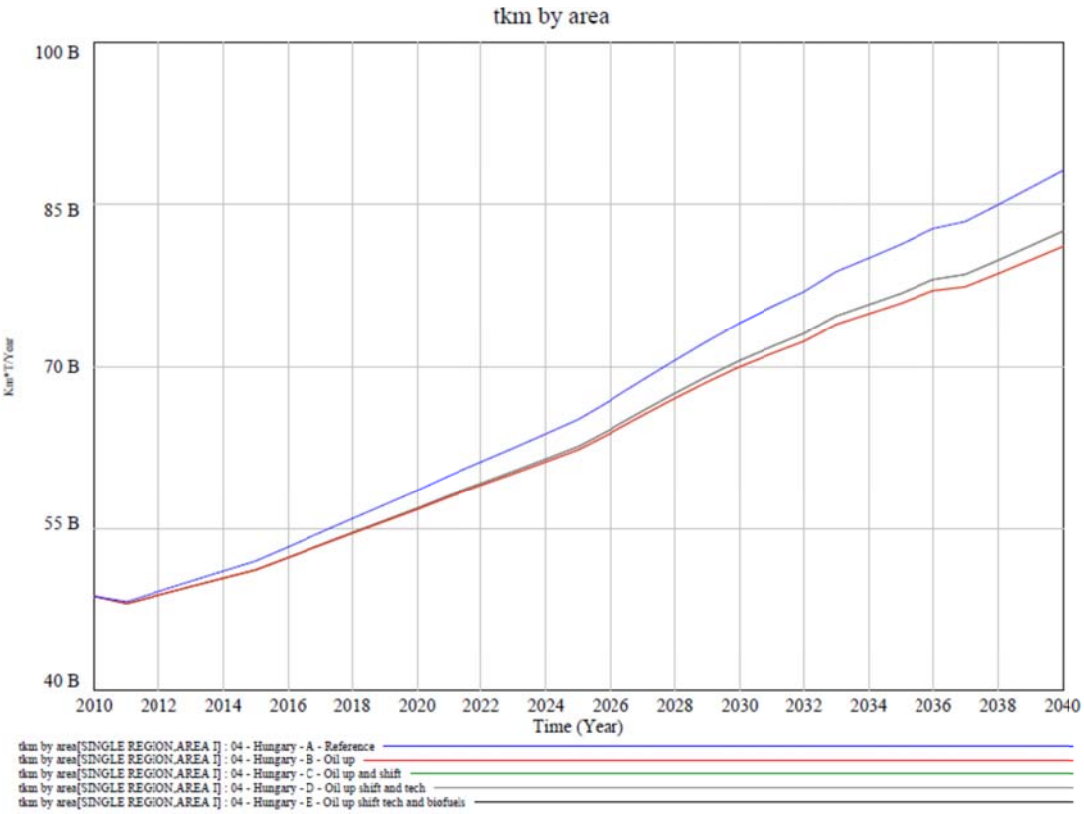


Figure 4.29 Hungary: energy use in passenger transport (toe)

Figure 4.30 Hungary: energy use in freight transport (toe)

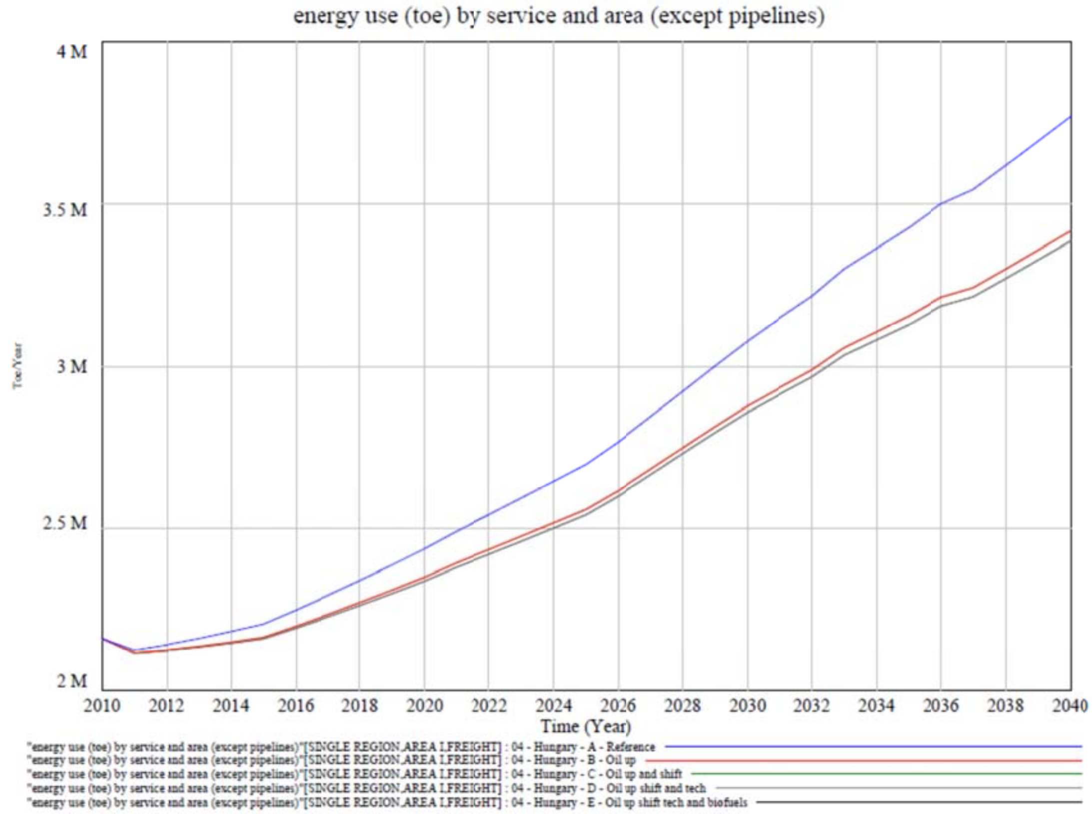


Figure 4.31 Hungary: TTW CO_2 emissions in passenger transport (kg CO_2)

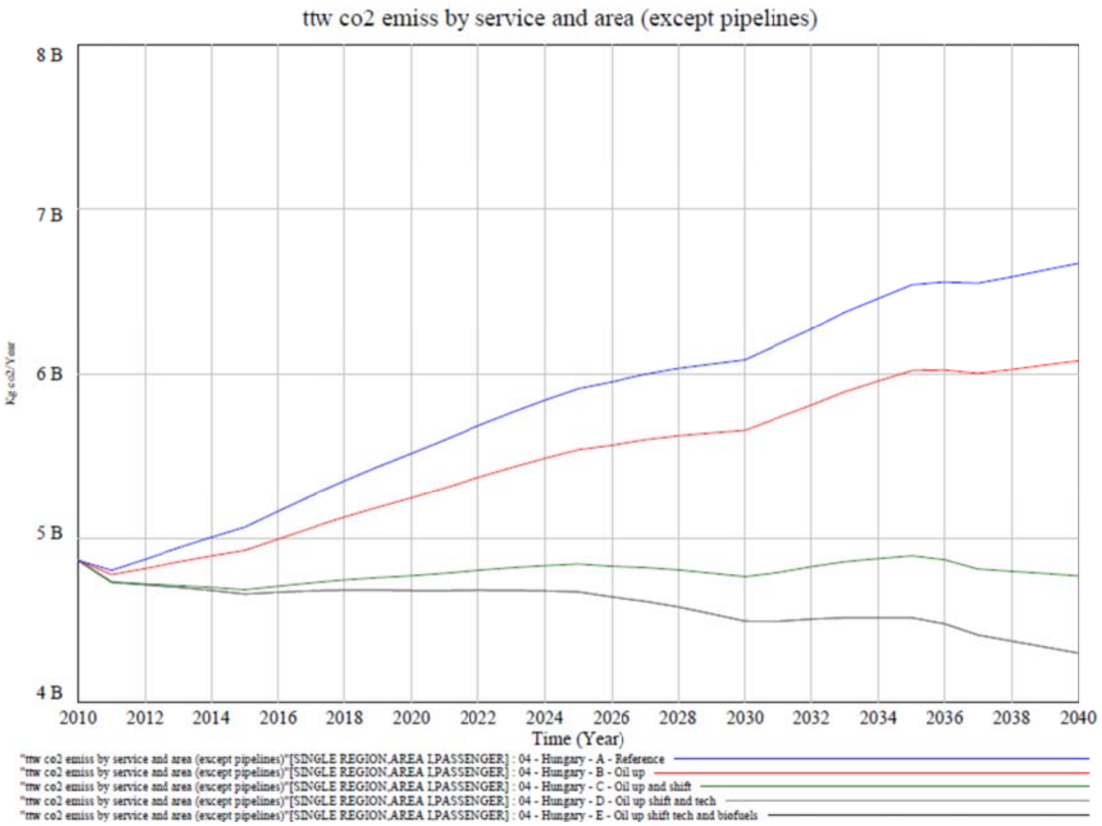


Figure 4.32 Hungary: TTW CO_2 emissions in freight transport (kg CO_2)

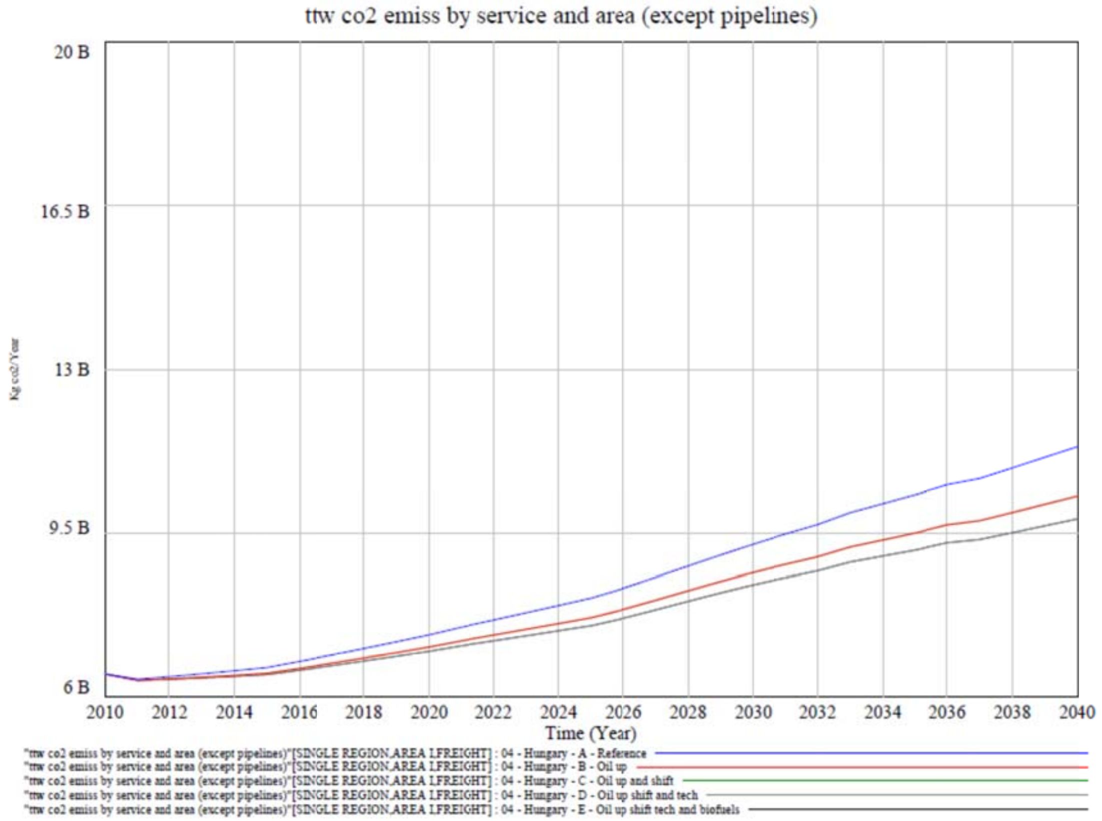


Figure 4.33 Hungary: WTW CO_2 emissions in passenger transport (kg CO_2)

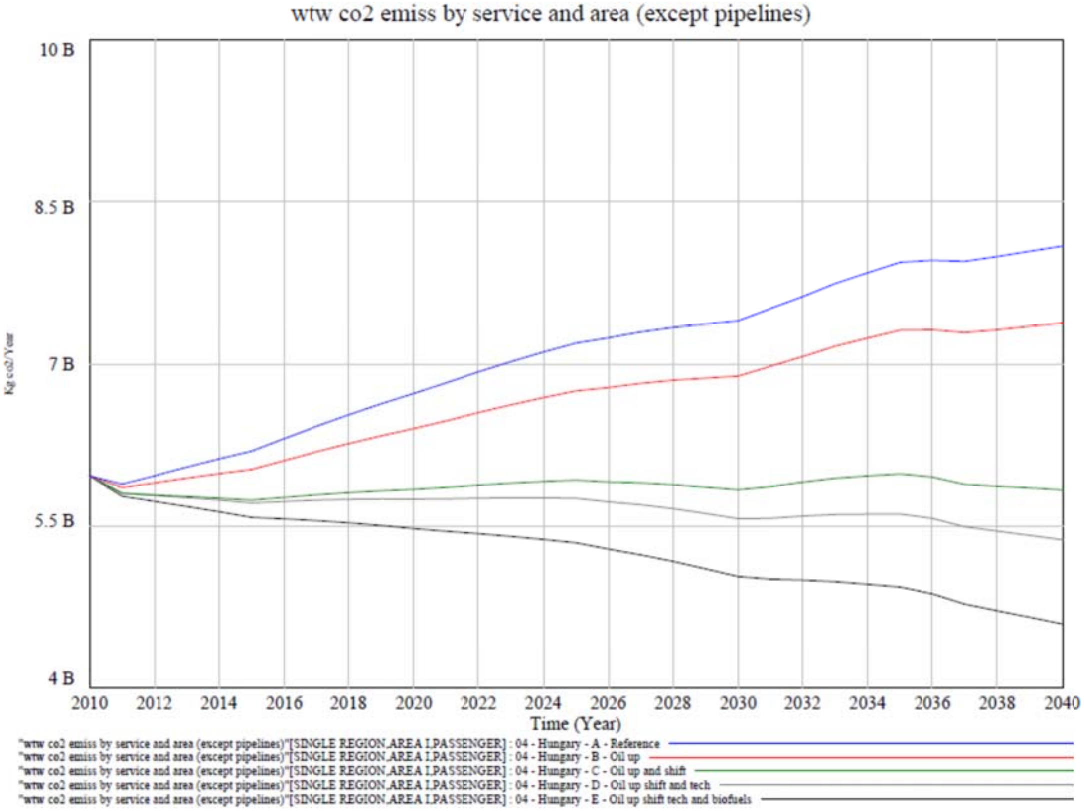


Figure 4.34 Hungary: WTW CO_2 emissions in freight transport (kg CO_2)

Scenario A – Reference

Table 4.16 Main outputs: Hungary, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	88.9	112.36	1.26
Total tkm	billion tkm	48.73	88.16	1.81
Total energy use	million toe	3.885	6.094	1.57
Total TTW CO_2 emissions	billion kg CO_2	11.36	18.032	1.59
Total WTW CO_2 emissions	billion kg CO_2	13.895	21.931	1.58

Scenario B – Oil up

Table 4.17 Main outputs: Hungary, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	88.9	105.7	1.19
Total tkm	billion tkm	48.73	81.12	1.66
Total energy use	million toe	3.885	5.536	1.42
Total TTW CO_2 emissions	billion kg CO_2	11.36	16.378	1.44
Total WTW CO_2 emissions	billion kg CO_2	13.895	19.92	1.43

Scenario C – Oil up and shift

Table 4.18 Main outputs: Hungary, *oil up and shift* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	88.9	96.25	1.08
Total tkm	billion tkm	48.73	81.12	1.66
Total energy use	million toe	3.885	5.089	1.31
Total TTW CO_2 emissions	billion kg CO_2	11.36	15.072	1.33
Total WTW CO_2 emissions	billion kg CO_2	13.895	18.376	1.32

Scenario D – Oil up, shift and tech

Table 4.19 Main outputs: Hungary, *oil up, shift and tech* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	88.9	97.23	1.09
Total tkm	billion tkm	48.73	82.55	1.69
Total energy use	million toe	3.885	4.93	1.27
Total TTW CO_2 emissions	billion kg CO_2	11.36	14.111	1.24
Total WTW CO_2 emissions	billion kg CO_2	13.895	17.504	1.26

Scenario E – Oil up, shift, tech and biofuels

Table 4.20 Main outputs: Hungary, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	88.9	97.23	1.09
Total tkm	billion tkm	48.73	82.55	1.69
Total energy use	million toe	3.885	4.93	1.27
Total TTW CO_2 emissions	billion kg CO_2	11.36	14.111	1.24
Total WTW CO_2 emissions	billion kg CO_2	13.895	14.665	1.06

Montenegro

The population in Montenegro is estimated to remain approximately constant at the base year value up to 2040. The GDP is 3.7 times larger in 2040 than in 2010. GDP per capita is projected to grow from 7000 to 25000 constant 2000 USD: this explains the significant raise of the passenger transport activity (the GDP per capita reached at the last year of the projections is still far away from the levels that are historically coupled with a saturation of the personal vehicle ownership). Freight activity (excluding vessels, not considered due to the lack of information) increases proportionally to the growth of the economic output.

Available statistics highlight that the transport system in Montenegro is characterized by being highly personal vehicle oriented. The passenger activity on public transport only represents about 30% of the total passenger transport activity (excluding aviation, which is not taken into account in this pilot). This is comparatively low if compared to the shares observed in other global areas with a similar average income. The personal vehicle ownership is also higher than in regions with a comparable income level. This situation may relate, partly, to the low size of the main city (Podgorica), it may be affected by the significant presence of rural areas in the rest of the country, and it may also result from limited or inaccurate statistical information (including on the actual income levels).

The historical information available for the *reference* scenario leads to high projections of the share of pkm on personal vehicles, causing even a reduction of the absolute amount of pkm on public transport over time.

The increases in fuel costs introduced in the *oil up* scenario result in 7% lower energy use and CO_2 emissions. The effect of the introduction of new technologies (*oil up, shift and tech* scenario) is limited by the delayed introduction of technologies assumed for the inputs and further hampered by the long average vehicle life (more than 20 years for light passenger vehicles), since this delays the renewal of the vehicle fleet. As in other cases, the *tech* scenario is also associated with a slight increment of total pkm (rebound effect).

In comparison with the *reference* scenario, the inputs of the *shift* scenario lead to an increase of the pkm on public transport modes and an important reduction of the average travel of personal passenger vehicles. Overall, it also results in a reduction of the total pkm. This highlights that the development of the transport system in the direction represented by the *shift* inputs requires important structural changes (such as urban densification) and not only a generalized improvement of public transportation.

Figure 4.35 Montenegro: total pkm

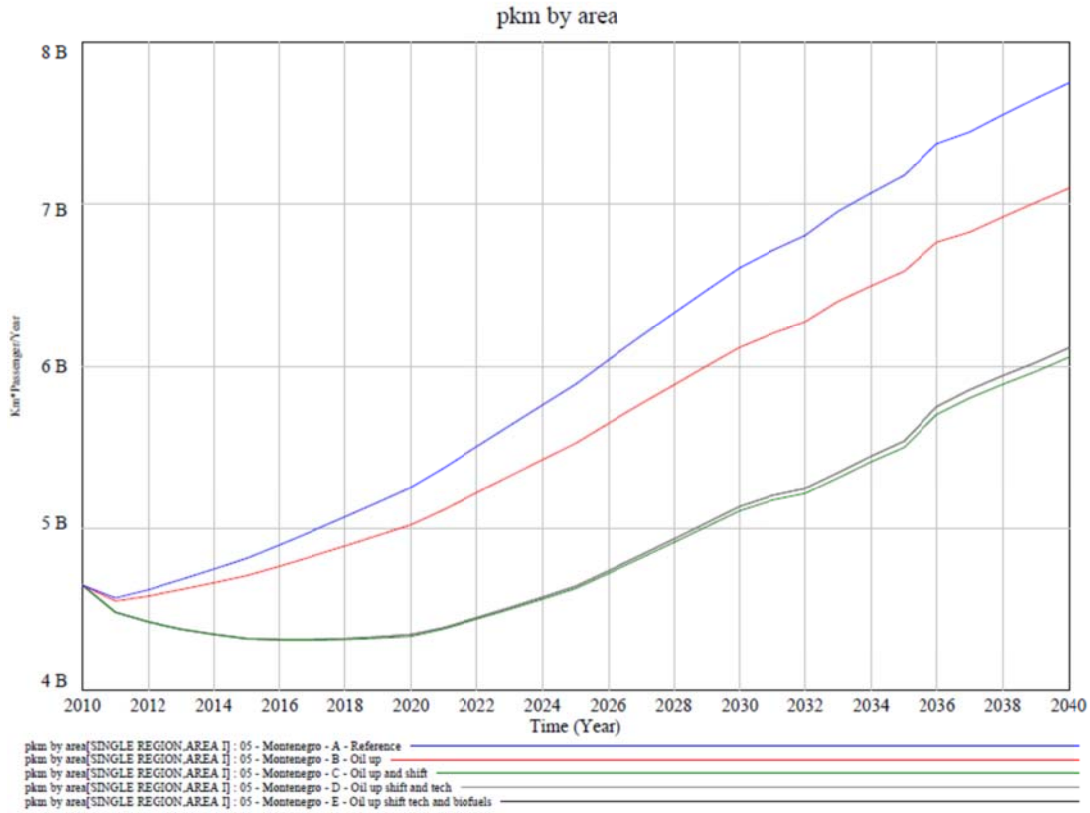


Figure 4.36 Montenegro: total tkm

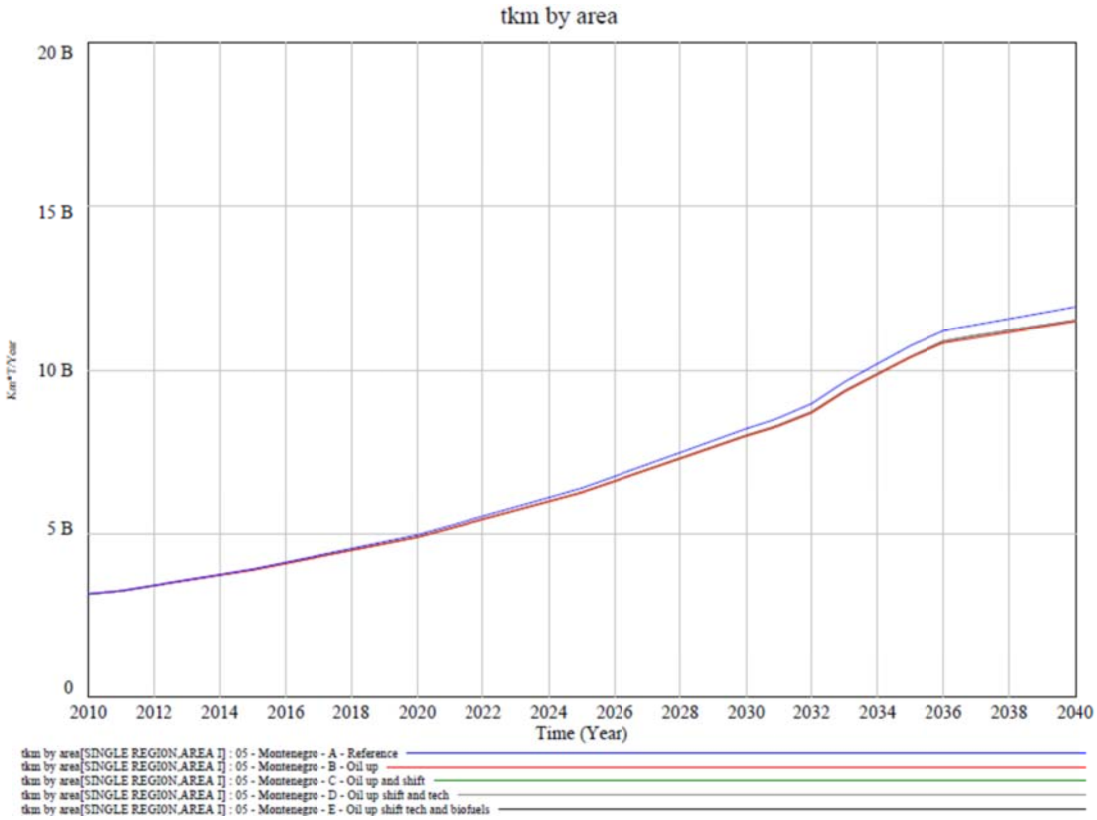


Figure 4.37 Montenegro: energy use in passenger transport (toe)

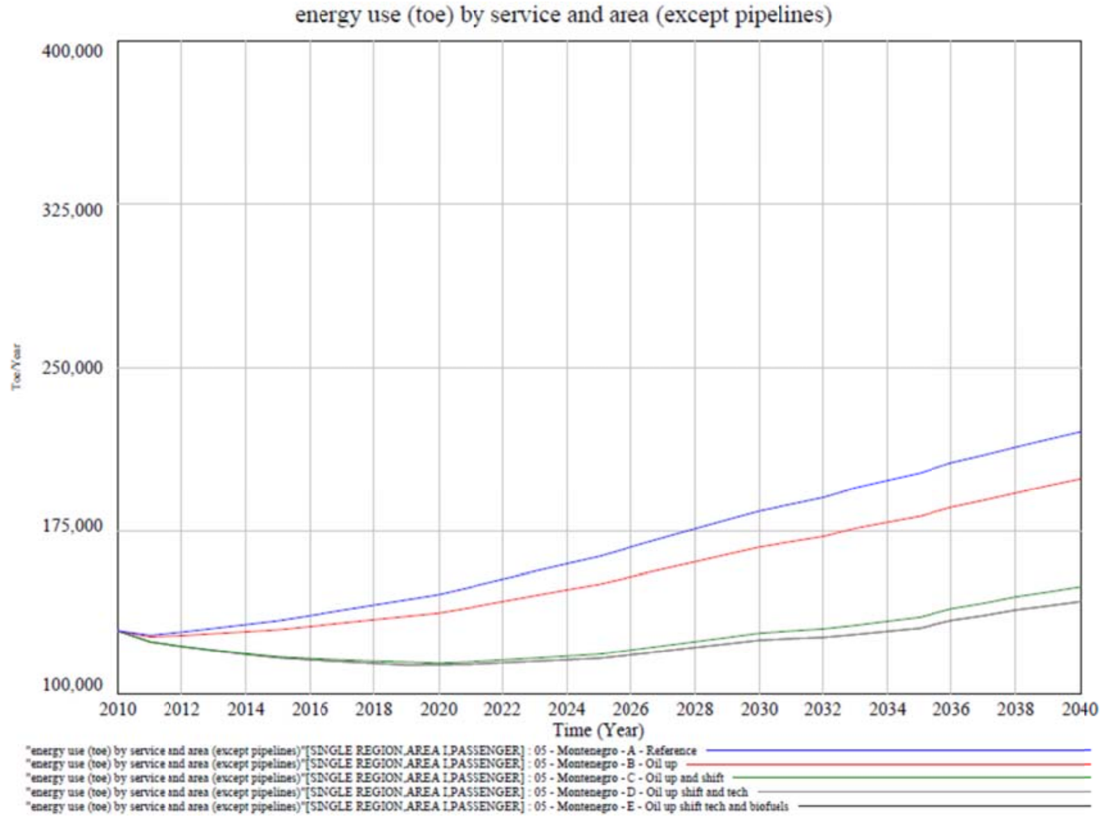


Figure 4.38 Montenegro: energy use in freight transport (toe)

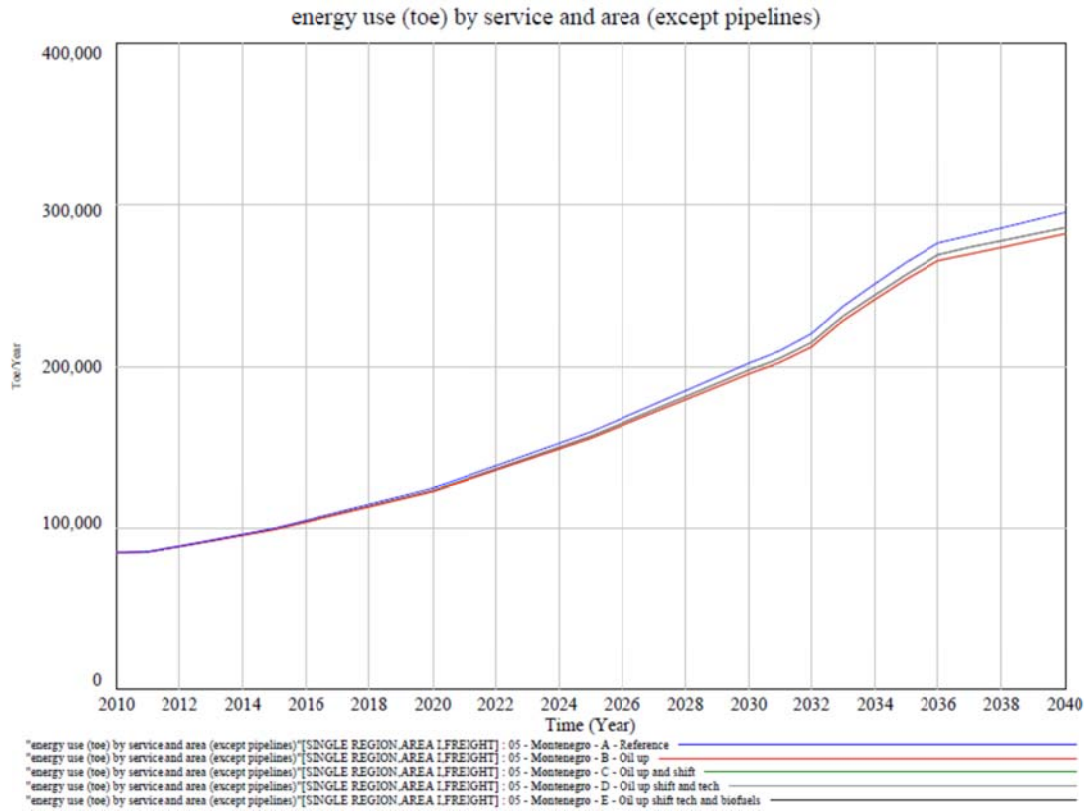


Figure 4.39 Montenegro: TTW CO_2 emissions in passenger transport (kg CO_2)

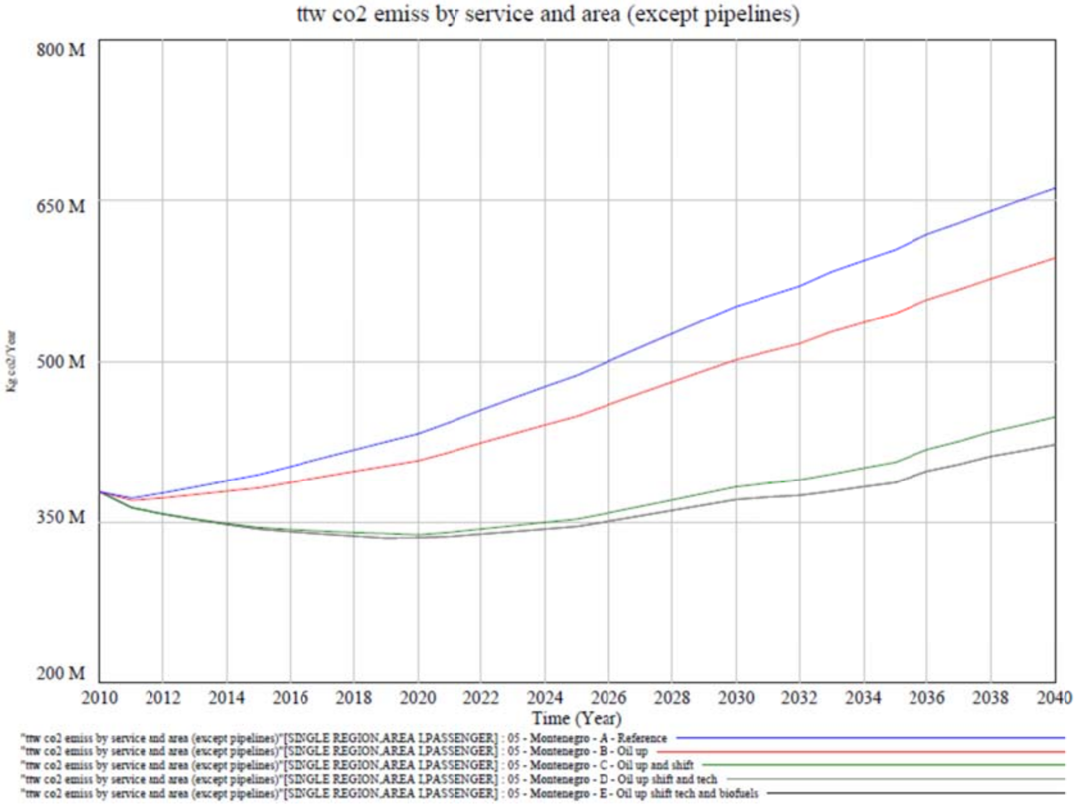


Figure 4.40 Montenegro: TTW CO_2 emissions in freight transport (kg CO_2)

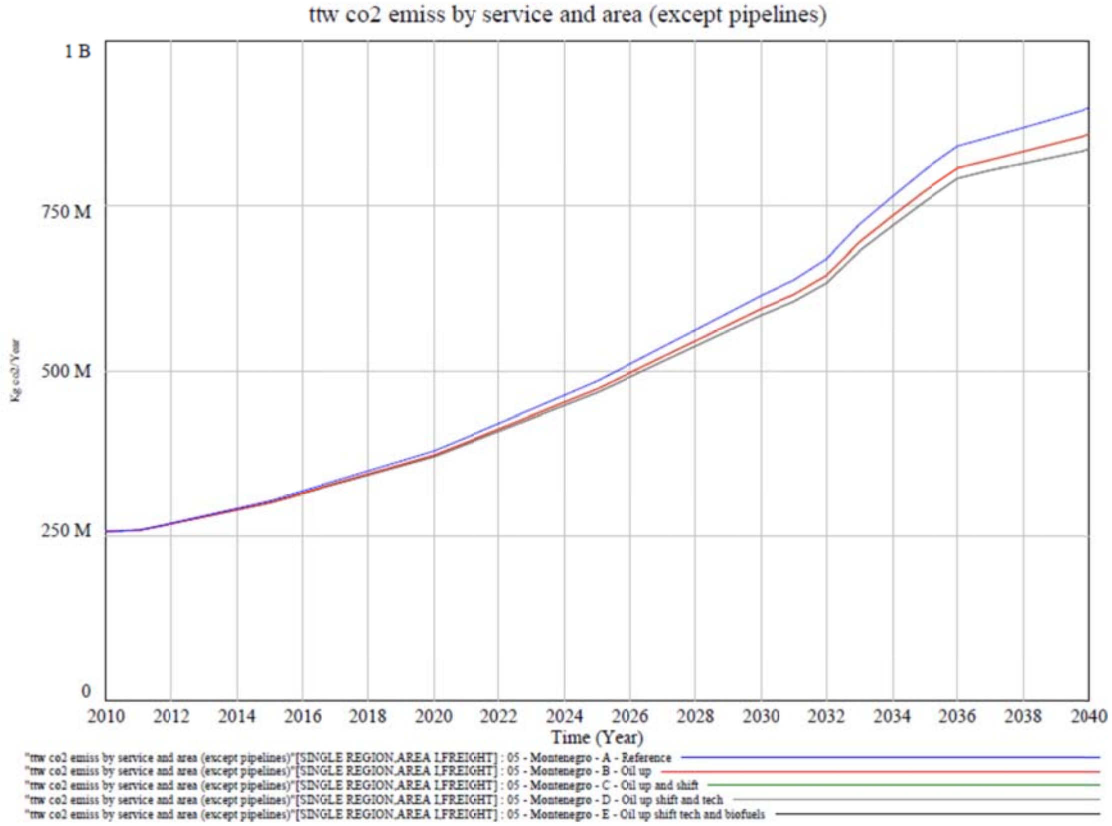


Figure 4.41 Montenegro: WTW CO_2 emissions in passenger transport (kg CO_2)

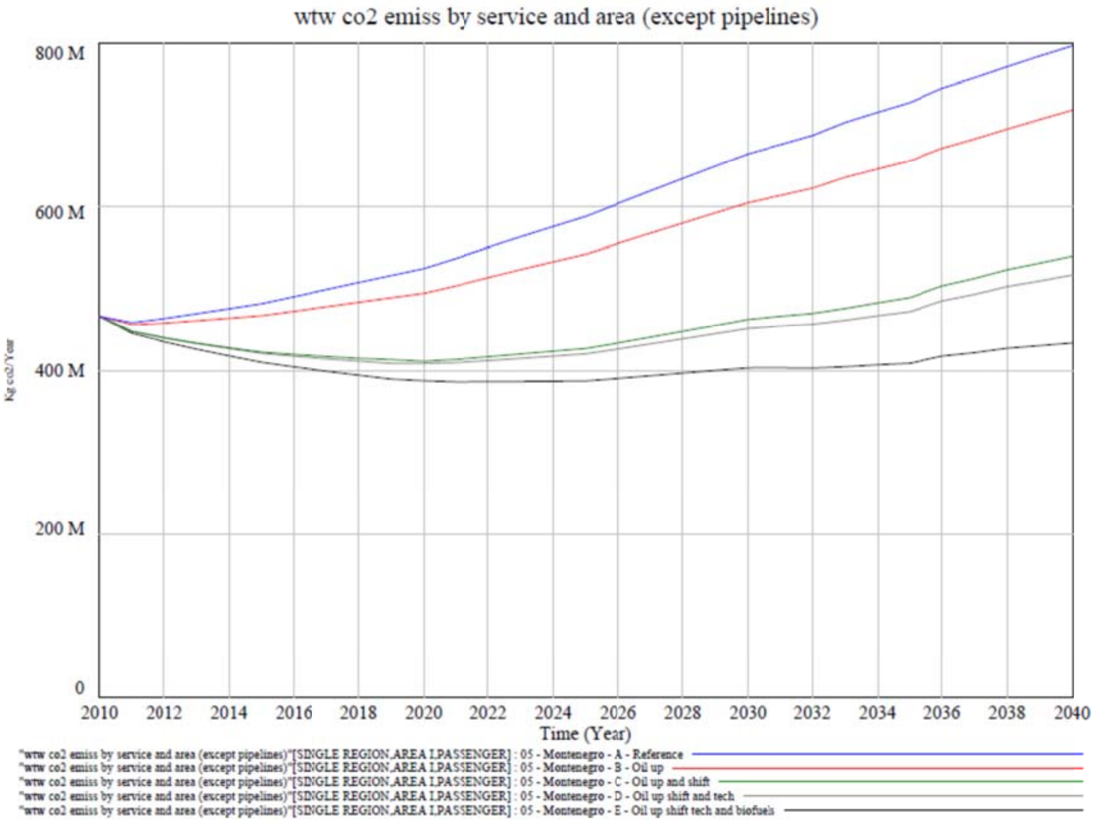
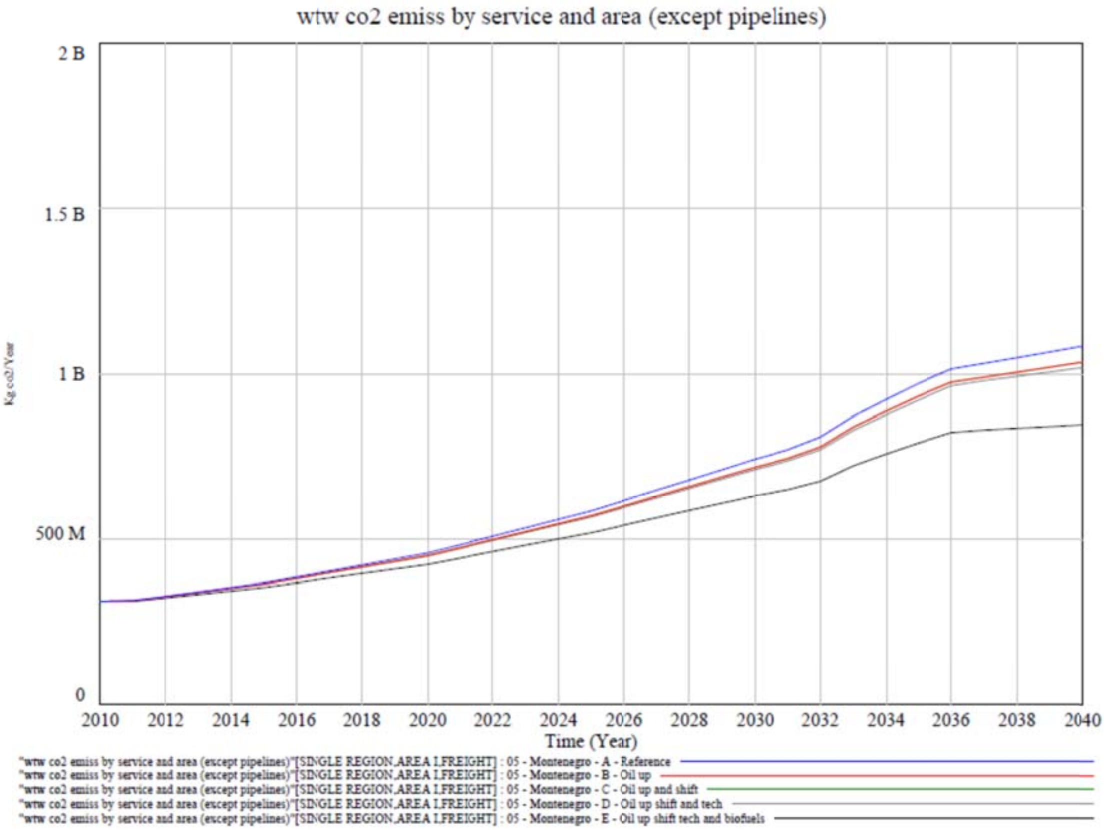


Figure 4.42 Montenegro: WTW CO_2 emissions in freight transport (kg CO_2)



Scenario A – Reference

Table 4.21 Main outputs: Montenegro, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	4.651	7.75	1.67
Total tkm	billion tkm	3.164	11.93	3.77
Total energy use	toe	214,118	516,141	2.41
Total TTW CO_2 emissions	million kg CO_2	635.27	1559.94	2.46
Total WTW CO_2 emissions	million kg CO_2	778.54	1880.99	2.42

Scenario B – Oil up

Table 4.22 Main outputs: Montenegro, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	4.651	7.1	1.53
Total tkm	billion tkm	3.164	11.49	3.63
Total energy use	toe	214,118	481,300	2.25
Total TTW CO_2 emissions	million kg CO_2	635.27	1455	2.29
Total WTW CO_2 emissions	million kg CO_2	778.54	1754.8	2.25

Scenario C – Oil up and shift

Table 4.23 Main outputs: Montenegro, *oil up and shift* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	4.651	6.056	1.3
Total tkm	billion tkm	3.164	11.49	3.63
Total energy use	toe	214,118	431,823	2.02
Total TTW CO_2 emissions	million kg CO_2	635.27	1306.8	2.06
Total WTW CO_2 emissions	million kg CO_2	778.54	1576.24	2.02

Scenario D – Oil up, shift and tech

Table 4.24 Main outputs: Montenegro, *oil up, shift and tech* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	4.651	6.114	1.31
Total tkm	billion tkm	3.164	11.53	3.64
Total energy use	toe	214,118	428,853	2
Total TTW CO_2 emissions	million kg CO_2	635.27	1258.21	1.98
Total WTW CO_2 emissions	million kg CO_2	778.54	1536.26	1.97

Scenario E – Oil up, shift, tech and biofuels

Table 4.25 Main outputs: Montenegro, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	4.651	6.114	1.31
Total tkm	billion tkm	3.164	11.53	3.64
Total energy use	toe	214,118	428,853	2
Total TTW CO_2 emissions	million kg CO_2	635.27	1258.21	1.98
Total WTW CO_2 emissions	million kg CO_2	778.54	1279.95	1.64

Thailand

In Thailand, the population slightly increases over time (multiplied by 1.03 in 2040) and the income triples by 2040. The resulting GDP per capita grows from 7500 to 22500 constant 2000 USD.

In the base year, the personal vehicle ownership levels and the share of public transport correspond to a system that, compared with regions with a similar income, could rely more on public transport options.

The range of average incomes taken into account is far from values associated with a saturation of the vehicle ownership. The total amount of personal passenger vehicles is therefore expected to increase across the whole projection period. Part of the motorcycles is also going to be replaced by cars, while the number of three wheelers should grow slightly.

Air transport is especially relevant in Thailand: it contributes to 40% of the total WTW CO_2 emissions from passenger transport at the base year. This share is expected to grow by the end of the projection period in all scenarios.

The assumptions characterizing the *oil up* scenario in Thailand result in higher than average changes in transport activity, energy use and CO_2 emissions, both for passenger and freight transport. This is due to the relatively high elasticities characterizing regions with relatively low average incomes, but also to the larger impact of oil price changes on fuel costs that are either subsidized or subject to low taxation.

Changing the passenger transport characteristic index from 0.26 to 0.34, as in the *shift* scenarios, does not lead to significant changes of the total pkm, but it does result in an increased share of pkm on public transport modes and a decrease on private passenger vehicles. This shift translates also into 13% reduction of WTW CO_2 emissions for passenger transport.

Tech scenario inputs are not reflected in a significant rebound effect in Thailand because of the relatively low role played by subsidized fuels in the total cost of driving and the little change induced by the penetration of new technologies. This is also a signal that achieving the *tech* scenario objectives is unlikely to be easy in a situation where fuel costs are not entirely passed to consumers.

The WTW CO_2 emissions reduction in o*il up, shift, tech and biofuels* scenario results from the counteracting combination of two aspects: gasoline is assumed to be blended with sugar cane ethanol (this leads to lower WTW emission factors than in other pilot regions), and the biodiesel component derived for 75% from palm oil rather from rapeseed and sunflower (this is associated with higher WTW emission factors than in other pilot regions).

Figure 4.43 Thailand: total pkm

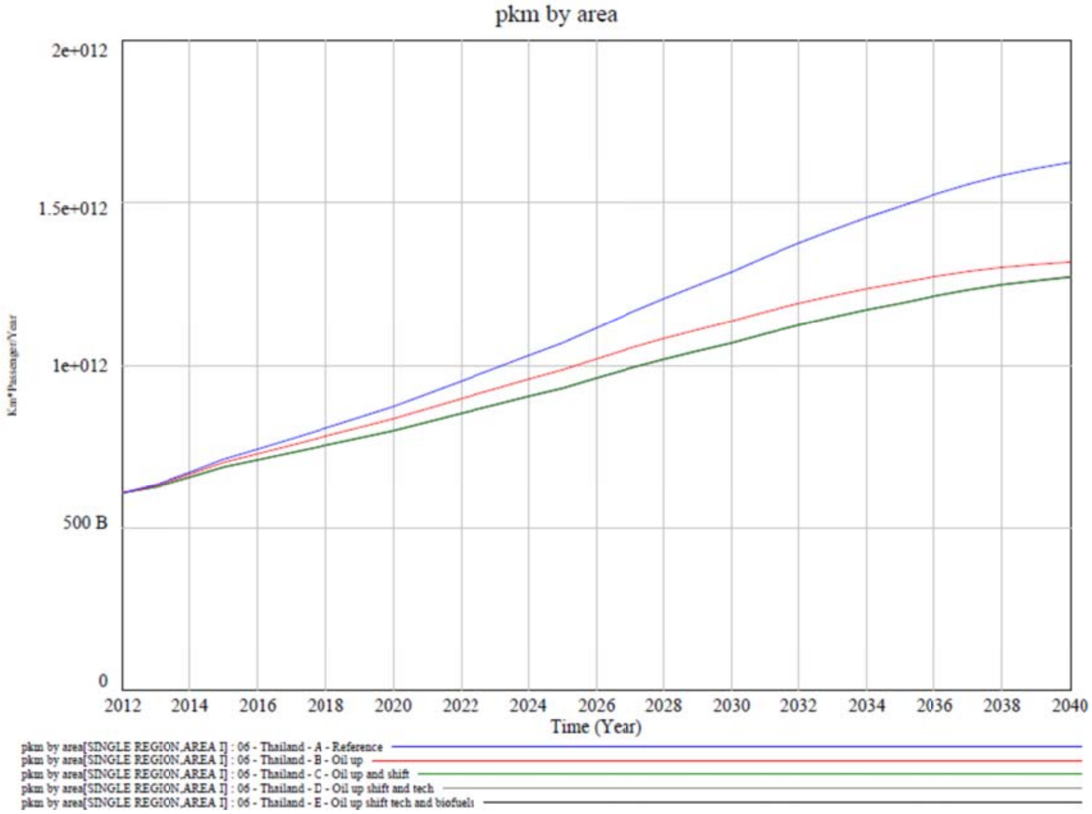


Figure 4.44 Thailand: total tkm

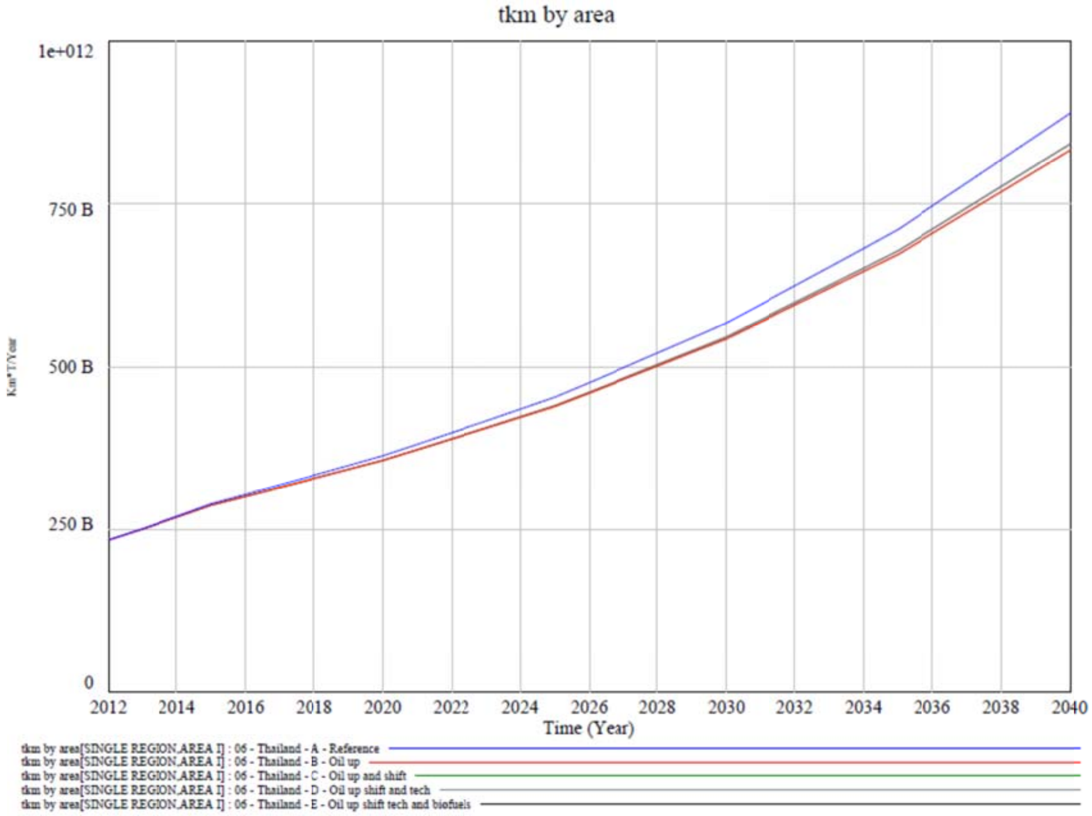


Figure 4.45 Thailand: energy use in passenger transport (toe)

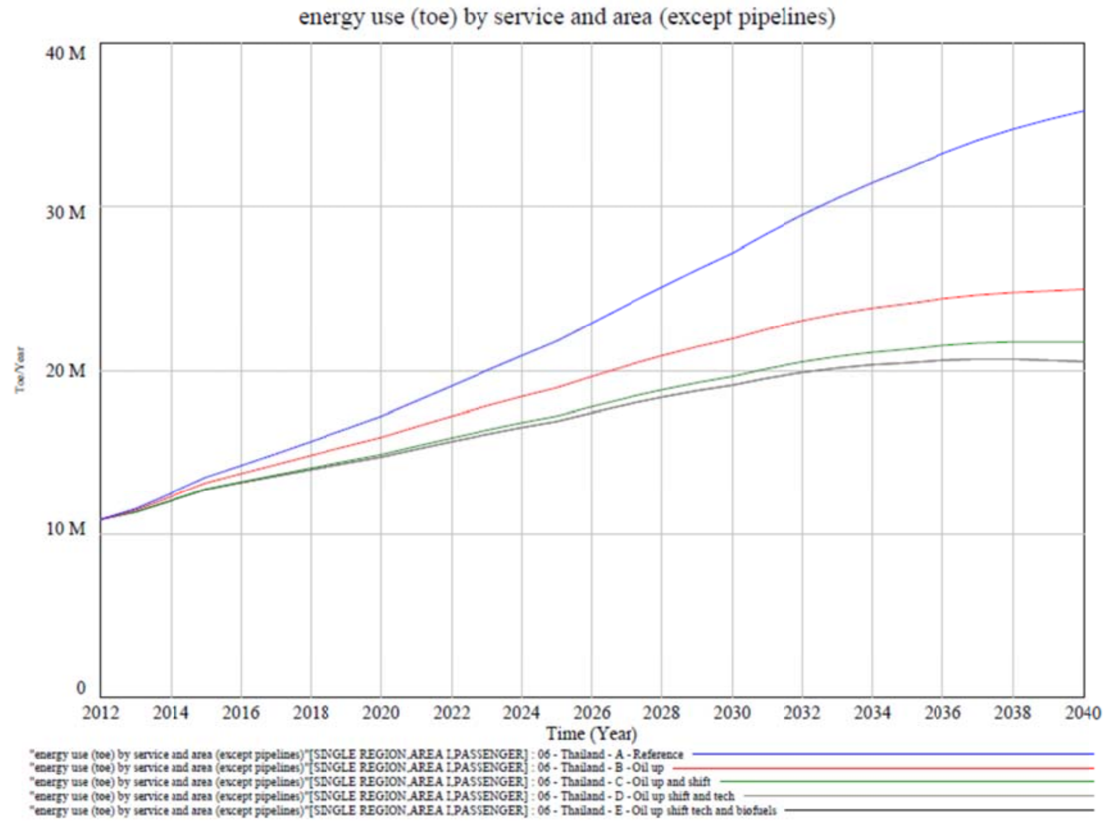


Figure 4.46 Thailand: energy use in freight transport (toe)

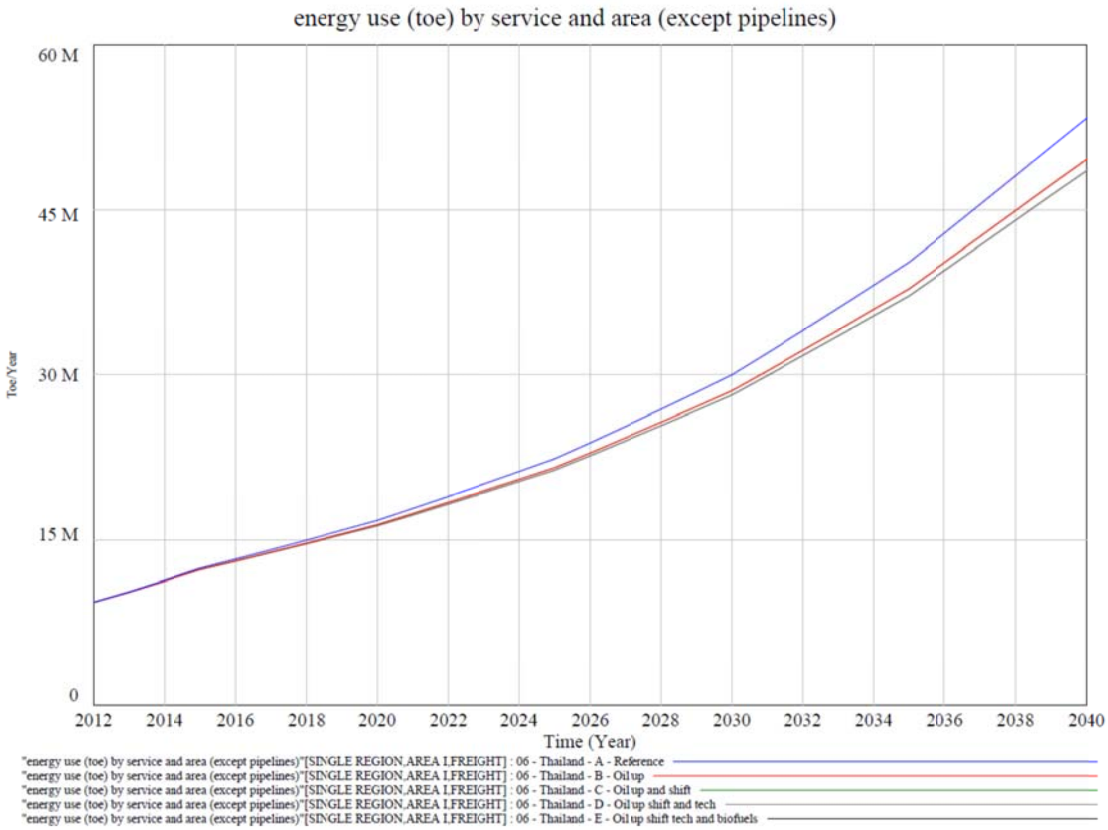


Figure 4.47 Thailand: TTW CO_2 emissions in passenger transport (kg CO_2)

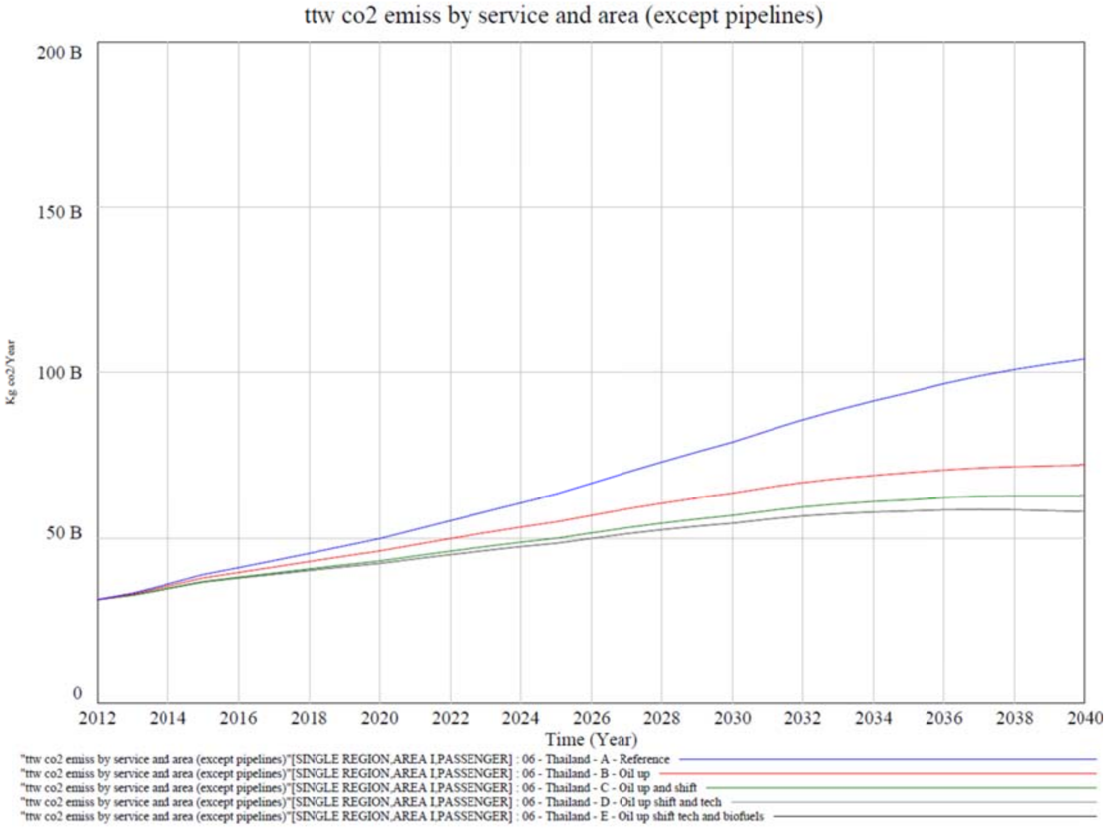


Figure 4.48 Thailand: TTW CO_2 emissions in freight transport (kg CO_2)

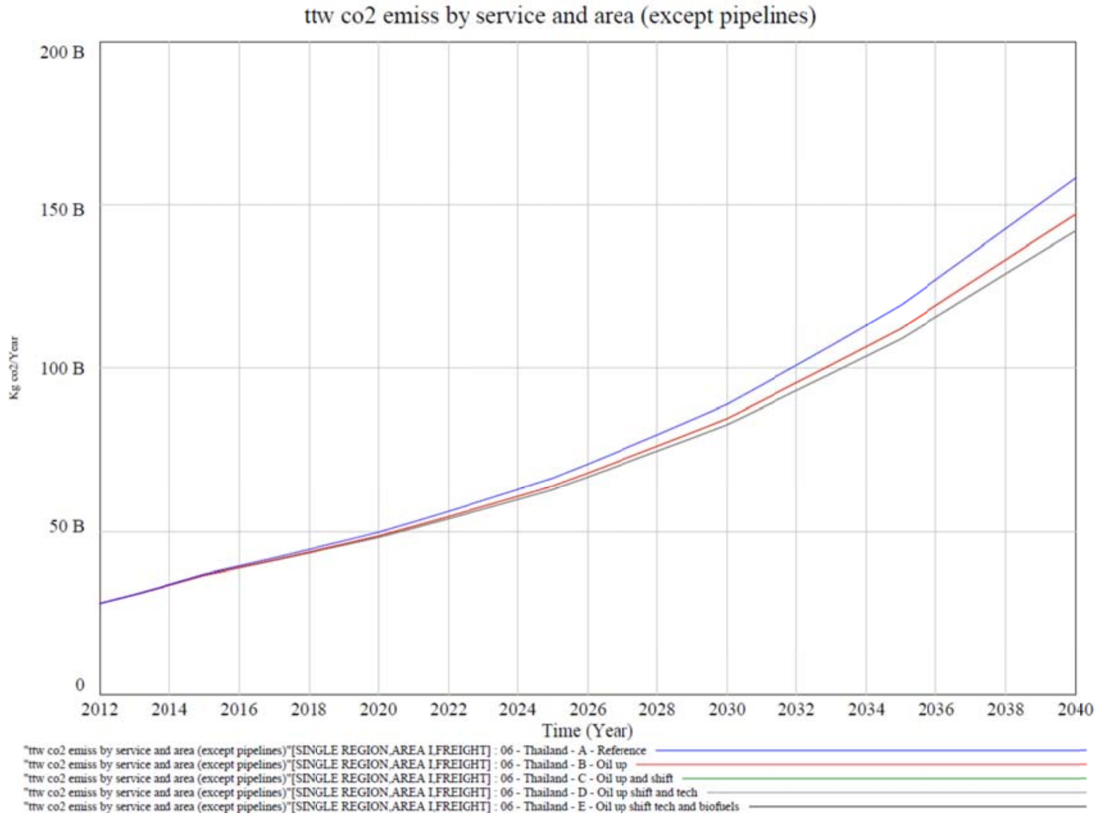


Figure 4.49 Thailand: WTW CO_2 emissions in passenger transport (kg CO_2)

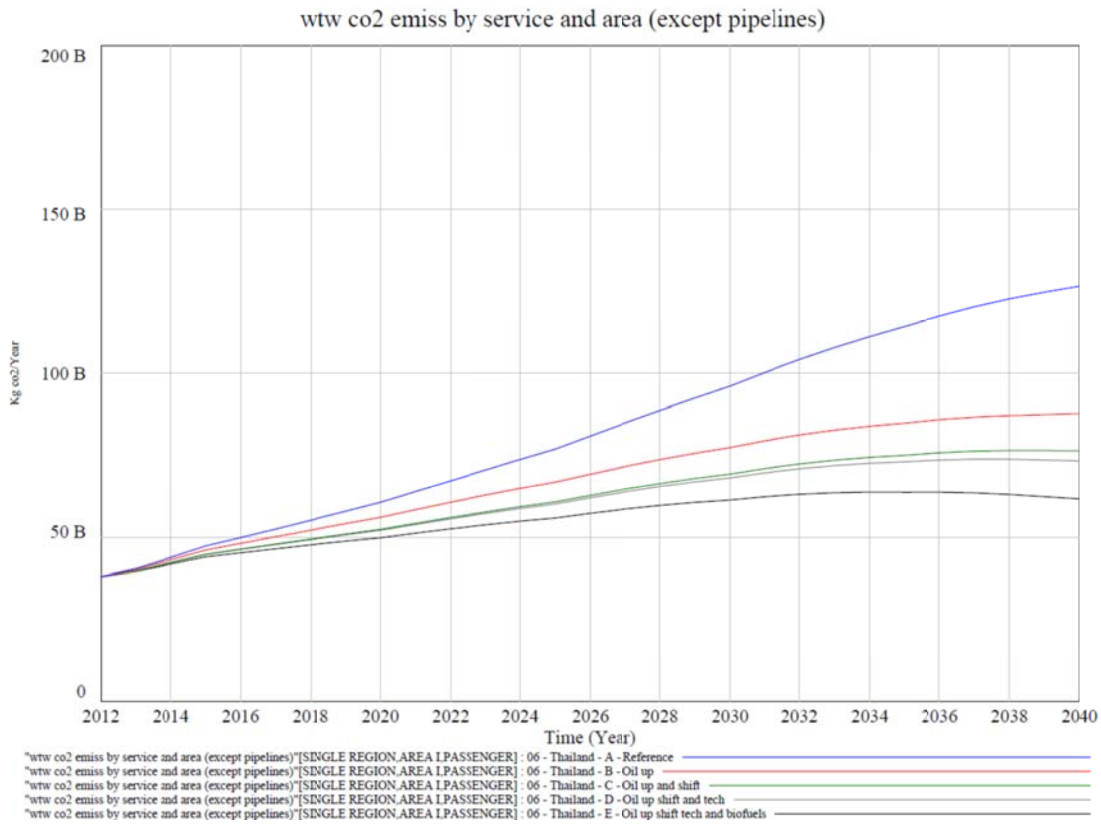
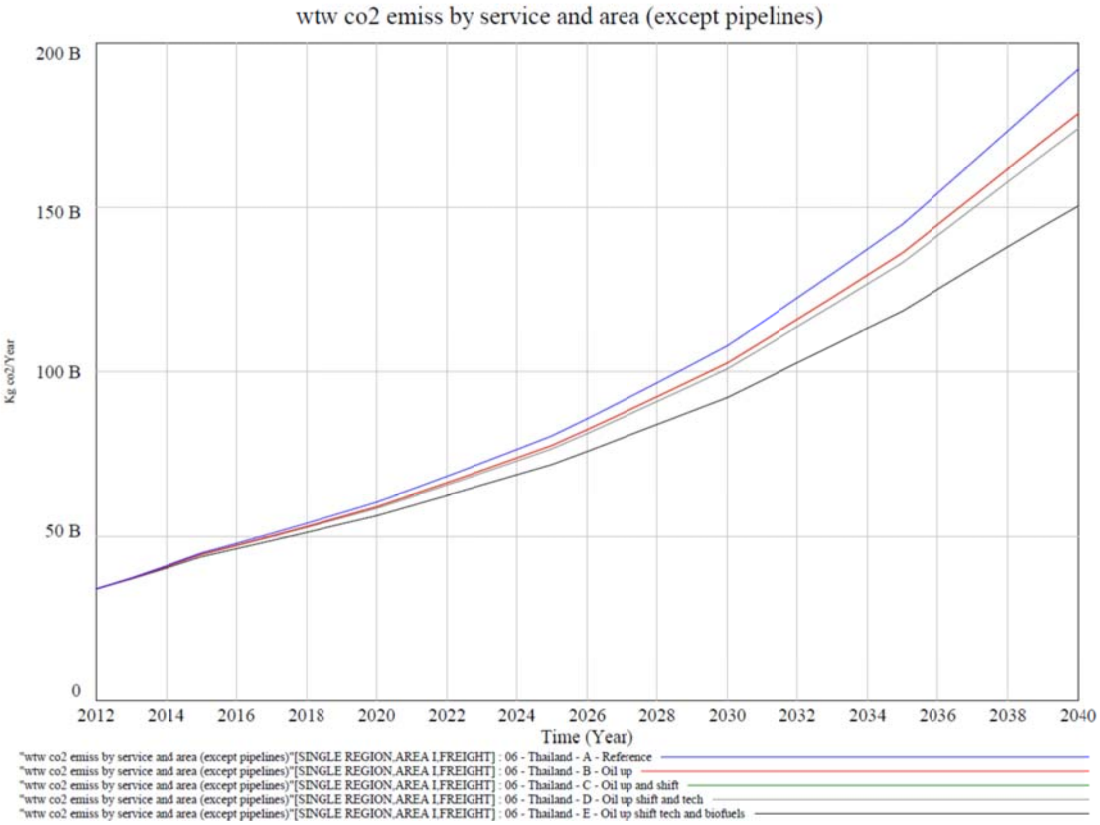


Figure 4.50 Thailand: WTW CO_2 emissions in freight transport (kg CO_2)



Scenario A – Reference

Table 4.26 Main outputs: Thailand, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	608.34	1623.67	2.67
Total tkm	billion tkm	234.08	889.27	3.8
Total energy use	million toe	20.228	89.27	4.41
Total TTW CO_2 emissions	billion kg CO_2	59.41	262.35	4.42
Total WTW CO_2 emissions	billion kg CO_2	71.94	318.73	4.43

Scenario B – Oil up

Table 4.27 Main outputs: Thailand, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	608.34	1318.35	2.17
Total tkm	billion tkm	234.08	832.4	3.56
Total energy use	million toe	20.228	74.62	3.69
Total TTW CO_2 emissions	billion kg CO_2	59.41	219.18	3.69
Total WTW CO_2 emissions	billion kg CO_2	71.94	266.35	3.7

Scenario C – Oil up and shift

Table 4.28 Main outputs: Thailand, *oil up and shift* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	608.34	1270.89	2.09
Total tkm	billion tkm	234.08	832.4	3.56
Total energy use	million toe	20.228	71.39	3.53
Total TTW CO_2 emissions	billion kg CO_2	59.41	209.83	3.53
Total WTW CO_2 emissions	billion kg CO_2	71.94	255	3.54

Scenario D – Oil up, shift and tech

Table 4.29 Main outputs: Thailand, *oil up, shift and tech* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	608.34	1273.29	2.09
Total tkm	billion tkm	234.08	842.2	3.6
Total energy use	million toe	20.228	69.14	3.42
Total TTW CO_2 emissions	billion kg CO_2	59.41	200.06	3.37
Total WTW CO_2 emissions	billion kg CO_2	71.94	247.28	3.44

Scenario E – Oil up, shift, tech and biofuels

Table 4.30 Main outputs: Thailand, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	608.34	1273.29	2.09
Total tkm	billion tkm	234.08	842.2	3.6
Total energy use	million toe	20.228	69.14	3.42
Total TTW CO_2 emissions	billion kg CO_2	59.41	200.06	3.37
Total WTW CO_2 emissions	billion kg CO_2	71.94	212.09	2.95

Tunisia

In Tunisia, the total population is expected to increase by 20% BY 2040, while the GDP is projected to be almost multiplied by 4. This sets an evolution of the personal income from 7500 up to 24000 constant 2000 USD.

Freight transport represents 33% of the total energy use at the base year. The share of light freight vehicles in Tunisia (93% of the total freight vehicles at the base year) is very large in comparison to the values seen in global regions with a similar income level. This may be due to data quality issues or specific circumstances of the country (possibly associated with the presence of fuel subsidies).

Freight transport is expected to contribute to 40% of the total energy use in 2040. This is the result of the combination of two aspects: the growth of the economic output (directly linked with large freight activity) and a large increment of that activity that is projected to place on light freight vehicles (less energy efficient than large freight modes). The last aspect is due to the way ForFITS projects light freight activity. If light freight vehicles statistics are too high in the base year, this could indeed represent an overestimation and would need specific attention in case of the development of an in-depth study.

Concerning passenger transport, the range of personal income in the projections is well below values that would lead to a saturation of personal vehicle ownership and the share of pkm on personal vehicles. The passenger activity is therefore projected to increase over time in all modes. Little changes in the trend of the projection is seen across the whole period 2010-2040.

Like in Thailand, the Tunisian fuel taxation scheme (low taxes on gasoline, and subsidies to diesel) boosts the effect of the assumptions made in the *oil up* scenario and reduces the rebound effect in the *tech* scenarios.

The slight change of the passenger transport characteristic index from 0.39 to 0.45, taken into account in the *shift* scenarios, corresponds to change in the modal choice for passenger transport that triggers a reduction in total energy use and CO_2 emissions.

Note: pipelines represent a huge amount of the total freight activity in Tunisia. This is mainly associated with to the transit of petroleum and gas from Algeria to Europe and has little impact on other transport-related aspects. The high order of magnitude compared to other freight transport led to the exclusion of pipelines from the results shown in the figures below and discussed earlier.

Figure 4.51 Tunisia: total pkm

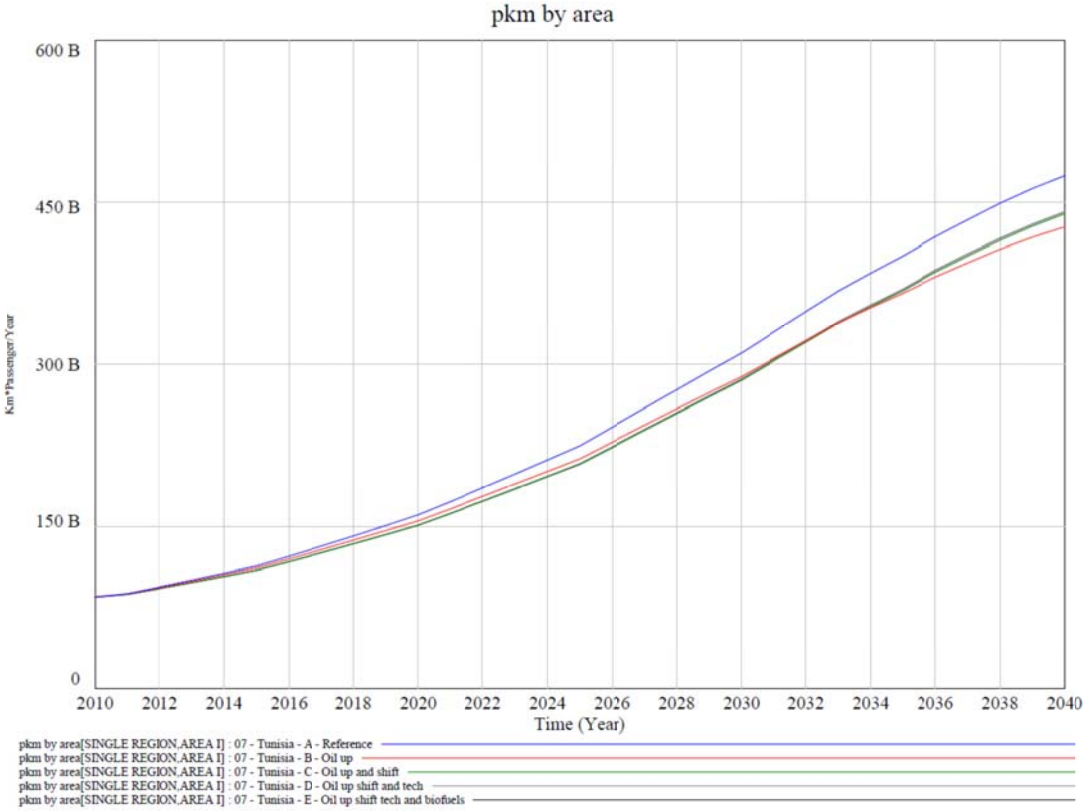


Figure 4.52 Tunisia: total tkm

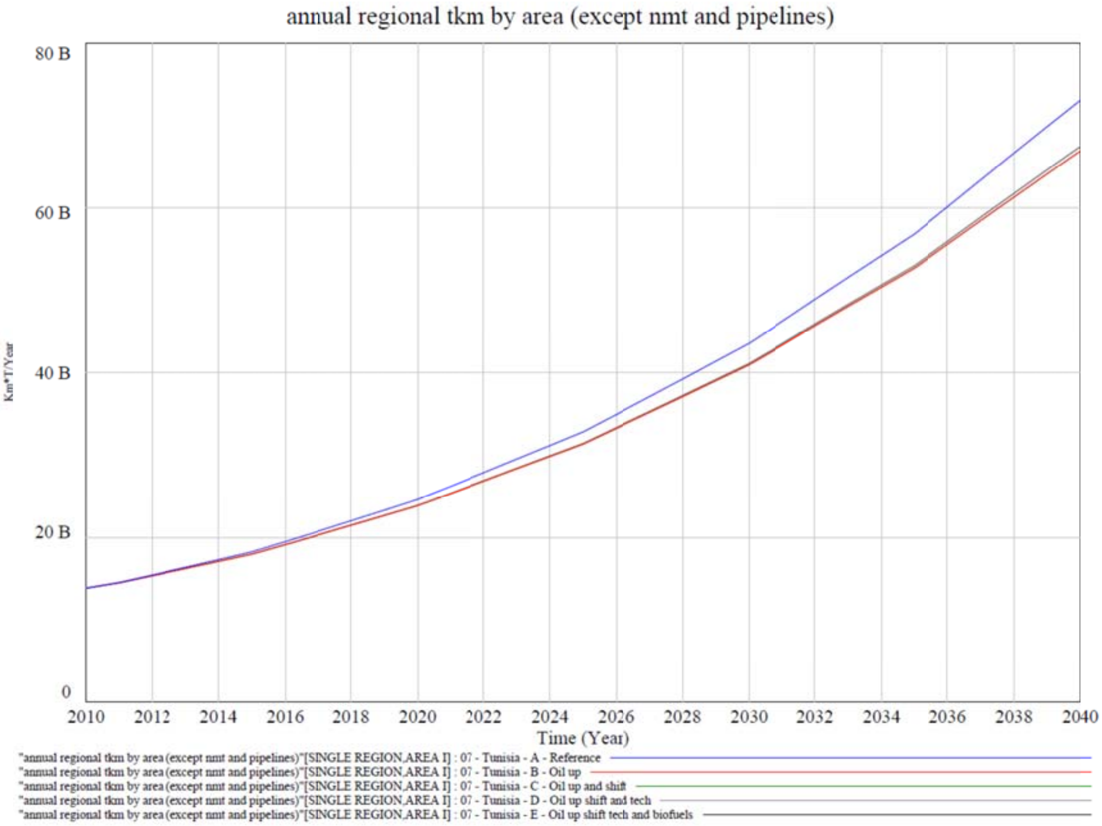


Figure 4.53 Tunisia: energy use in passenger transport (toe)

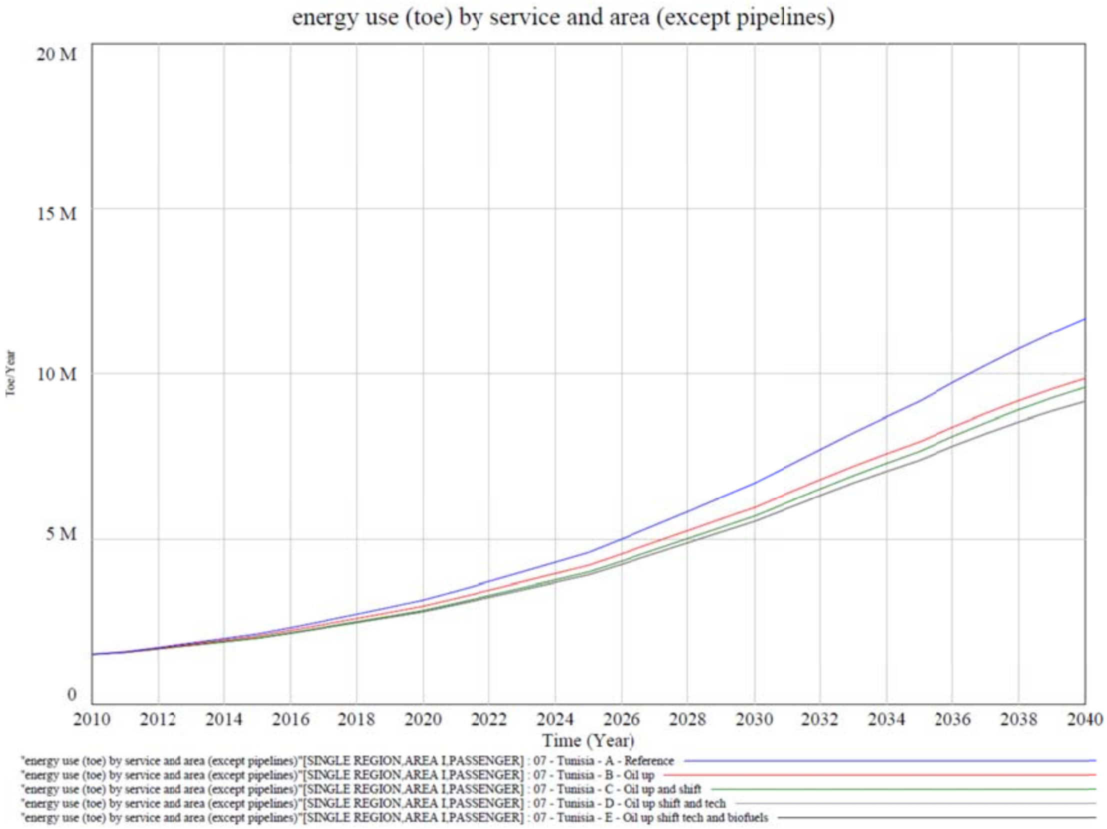


Figure 4.54 Tunisia: energy use in freight transport (toe)

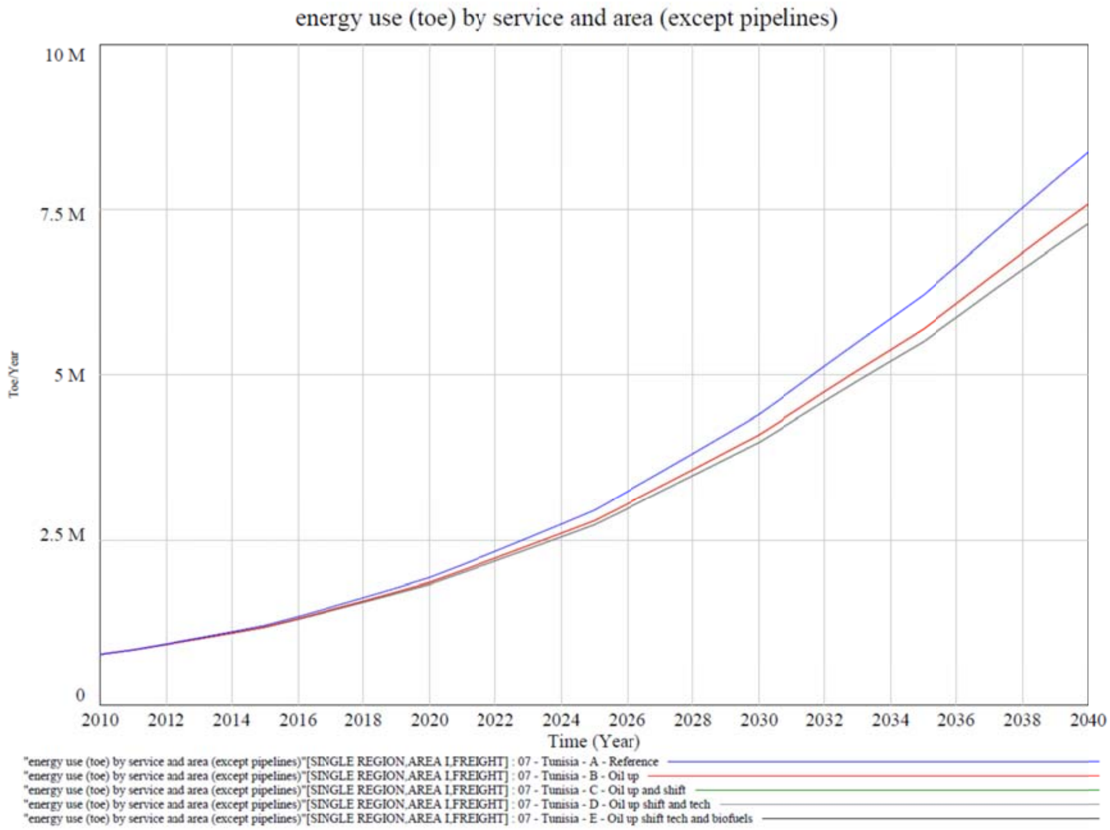


Figure 4.55 Tunisia: TTW CO_2 emissions in passenger transport (kg CO_2)

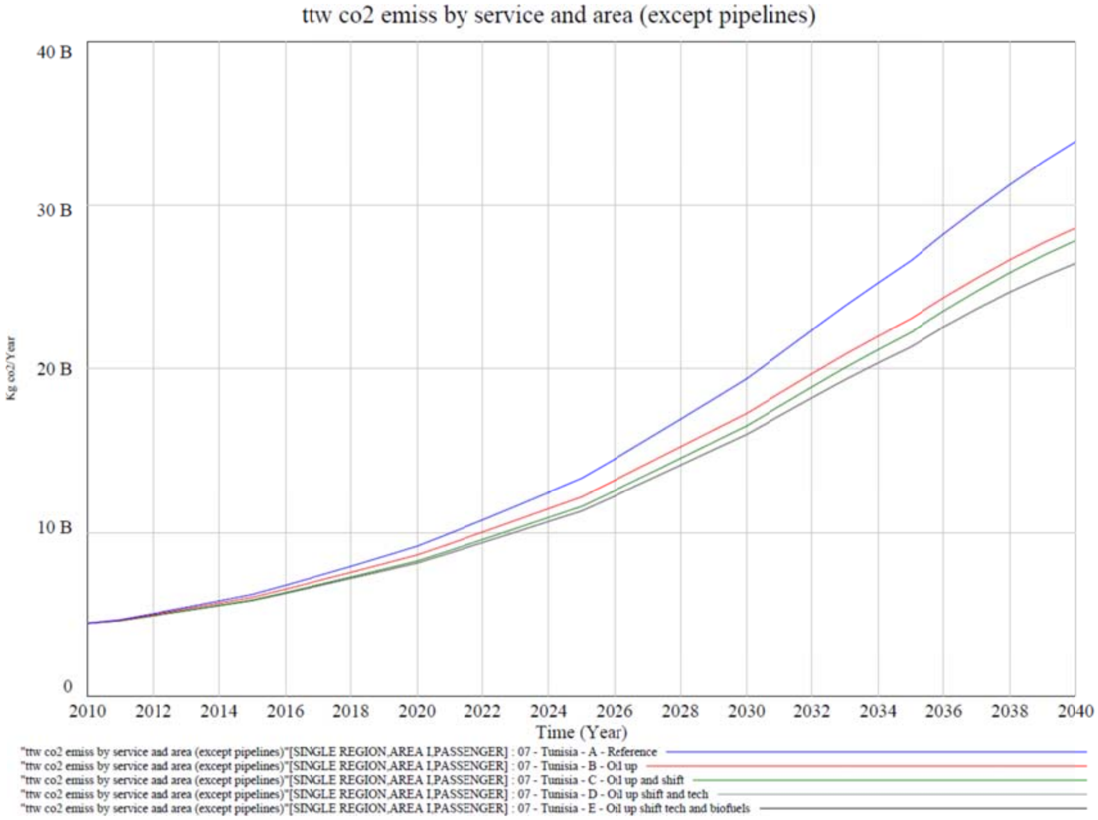


Figure 4.56 Tunisia: TTW CO_2 emissions in freight transport (kg CO_2)

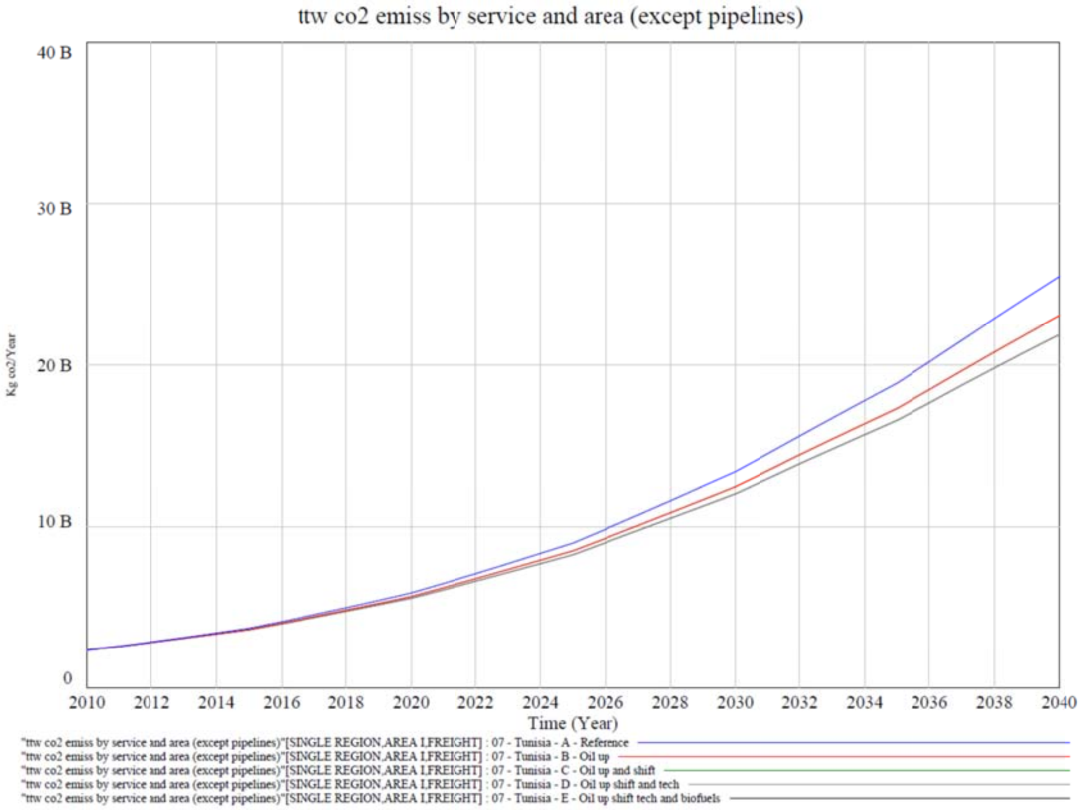


Figure 4.57 Tunisia: WTW CO_2 emissions in passenger transport (kg CO_2)

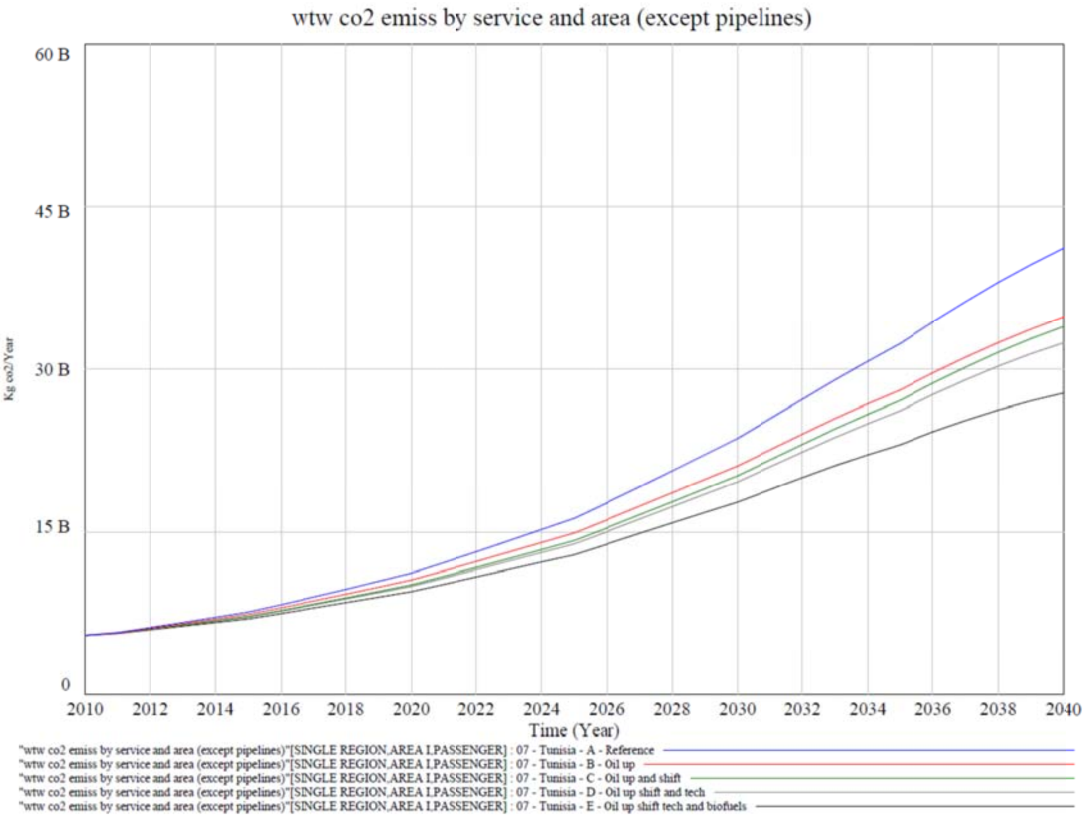
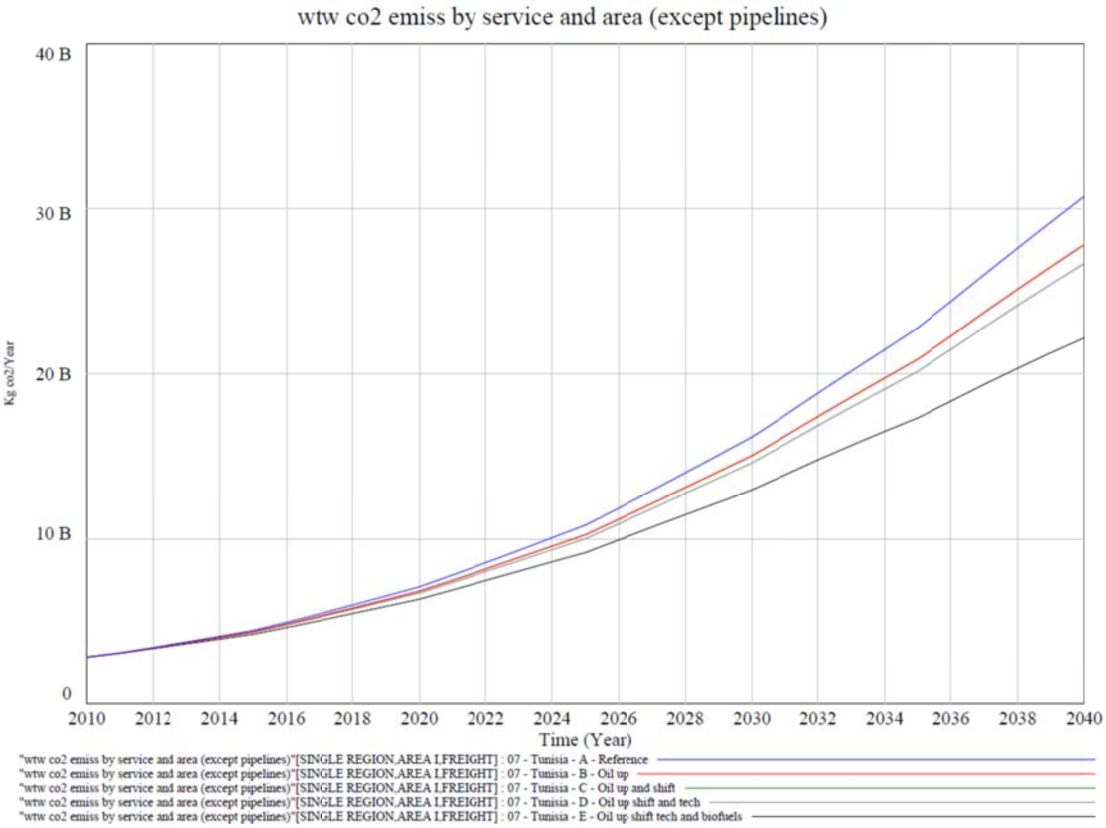


Figure 4.58 Tunisia: WTW CO_2 emissions in freight transport (kg CO_2)



Scenario A – Reference

Table 4.31 Main outputs: Tunisia, *reference* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	84.88	474.46	5.59
Total tkm	billion tkm	13.81	73.07	5.29
Total energy use	million toe	2.30	20.062	8.73
Total TTW CO_2 emissions	billion kg CO_2	6.803	59.39	8.73
Total WTW CO_2 emissions	billion kg CO_2	8.295	71.97	8.68

Scenario B – Oil up

Table 4.32 Main outputs: Tunisia, *oil up* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	84.88	427.23	5.03
Total tkm	billion tkm	13.81	66.9	4.84
Total energy use	million toe	2.30	17.453	7.59
Total TTW CO_2 emissions	billion kg CO_2	6.803	51.69	7.6
Total WTW CO_2 emissions	billion kg CO_2	8.295	62.68	7.56

Scenario C – Oil up and shift

Table 4.33 Main outputs: Tunisia, *oil up and shift* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	84.88	439.28	5.18
Total tkm	billion tkm	13.81	66.9	4.84
Total energy use	million toe	2.30	17.186	7.48
Total TTW CO_2 emissions	billion kg CO_2	6.803	50.92	7.48
Total WTW CO_2 emissions	billion kg CO_2	8.295	61.81	7.45

Scenario D – Oil up, shift and tech

Table 4.34 Main outputs: Tunisia, *oil up, shift and tech* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	84.88	441.05	5.2
Total tkm	billion tkm	13.81	67.44	4.88
Total energy use	million toe	2.30	16.458	7.16
Total TTW CO_2 emissions	billion kg CO_2	6.803	48.35	7.11
Total WTW CO_2 emissions	billion kg CO_2	8.295	59.16	7.13

Scenario E – Oil up, shift, tech and biofuels

Table 4.35 Main outputs: Tunisia, *oil up, shift, tech and biofuels* scenario

	Unit	Base year	2040	Ratio 2040/BY
Total pkm	billion pkm	84.88	441.05	5.2
Total tkm	billion tkm	13.81	67.44	4.88
Total energy use	million toe	2.30	16.458	7.16
Total TTW CO_2 emissions	billion kg CO_2	6.803	48.35	7.11
Total WTW CO_2 emissions	billion kg CO_2	8.295	50.02	6.03

5. Recommendations

This Chapter builds on the pilot application of ForFITS to the cases selected, leveraging on the information collected and described in Chapter 2, the hypotheses used for the definition of the scenarios (illustrated in Chapter 3) and the results of model runs outlined in Chapter 4 to formulate recommendations.

Data

Chapter 2 underlined the importance of the availability of statistics and technical information for the use of modelling instruments capable to provide insights on the evolution of the transport system like ForFITS.

A review on statistics, mitigation polices, and modelling tools related with CO_2 emissions from inland transport (UNECE; 2012) already stressed the fundamental importance of statistics, also providing suggestions to improve the current situation. They included considerations on:

a) the need to establish a legislative framework and structural funding mechanisms for data collection;
b) the need for an effective coordination of the work of local, national and even international authorities;
c) the advantages of harmonization and coordination of definitions and the data collection;
d) the importance to maximize the use of existing information;
e) the relevance of benchmarking and support for the visibility and dissemination of best practices; and
f) the need for capacity building and the provision of seed grants for regions where the development of a statistical database and the associated surveying tools is not yet developed.

The difficulties encountered in the definition of the ForFITS pilot runs, well demonstrated by the need to accept a number of compromises and rely on assumptions (even if backed up by the need to match results available from aggregated statistics), confirm the validity of these messages.

Comparative assessment of results

Transport policy options aiming to reduce or eliminate the emissions of GHG and noxious pollutants have been grouped according to three fundamental strategies (ABD, 2009):

- avoiding or reducing the need for travel, managing the total travel demand ("avoid");
- shifting travel to more sustainable transport modes ("shift"); and
- improving the sustainability of vehicles, fuels and infrastructures concerning all modes ("improve").

The following section considers the scenarios outlined in Chapter 3 and discussed in Chapter 4, contextualizing their impacts in the above mentioned framework. Table 5.1 shows comparative changes of WTW CO_2 emissions in 2040 in each of the scenarios progressively considered for all the pilot regions, starting from the results of the *reference* scenario.

Table 5.1 **Comparative changes of WTW CO_2 emissions in 2040 in the scenarios progressively considered for all pilot regions**

	Oil up vs. *Reference*	*Oil up and shift* vs. *Oil up*	*Oil up, shift and tech* vs. *Oil up and shift*	*Oil up, shift, tech and biofuels* vs. *Oil up, shift and tech*
Chile	-8.9%	-0.4%	-5.7%	-15.0%
Ethiopia	-13.3%	-0.9%	-5.7%	-16.1%
France	-15.7%	-2.6%	-3.5%	-16.2%
Hungary	-9.2%	-7.8%	-4.7%	-16.2%
Montenegro	-6.7%	-10.2%	-2.5%	-16.7%
Thailand	-16.4%	-4.3%	-3.0%	-14.2%
Tunisia	-12.9%	-1.4%	-4.3%	-15.4%

Reference scenario

The *reference* scenario aims to describe a development pattern characterized by the absence of major policy and system changes, with the main exception of a tendency to apply progressive technology improvements to existing vehicle powertrains.

Oil up scenario

The *oil up* scenario leverages on the importance of oil as primary energy source for transportation to take into account the impact of changes of fuel prices on the transport system. The results shown in Chapter 4 highlight that this sort of change shall be associated primarily with the avoidance of transport and mobility and the shift towards more energy efficient mobility options. Increases in the cost of driving tend to translate in an improvement of the way people and goods are moved, reducing the overall need for mobility, reflecting the logical framework of supply and demand economic models. In freight transport, this may be coupled with revisions in the logistics system (lower shares of empty running, higher average loads, but also lower vehicle travel due to structural changes in sourcing and manufacturing processes or modal choice). In passenger transport, this can be associated with a change in consumer habits, with part of the mobility moving towards more energy efficient modes (the cost of driving in these modes is less affected by the variation of energy prices), and part of the travel being reduced by changes in average daily travel distances or avoided travel. Even if the *oil up* scenario does not consider explicitly policy inputs, it is important to underline that policy actions influencing the fuel prices would be subject to the same dynamics.

The impacts of the assumptions behind the *oil up* scenario differ across pilot regions: the largest reductions in energy use and CO_2 emissions take place:

a) in areas with a lower average income (because of the higher direct elasticity of vehicle travel and ownership with respect to changes in the cost of driving);

b) in areas with low fuel taxation (because of the higher relevance of the untaxed component in it, leading to wider percent changes); and
c) in areas with a higher availability of energy efficient mobility options, such as public transport (because of the effect of cross elasticities of passenger transport activity with respect to changes in the cost of driving).

In Ethiopia, Thailand and Tunisia, the comparatively high variations between the *reference* and the *oil up* WTW CO_2 emission estimates are primarily imputable to the first two reasons listed above. The result concerning the French pilot case is explained by the third point, especially relevant in the urban component of this pilot evaluation, but also by the comparatively high elasticity of annual vehicle travel in rural areas with respect to changes in the cost of driving.

Oil up and shift scenario

Unlike the *oil up* scenario, the *oil up and shift* is entirely a policy scenario. The influence of the policy changes is limited to effects on the passenger transport system. The hypotheses characterizing this scenario are also contributing to the avoidance of transport and mobility and the shift towards more energy efficient mobility options. Its impacts, however, are due to structural changes in the system (reflected in a variation of the behaviour of modelling parameters) and not by a response driven by the characteristics of the system, as in the case of the *oil up* scenario.

The impacts of the *oil up and shift* scenario differ across pilot regions. In this case, the response reflect the differences in the assumptions made in each pilot, since they impose stronger changes to pilot regions whose passenger transport system is less public transport oriented. These are the cases when the development of the transport system in the direction represented by the *shift* inputs requires important structural changes, including aspects related to urban planning and not only limited to the improvement of public transport and the reduction of the appeal of private vehicle usage in urban areas.

Montenegro, Hungary and Thailand where the pilot regions with the highest impacts in terms of WTW CO_2 emission reduction in the *oil up and shift* scenario. They are also the regions with the highest input variations.

Oil up, shift and tech scenario

The *oil up, shift and tech* scenario attempts to evaluate the impact of improving the characteristics of vehicles entering the market beyond the levels already taken into account in the *reference* and other scenarios described earlier. In regions with high fuel taxation, the *tech* component of this scenario is coupled with a rebound effect in transport activity that weights more than the increase of activity seen in regions with low fuel taxation. This reflects the higher cost impact of fuel savings in areas where fuels have a higher unit price for consumers. The rebound, however, is not sufficient to overcome the increased fuel savings. As a result, energy consumption and CO_2 emissions tend to decrease with the accelerated introduction of advanced powertrain technologies capable to reduce the average fuel consumption of vehicles.

The impacts of the *tech* component on different pilot results depend are the result of the combination of four main elements:

a) the gap in terms of fuel consumption improvement characterizing advanced alternatives with respect to conventional powertrain technologies (direct impact: fuel savings from full electrification of vehicles, for instance, far exceed, on a TTW basis, the fuel savings due to vehicle hybridization);
b) the extent to which new technologies have been assumed to enter specific markets (direct impact);
c) the rapidity of the growth of the vehicle stock (new vehicles in rapidly growing markets gain larger shares in the stock than old vehicles); and
d) the average survival age of vehicles (high average survival age are associated with slower stock renewals).

Oil up, shift, tech and biofuels scenario

The *oil up, shift, tech and biofuels* scenario attempts to take into account the effect of another dimension of the improvement of the technical characteristics of the transport system, focusing on fuels. The hypothesis used for the characterization of this scenario is similar across all pilot regions. They assume that 20% of the energy content of the main fuel blends is derived from biofuels in all cases, and they consider the same variation of WTT emission factors in all pilots but Thailand[7]. This results in a WTW CO_2 emission reduction close to 15-16% in all pilots.

The variations between pilots are mainly associated with changes in the importance of the diesel blend over the gasoline blend over time. In all cases but Thailand, the WTW emission factors for the gasoline blend evolves from 2.72 kg CO_2/lge to 2.37 kg CO_2/lge. For the diesel blend, WTW emission factor is always slightly higher (from 2.94 kg CO_2/lge to 2.44 kg CO_2/lge). This means that in cases where there is a tendency towards an increase of the share of diesel fuel demand (e.g. because of differing growth rates of passenger vs. freight transport), the reduction of WTW CO_2 emissions will be lower than in regions where diesel becomes less relevant over time.

Policy insights

Notwithstanding the limitations associated to the limited amount of data available, the pilot analysis outlined in this report provides interesting insights for the development of transport policies with implications on the attempt to mitigate climate change.

The Intergovernmental Panel on Climate Change sets global CO_2 emissions policy goals that contemplate a cut of GHG emissions by at least 50% by 2050. This requires a reduction of CO_2 emissions from transportation from current levels in the same timeframe, even when significant savings coming from other sectors are taken into account.

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[7] In Thailand, lower WTT emissions in the sugar cane ethanol component of the gasoline blend are counterbalanced by higher emissions in biodiesel from palm oil for the diesel blend.

The limited CO_2emission reductions resulting from the ForFITS pilot runs highlight that measures and assumptions considered in the framework of this study are not sufficient to deliver the ambitious changes required to meet the CO_2 emission mitigation policy goals. The nature of the inputs taken into account (doubling of oil price, structural changes in passenger transport, increases in advanced powertrain technology uptake and biofuels), however, is not marginal. This demonstrates that changing transport trends will require not only an aggressive adoption of measures capable to reduce energy demand from transportation, but also instruments encouraging changes in travel patterns.

The comparative analysis of the pilot runs also shows that, if historical development patterns of transport activity remain valid, the growth of transport activity in developed countries is going to be significantly lower than in developing countries. In addition, it underlines that less developed countries are subject to stronger drivers towards an increase of the energy intensity of the passenger and freight transport systems.

On the other hand, the long lifetime of transportation infrastructure and the deep roots of the transport systems, spanning from land use choices in urban environments to cultural aspects of countries, are such that changing the structure of the built environment is likely to be harder in the developed world, while it may benefit from important opportunities to avoid the lock-in of inefficient mobility solutions in less-developed countries.

While developed countries are in a better position to reduce the absolute value of their WTW CO_2 emission, less developed countries enjoy a larger emission reduction potential (at similar costs), especially if compared with the pattern set by the less efficient examples in the developed world.

Results from the *oil up* scenario show that energy consumption and CO_2 emissions from transportation may be significantly affected by changes taking place in the energy system such as a variation of the oil price. These changes are not negligible. The scenario results demonstrate that they may contribute to ease the task of reducing emissions if they lead to an increase of transport prices. Similar impacts, not contemplated in any of the scenarios considered, could be due to changes to GDP and the populations that fall below (or above) the levels considered in the pilot runs.

Changes to the fuel taxation profile hits the same levers that determine a reaction of the transport system to changes in the fuel price seen by consumers. When looking at GHG emissions, the introduction of a carbon tax and the use of cap-and-trade market-based mechanisms (i.e. a tax on each unit of GHG emissions) have been identified as examples of taxation policies capable to deliver effectively CO_2 emission abatements (UNECE, 2012). Other policies influencing the taxation of fossil fuels would have an impact stimulating energy savings and CO_2 emission reduction. The elimination of subsidies for fossil fuels is an instrument included in this category encountering widespread consensus, since it is considered capable to contribute to GHG emission reduction while providing a level the playing field for the competition amongst transport fuel options and without adverse impacts on energy security (see for instance IEA, 2012). Looking at the conditions of the regions analysed in the pilots, this is especially relevant for Thailand and Tunisia.

The inputs to the *oil up and shift* scenario leveraged on the idea that efforts on structural aspects should be more relevant in areas where the current situation is worse than average. Even if this approach appears fair in principle, local specificities need to be taken into account. Differing urbanization rates, for instance, are likely to have an impact on the actual potential of instruments required for the implementation of the *shift* scenario, since planning policies and the support of public transport options are likely to have greater effects in urban areas.

Model results show that the introduction of vehicle improvements considered in the *tech* scenario is not delivering effective results. The additional efforts necessary to attain CO_2 emission policy goals are particularly relevant in this area. In the pilot cases, the average improvement of the fuel consumption of newly registered vehicles in the *tech* scenarios in 2030 is limited to a range included between 23% and 30%, while it attains 18% to 23% in the *reference* scenario. According to the IEA, the implementation of incremental fuel economy technologies could cost-effectively cut the fuel use and CO_2 emissions per kilometre of new light-duty vehicles worldwide by 30% by 2020 and 50% by 2030 (IEA; 2009). More efforts are therefore needed to achieve these targets. Several policy instruments can help delivering this. The most notable ones are fuel economy standards (both for light vehicles and heavy duty vehicles), fuel consumption and CO_2 emission labelling, and differentiated taxation based on the same performance characteristics.

Improvements on the fuel side have been represented in the pilots by drop-in biofuel mandates reaching a contribution equal to 20% of the energy demand of transport fuels. The resulting WTW CO_2 emission reduction is significant. This result is encouraging, especially when considered against the absence of carbon-intensive fuels in any of the scenarios examined. These positive insights are backed by the fact that advanced (second-generation) biofuels, such as lignocellulosic ethanol and biodiesel derived from biomass to liquids processes have been indicated as options bearing the best long term potential to provide sustainable, low life-cycle GHG fuels (IEA; 2009). Important critical elements, however, should not be neglected when considering an evolution towards a larger biofuel contribution to the transport energy mix. First, biofuels have been arbitrarily assumed to be partly coming from woody biomass, improving their WTW emission reduction potential, even if the commercially viable production of such fuel options may only materialize under optimistic cost development outlooks. Second, the WTT emission factors retained for biofuels exclude any contribution from land-use change (something that would change completely their WTT GHG emission characteristics), even if an increase in biofuel demand capable to satisfy 20% of the transport supply may indeed result in pressures on land-use that could ultimately induce land-use change. A further cautionary element, also related with the pressure exerted by a growing demand for biofuels on the agricultural system, is represented by the need to make sure that the increase of biofuel use does not impact food security by altering food prices.

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