Impact of transport policies and the renewable energy package and on the energy use of transport

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Abstract

The aim of this paper is to describe the impact of transport policies and the renewable energy package on the energy use and the emissions of transport in EU27. The paper is based on the EU project called iTREN2030. In iTREN2030 two transport and energy scenarios are developed applying a set of models, among them the energy model POLES.

POLES is a system dynamics model for the development of long-term (2050) energy supply and demand scenarios for the different regions of the world. Besides the energy market it comprises a transport model and a policy sphere. In addition to the complex interrelationships between the energy markets the investigated scenarios cover a long period of time.

POLES has been applied in a variety of projects like WETO-H2 (WETO, 2006). This paper refers to work that is currently carried out in the EU project iTREN2030. Within the iTREN2030 project POLES is applied together with the models TREMOVE, ASTRA and TRANSTOOLS. The objective of the project is to develop between the models harmonised scenarios covering transport, energy, environment and economy. For this purpose two scenarios were developed:

- the reference scenario considering policies already implemented (Reference Scenario)
- the renewable scenario considering policies which are likely to be implemented until 2025 (Integrated Scenario)

On the transport side the regulation of CO2 emission for different types of transport vehicles has to be mentioned. On the energy side the renewable energy package is expected to have a major impact on the energy system. The main policy instruments which are investigated are the carbon value (to reduce 20% of the CO2 emissions until 2020) and the renewable energy support schemes (to increase the renewable share of final demand to 20% until 2020).

The paper discusses the following outcomes of the project:

- Development of fuel consumption of the transport sector compared to other sectors
- Development of fuel consumption of different modes of transport
- Development of consumption of different types of fuel
- Impact on the development of CO2 and GHG emission by transport

At the current stage results of the Integrated Scenario are not finally finished. But preliminary results of the Integrated Scenario can already be discussed. They show that the implemented policies have a high impact on energy use and emissions of transport.

[1] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission

1 Introduction

The aim of this paper is to describe the impact of transport policies and the renewable energy package on the energy use and the emissions of transport in EU27. The paper is based on the EU project called iTREN2030. The basic objective of iTREN-2030 is to extend the forecasting and assessment capabilities of the TRANS-TOOLS transport model to the new policy issues arising from the technology, environment and energy fields. The TRANS-TOOLS model was developed to constitute the reference tool for supporting transport policy in the EU in the 6th RTD Framework Programme (Burgess et al. 2006).

The other three modelling tools, ASTRA, POLES and TREMOVE, are harmonised with TRANS-TOOLS and made consistent with each other. This results in a coherent scenario for technology, transport, energy, environment and economic development for the EU27+2 until 2030 that can be compared with results of previous studies. The role of each of the four models can be briefly summarised as:

- ASTRA: provides the demographic and economic framework conditions for EU27+2 as well as scenario results for transport energy demand, selected items of vehicle fleets (e.g. new technology vehicles) and of transport demand (e.g. slow modes). The model also supports the consistency check as, besides non-transport energy issues, it includes all relevant transport and energy indicators on an aggregated and integrated manner.
- POLES: estimates energy prices including carbon prices and changes of fuel taxes as well as energy demand of sectors other than transport and the rest of the world.
- TRANS-TOOLS: provides the transport demand by mode on a link-based network level for EU27 plus neighbouring countries.
- TREMOVE: calculates vehicle fleets of conventional vehicles with a detailed technology classification, transport energy demand and transport emissions EU27+4.

From the energy perspective which is discussed in this paper the POLES model is the most relevant. POLES is a system dynamics model for the development of long-term (2050) energy supply and demand scenarios for the different regions of the world. Besides the energy market it comprises a transport model and a policy sphere. In addition to the complex inter-relationships between the energy markets the investigated scenarios cover a long period of time. POLES has been applied in a variety of projects like WETO-H2 (WETO 2006).

The objective of the project is to develop between the models harmonised scenarios covering transport, energy, environment and economy. For this purpose two scenarios were developed:

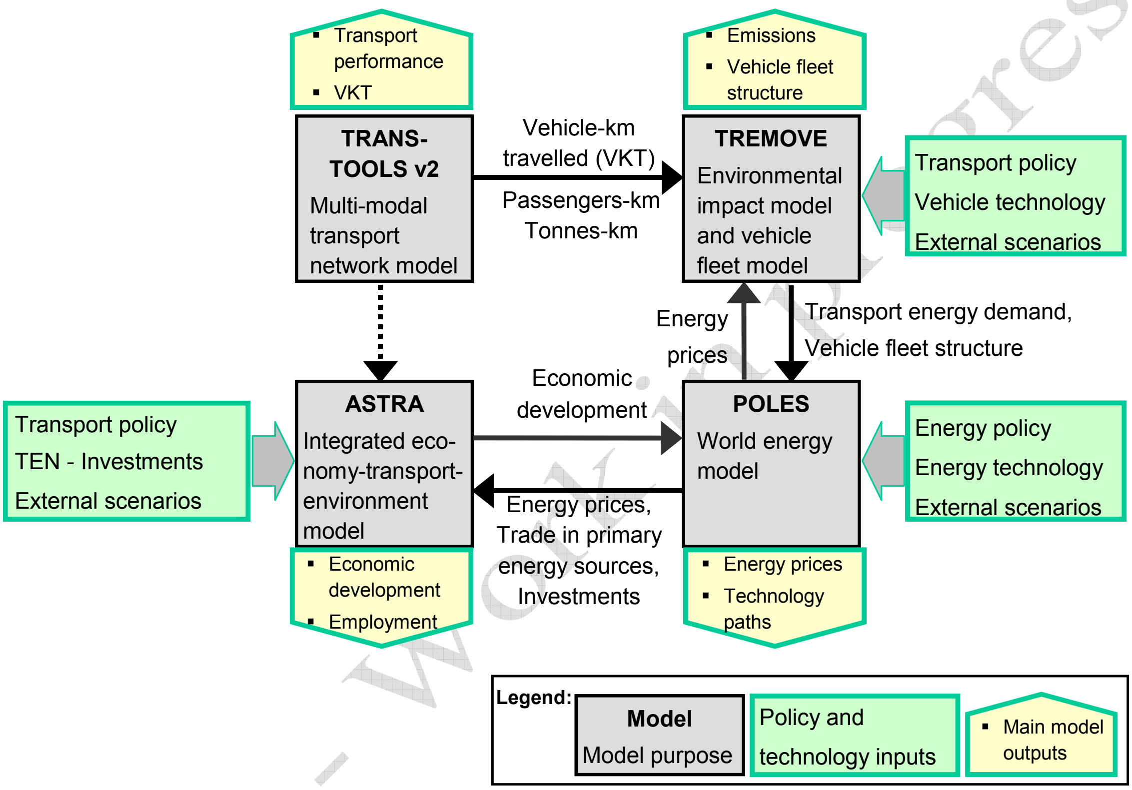
- the reference scenario considering policies already implemented (reference scenario)
- the renewable scenario considering policies which are likely to be implemented until 2025 (integrated scenario)

The Reference Scenario is the result of the integration and harmonisation of the four iTREN-2030 models that use common or comparable external assumptions (e.g. population growth rates) and consider a common set of policies. In particular, the Reference Scenario is based on the transport demand projections coming from the TRANS-TOOLS version developed in the TEN-Connect project (TTv2). The other models have used or adapted their endogenous transport demand forecasts to those of TRANSTOOLS to produce projections for energy, emissions, fleet and so on. The Reference Scenario is not the final outcome of iTREN-2030. In a later step the harmonised models will be used to build and simulate the Integrated Scenario based on the trends of the Reference Scenario and on an adapted policy framework until 2030. This Integrated Scenario will represent the main result of iTREN-2030.

2 Method

2.1 Model overview

The concept of integration in iTREN-2030 is developed in terms of linkages between the four modelling tools: TRANS-TOOLS, ASTRA, POLES and TREMOVE. Since the development of TRANS-TOOLS occurred also outside iTREN-2030, the TRANS-TOOLS model only provides the other models with information on transport performance (see Figure 1). Basically, the TRANS-TOOLS transport demand projections developed in the TEN-Connect project (see downloads from http://energy.jrc.ec.europa.eu/transtools, Rich et al. 2009) are taken as reference scenario for iTREN-2030.



Source: iTREN-2030

Figure 1: Models linkages activated between the iTREN-2030 models

Furthermore, since TRANS-TOOLS model version developed in TEN-Connect (TTv2) cannot be integrated within the iTREN-2030 modelling runs because of incompatibility problems in the freight model and of insufficient documentation, also the Integrated Scenario will not exploit bi-directional linkages as originally planned.

The dotted line linking TRANS-TOOLS to ASTRA indicates that demand data is not actually transferred from the former to the latter, rather ASTRA transport demand projections have been re-calibrated to be harmonised with TRANS-TOOLS forecasts. Despite some linkages could not be achieved, the iTREN-2030 methodology is still based on the integration of analysis domains and tools for energy, transport and technology. Integration is put in practice in two ways: **data exchange** and **data harmonisation** across models.

2.2 The modelling tools

In the following paragraphs, the four modelling tools used in TRANS-TOOLS are described. The role of the models have been explained in the previous section, here the main features of each tool are presented.

2.2.1 The ASTRA model

ASTRA (Assessment of Transport Strategies) is applied for Integrated Assessment of policy strategies. The model is implemented as System Dynamics model. The ASTRA model has been developed and applied in a sequence of European research and consultancy projects for more than 10 years now by three Institutions: Fraunhofer-ISI, IWW and TRT. Applications included analysis of transport policy (e.g. TIPMAC, TRIAS), climate policy (e.g. ADAM project) or renewables policy (e.g. Employ-RES project).

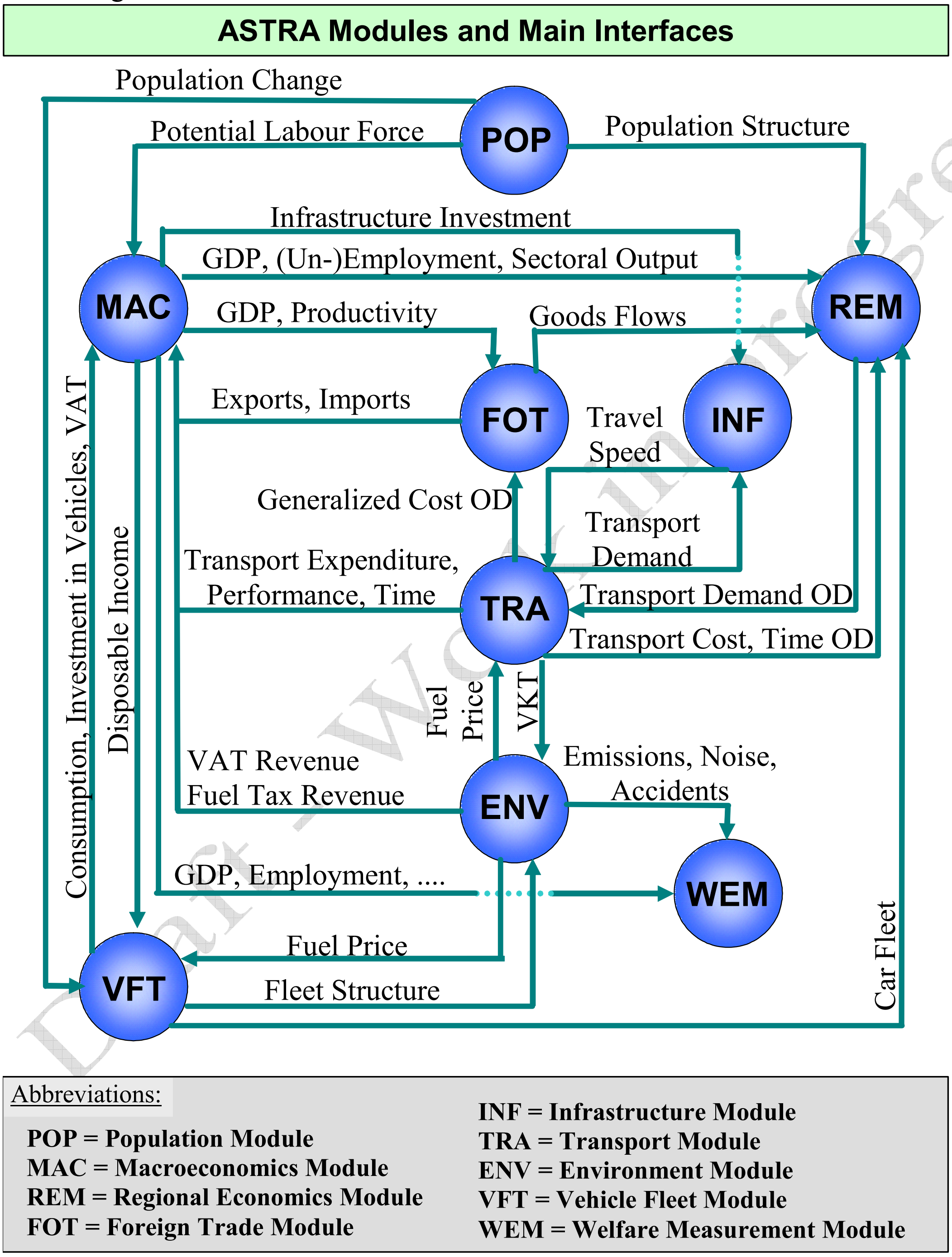
The ASTRA model consists of nine modules that are all implemented within one Vensim© system dynamics software file:

- Population module (POP),
- Macro-economic module (MAC),
- Regional economic module (REM),
- Foreign trade module (FOT),
- Infrastructure module (INF),
- Transport module (TRA),
- Environment module (ENV),
- Vehicle fleet module (VFT) and
- Welfare measurement module (WEM).

An overview on the nine modules and their main interfaces is presented in Figure 2.

The MAC provides the national economic framework, which imbeds the other modules. The MAC could not be categorised explicitly into one economic category of models for instance a neo-classical model. Instead it incorporates neo-classical elements like production functions. Keynesian elements are considered like the dependency of investments on consumption, which are extended by some further influences on investments like exports or government debt. Further elements of endogenous growth theory are incorporated like the implementation of endogenous technical progress (e.g. depending on sectoral investment) as one important driver for the overall economic development.

Six major elements constitute the functionality of the macroeconomics module. The first is the sectoral interchange model that reflects the economic interactions between 25 economic sectors of the national economies. Demand-supply interactions are considered by the second and third element. The second element, the demand side model depicts the four major components of final demand: consumption, investments, exports-imports and the government consumption. The supply side model reflects influences of three production factors: capital stock, labour and natural resources as well as the influence of technological progress that is modelled as total factor productivity. Endogenised total factor productivity depends on investments, freight transport times and labour productivity changes. The fourth element of MAC is constituted by the employment model that is based on value-added as output from input-output table calculations and labour productivity. Employment is differentiated into full-time equivalent employment and total employment to be able to reflect the growing importance of part-time employment. In combination with the population module unemployment was estimated. The fifth element of MAC describes government behaviour. As far as possible government revenues and expenditures are differentiated into categories that can be modelled endogenously by ASTRA and one category covering other revenues or other expenditures. Categories that are endogenised comprise VAT and fuel tax revenues, direct taxes, import taxes, social contributions and revenues of transport charges on the revenue side as well as unemployment payments, transfers to retired and children, transport investments, interest payments for government debt and government consumption on the expenditure side. Sixth and final of the elements constituting the MAC are the micro-macro bridges. These link micro- and meso-level models, for instance the transport module or the vehicle fleet module to components of the macroeconomics module. That means, that expenditures for bus transport or rail transport of one origin-destination pair (OD) become part of final demand of the economic sector for inland transport within the sectoral interchange model.



Source: Schade/Fiorello/Beckmann et. al. (2008)

Figure 2: Overview on the structure of the ASTRA modules

The macroeconomics module provides several important outputs to other modules. The most important one is, for sure, Gross Domestic Product (GDP). This is for instance required to calculate sectoral trade flows between the European countries. Other examples are employment and unemployment representing two influencing factors for passenger transport generation. Sectoral production value is driving national freight transport generation. Disposable income exerting a major influence on car purchase affecting finally the vehicle fleet module and even passenger transport emissions.

For more details on ASTRA, the most comprehensive description of the model can be found in Schade, 2005.

2.2.2 The POLES model

The POLES model is a simulation model for the development of long-term (2050) energy supply and demand scenarios for the different regions of the world (Figure 3). POLES has been developed and applied in a variety of EU projects, e.g. the WETO, WETO-H2, TRIAS, HOP! and GRP project.

The model structure corresponds to a hierarchical system of interconnected modules and articulates three level of analysis:

- international energy markets;
- regional energy balances;
- national energy demand, new technologies, electricity production, primary energy production systems and CO2 sector emissions.

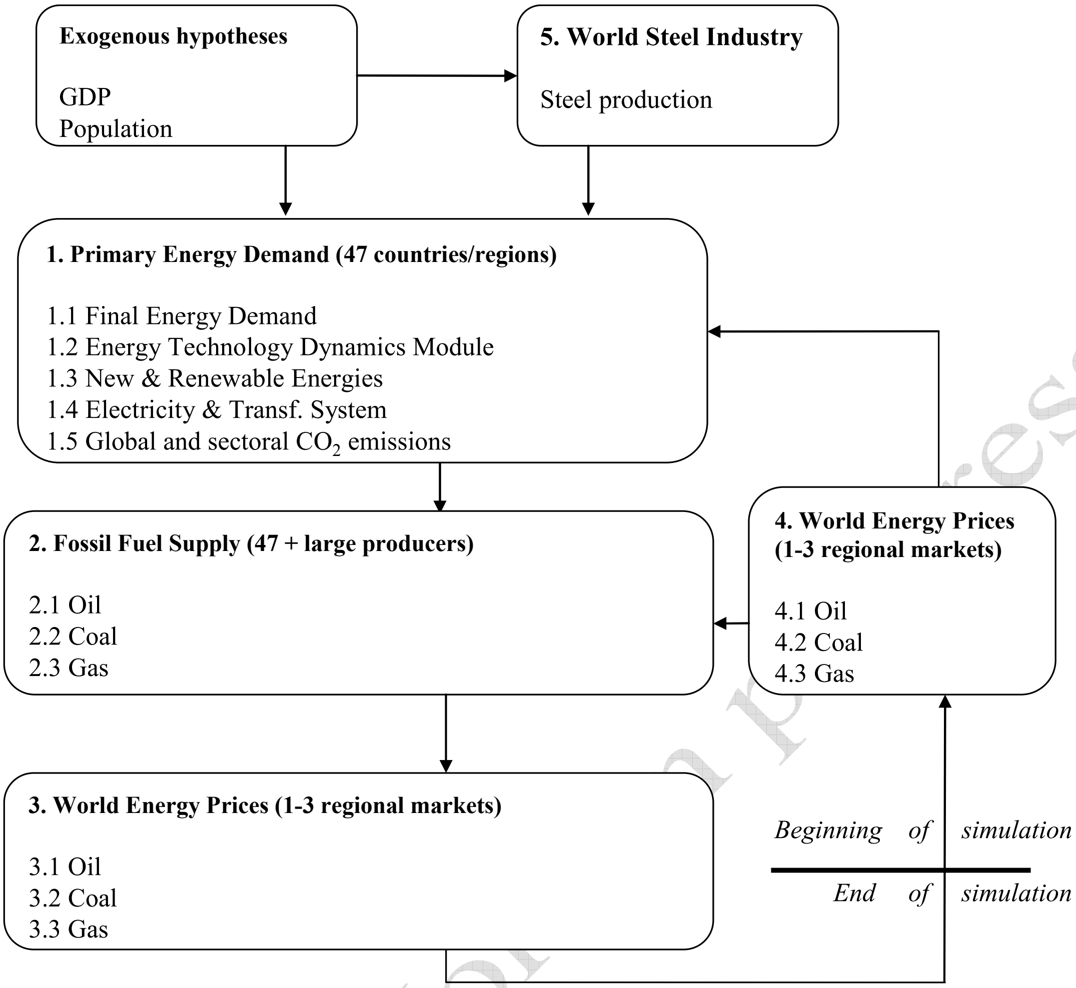
The main exogenous variables are the population and GDP (which in iTREN-2030 are derived iteratively with ASTRA), for each country / region, the price of energy being endogenised in the international energy market modules. The dynamics of the model corresponds to a recursive simulation process, common to most applied models of the international energy markets, in which energy demand and supply in each national / regional module respond with different lag structures to international prices variations in the preceding periods. In each module, behavioural equations take into account the combination of price effects and of techno-economic constraints, time lags or trends.

In POLES, the world is divided into 47 zones. In most of these regions the larger countries are identified and treated, as concerns energy demand, with a detailed model. In this version these countries are the G7 countries plus the countries of the rest of the European Union and five key developing countries: Mexico, Brazil, India, South Korea and China. The countries forming the rest of the 14 above-mentioned regions are dealt with more compact but homogeneous models.

For each region, the model articulates four main modules dealing with:

- Final Energy Demand by main sectors;
- New and Renewable Energy technologies;
- The Electricity and conventional energy and Transformation System;
- The Primary Energy Supply.

This structure allows for the simulation of a complete energy balance for each region, from which import demand / export capacities by region are estimated. At the same time the horizontal integration is ensured in the energy markets module of which the main inputs are the import demands and export capacities of the different regions. Only one world market is considered for the oil market (the "one great pool" concept), while three regional markets (America, Europe, Asia) are distinguished for coal and gas, in order to take into account for different cost, market and technical structures.



Source: Schade/Fiorello/Beckmann et. al. (2008)

Figure 3: POLES modules and simulation process

According to the principle of recursive simulation, the comparison of imports and exports capacities for each market allows for the determination of the variation of the price for the following period of the model. Combined with the different lag structure of demand and supply in the regional modules, this feature of the model allows for the simulation of under- or over-capacity situations, with the possibility of price shocks or counter-shocks similar to those that occurred on the oil market in the seventies and eighties.

In the final energy demand module, the consumption of energy is divided into 11 different sectors, which are homogenous from the point of view of prices, activity variables, consumer behaviour and technological change. Each of such sector belongs to one of the three ‘blocks’: Industry, Transport and Residential-Tertiary-Agriculture. In each sector, the energy consumption is calculated separately for substitutable technologies and for electricity, with a taking into account of specific energy consumption (electricity in electrical processes and coke for the other processes in the steel-making, feedstock in the chemical sector, electricity for heat and for specific uses in the residential and service sectors).

The POLES model calculates oil production for every key producing country or region, based on oil reserves. This is performed in three steps. Firstly, the model estimates the cumulative amount of oil discovered as a function of the Ultimate Recoverable Resources (URR) and the cumulative drilling effort in each region. The amount of URR is not held constant but is calculated by revising the value for the base year, based on a recovery ratio that improves over time and increases with the price of the resource. According to WETO-H2, while the recovery rate is differentiated across regions, the world average accounts for 35% today and, due to the price-driven technology improvements, increases to around 50% in 2050.

Secondly, the model calculates remaining reserves as equal to the difference between the cumulative discoveries and the cumulative production for the previous period. The accounting is described by the formula: $R_{t+1} = R_t + DIS_t - P_t$ (where R = reserves, DIS = discoveries, P = production, subscript t = year of account).

Finally, the model calculates the production, which differs among regions of the world. In the "price-taker" regions (i.e. Non-OPEC) it is resulting from an endogenous Reserves-to-Production ratio that decreases over time and the calculated remaining reserves in the region; the production from "swing-producers"(i.e. OPEC) is assumed to be that amount needed to balance the world oil market (OPEC total oil production= total oil demand – Non-OPEC total oil production). Thus, the model calculates a single world price, which depends in the short-term on variations in the rate of utilisation of capacity in the OPEC Gulf countries and in the medium and long-term on the world R/P ratio (including unconventional oil). The unconventional oil enters in the composition of the world oil supply when the oil international price makes it competitive against the conventional oil, that is when the world oil price exceeds the cost of an unconventional source of oil.

The gas discoveries and reserves dynamics are modelled in a way that is similar to that used for oil; whereas the gas trade and production are simulated in a more complex process that accounts for the constraints introduced by gas transport routes to the different markets; The production of gas in each key producing country is derived from the combination of the demand forecast and of the projected supply infrastructures in each region (pipelines and LNG facilities). Three main regional markets are considered for gas price determination, but the gas trade flows are studied with more detail for 14 sub-regional markets, 18 key exporters and a set of smaller gas producers. The price of gas is calculated for each regional market; the price depends on the demand, domestic production and supply capacity in each market. There is some linkage to oil prices in the short-term, but in the long-term, the main driver of price is the variation in the average Reserve-to-Production ratio of the core suppliers of each main regional market. As this ratio decreases for natural gas as well as for oil, gas prices follow an upward trend that is similar in the long-term to that of oil.

A recent module developed in POLES is the Biofuels model. It has improved the capability of POLES to deal with a potentially relevant alternative source of energy for the transport sector. The biofuels model is based on the production costs of biofuels and those of the fossil alternative they substitute, taking into account the biomass potential of each region. In addition, the model considers the 1st and 2nd generation of biofuels and as well the use of biomass for electricity and the direct use of biomass in the residential and the industrial sector.

With other modules, POLES simulates global transport demand. However, in iTREN-2030 European transport demand is provided to POLES by ASTRA taking into account the TRANS-TOOLS transport demand from TTv2.

2.2.3 The TRANS-TOOLS model

The TRANS-TOOLS Model is an IPR free European wide network-based transport planning tool. The model covers both passenger and freight transport with interactions to an economic model and impacts models.

Transport policies which may be assessed by the TRANS-TOOLS Model include, for instance:

- Construction and improvement of the infrastructure e.g. Trans-European Networks to eliminate bottlenecks, promote mode shifts, improve quality of service etc.
- Implementation of infrastructure charging systems.
- Change of transport costs due to policy interventions, increases in fuel prices etc.

The geographical scope of the model includes all European countries and the zoning system is based on NUTS3, consisting of 1441 zones in the most recent version. Separate networks for road transport, rail passenger and freight transport, inland waterways transport, and passenger transport by air are modelled.

The TRANS-TOOLS Model is similar to a traditional four step model including freight and passenger modelling. The main sub-models are:

- Freight demand model
- Passenger demand model
- Assignment model

The TRANS-TOOLS Model computes transport flows (passenger, vehicles and tonnes) at link level or zonal level, and transport performance (travel distance, cost, times, passenger-km, tonne-km etc).

The passenger model, as developed in the TEN-Connect project, is based on the Generation-Attraction (GA) approach (the person that conducts the trip). If change in GDP, occupation, migration etc. correctly should reflect demand for transport it is important that socio-economic drivers can be related to the person that is conducting the trip – regardless whether the trip is outward or backward. Generally, the approach for transforming matrices to GA is different for different trip purposes. The TRANS-TOOLS model uses four trip purposes: Business, Private, Commuting and Tourism.

- Business trips are based on GDP and work place in the zone of origin and destination respectively
- Commuting is part of private trips in the TRANS-TOOLS model. Based on assumptions on trip lengths, commuting is separated from private trips, assuming commuting to be mainly short distance (yet several metropolitan regions in TRANS-TOOLS have 3-6 NUTS3 zones, and therefore between NUTS3 commuting). The separated OD is transformed to GA based on population, workplaces and GDP.
- The remaining private trips are transferred from OD to GS based on GDP and population in the zone of origin and destination respectively
- Tourism is based on population, GDP and a tourist attractiveness measure in the zone of origin and destination

Travel costs, travel time and information about the trip itself like frequencies and number of transfers are used to split the trips between the modes. Subsequently, for each origin-destination pair the modal split model calculates the probability of selecting a modal alternative out of a set of available modes. A non-linear logit function is used in order to calculate the choice probability. The explanatory variables represent the transport service level between two zones e.g. in the dimensions travel costs and travel time. Output of TRANS-TOOLS passenger demand model to assignment model are unimodal passenger O/D transport matrices at NUTS3 level in number of passengers per mode (rail, road, air) and trip purpose as well as unimodal passenger O/D transport matrices at NUTS3 level in number of vehicles for road relations per trip purpose.

The network assignment module produces the direct output from the TRANS-TOOLS Model. However, the models also generate level-of-service data (LOS) as input to passenger, freight, and logistic models in a feed back loop. Four independent assignment models are developed within the TRANS-TOOLS Model:

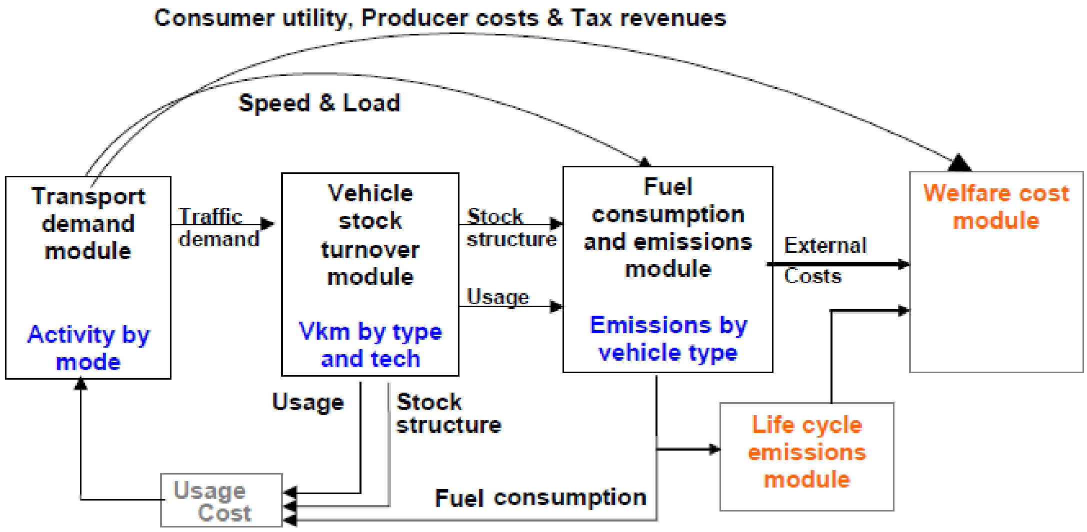
- Road network (passenger and freight)
- Rail network (passenger and freight)
- Inland waterway (freight)
- Air network (passenger).

Passengers by rail and air and freight by rail and inland waterways are assigned based on an average day, since congestion is not considered and information on service data differentiated by time and day is not available. LOS in the road assignment is calculated by time period. In TRANS-TOOLS, a stochastic assignment procedure is applied being founded on probit-based models.

2.2.4 The TREMOVE model

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. It is an integrated simulation model developed for the strategic analysis of the costs and effects of a wide range of policy instruments and measures applicable to local, regional and European transport markets. The model has been developed by the Catholic University of Leuven and Transport & Mobility Leuven.

TREMOVE models both passenger and freight transport in 31 countries (EU27 plus CH, NOR, HR, TR), and covers the period 1995-2030 providing yearly results. The TREMOVE model consists of separate country models. While the numeric values of the model differ from country to country, the model code is identical across countries, figure 2.4 maps the modular structure of TREMOVE. Each country model describes transport flows and emissions in three model regions: one metropolitan area, an aggregate of all other urban areas and an aggregate of all nonurban areas. Trips in the non-urban areas are further separated in short (-500 km) and long (+ 500 km) distance trips. The model explicitly takes into account that, depending on the area taken into consideration, the relevant modes and network types differ.



Source: iTREN-2030

Figure 4: Modular Structure of TREMOVE

The transport demand module represents, for a given year and transport mode, the number of passenger-kilometres or ton-kilometres that will be performed in each “model region” of the country considered. Since the iTREN-2030 project, the exogenous baseline is taken from TRANS-TOOLS.

In the fuel consumption and emissions module fuel consumption and exhaust and evaporative emissions are calculated for all modes. Emission factors have been derived consistently from EU sources, thus might deviate from national estimates. For road vehicles, TREMOVE emission factors are based upon (a preliminary version of) the COPERT IV emission calculation methodology, to which following additions have been made:

- Disaggregation of COPERT diesel car fuel consumption factor into three factors according to engine displacement, based upon EU CO_2 monitoring data;
- Upward scaling of COPERT fuel consumption factors for 2002 cars, based upon EU test-cycle monitoring data and information on the difference between test-cycle and real-world fuel consumption[2];
- Introduction of fuel efficiency improvement factors up to 2009. For cars these are based upon the voluntary agreements between EU and the car industry. For other road vehicles predictions are derived from the Auto Oil II Programme;
- Update of moped and motorcycle emission factors based on recent information[3]
- Emission factors for CNG vehicles.

Fuel consumption and emission factors for diesel trains and aircrafts12 (by distance class) have been derived from the TRENDS database. For electric trains, trams and metros only total energy consumption (kWh) is calculated in this module. The fuel consumption and emission factors for inland waterway vessels have been calculated following the first version of the approach developed within the ARTEMIS[4] project. Factors have been estimated using data on vessel characteristics for the 21 types included in TREMOVE and using estimates on waterway characteristics.

To evaluate policies in TREMOVE, a welfare assessment module has been constructed. Differences in welfare between the baseline and the simulated policy scenarios are calculated. Based on the utility functions for the private transport demand, the aggregate utility level of households is quantified. The modelling of business decisions leads to an aggregate measure for the change in production costs of firms. Additionally, welfare changes stemming from changes in tax revenues are incorporated by using the marginal cost of public funds. This latter approach accounts for the options of the government to beneficially use additional tax revenues from the transportation sector to lower taxes in other sectors. Emissions to air are calculated in detail as explained in the next section. The external costs of these emissions are also incorporated in the welfare evaluation of policy measures.

[2] Van den Brink and Van Wee (2001) and TNO (2006).
[3] Ntziachristos et. al. (2004).
[4] Georgakaki (2003).

3 Scenario Results

3.1 The Reference Scenario

3.1.1 Policies in the Reference Scenario

The energy policies implemented in the iTREN-2030 Reference Scenario are the following:

- CO_2 emission targets agreed by Kyoto Protocol and implemented in national allocation plans (NAP I + II).
- Existing national regulations e.g. phasing-out of nuclear energy in some countries and quotas for renewables incl. biofuels.
- Share of renewable energy in the electricity production.
- Improvements in energy efficiency leading to a reduction of final energy consumption (e.g. buildings).

About emission targets, in the Reference Scenario it is assumed that national allocation plans will be continued. Plans are defined country-wise and on a sectoral basis, therefore their translation in modelling input is quite complex. Main policy instrument to reach the CO_2 emission target is the European Emission Trading System (EU-ETS). In POLES ETS is reflected by a carbon value which is applied to energy intensive sectors which are included in the first phases of EU-ETS. The carbon value rises form 5 Euro/t CO_2 in 2010 to 22 Euro/t CO_2 in 2020.

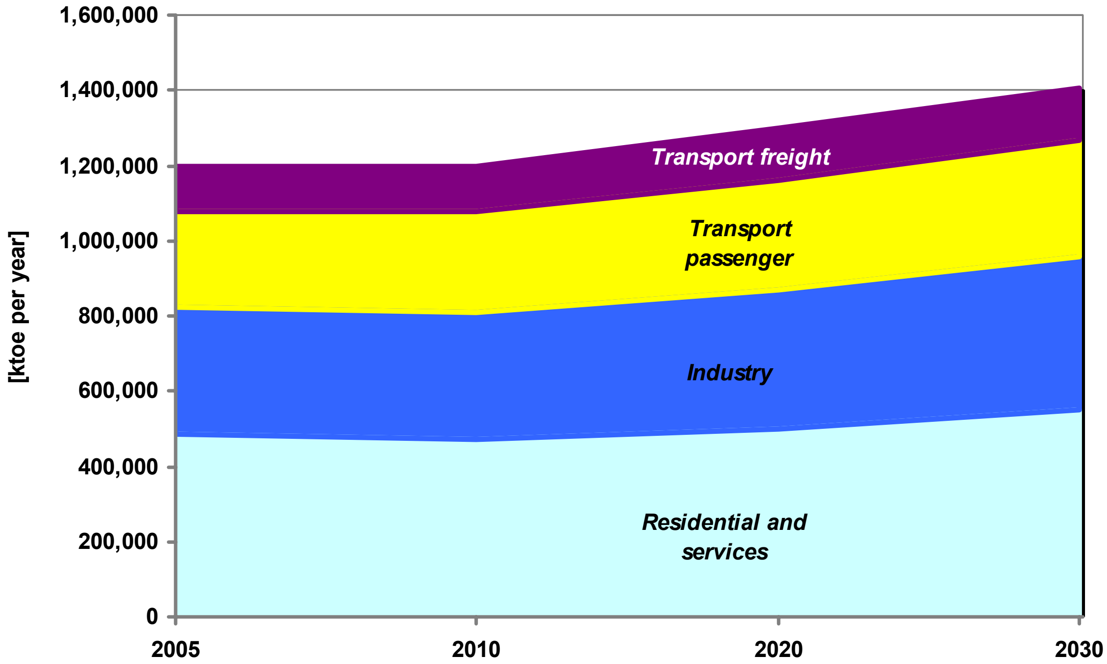
In terms of energy supply, it is assumed that the policy mix (including nuclear and renewables) is mainly driven by prices. However, some countries decided on a phasing-out of nuclear energy. In the iTREN-2030 Reference Scenario the phasing-out of nuclear is considered in the investment model so that in those countries the stock of nuclear powerplants is not renewed. National targets exist about biofuels in transportation. In POLES biofuels enter the market on the basis of their production cost in comparison with conventional fossil fuels.

The increase of electricity from renewable energy sources is considered by the feed-in-tariff. POLES takes into account the existing feed-in-tariffs and the future development as it is fixed in national regulation.

Improvements of energy efficiency and increase of energy savings are considered as well. Member States are supposed to reduce their final energy consumption by 1% per year from 2008 onwards for 9 years (EU Directive 2006/32/EC from 2006). Special focus is set on the reduction of energy consumption for buildings. POLES takes into account the improvements of energy efficiency by the parameters of the energy demand functions.

3.1.2 The results of the Reference Scenario

The increase of final energy demand is assumed to continue but at a slower pace as in the past. For the residential and service (including agriculture) sectors we foresee a growth around 13% between 2005 and 2030, considering lower trends than observed in the past decades (which had growth rates of around 2% per year) and the implemented policies to improve energy efficiency. The increase in the industrial sector should reach 21%. For the transport sector, the final energy demand is expected to increase in EU27 by around 0.8% per year i.e. 20% as a whole over the time period considered. Therefore, the energy consumption of the transport sector is in line with other sectors.



Source: iTREN-2030 – POLES model

Figure 5: Final energy demand by consuming sector in EU27 countries

Looking in more detail at the energy consumption of the transport sector, a higher growth is estimated for the final energy demand of passenger transport than for freight transport. The growth in final energy demand stems mainly from road passenger transport and air transport. Final energy demand of road passenger transport and air transport increase by almost 22%. On the freight side mainly energy demand of road freight transport is growing by 16%.

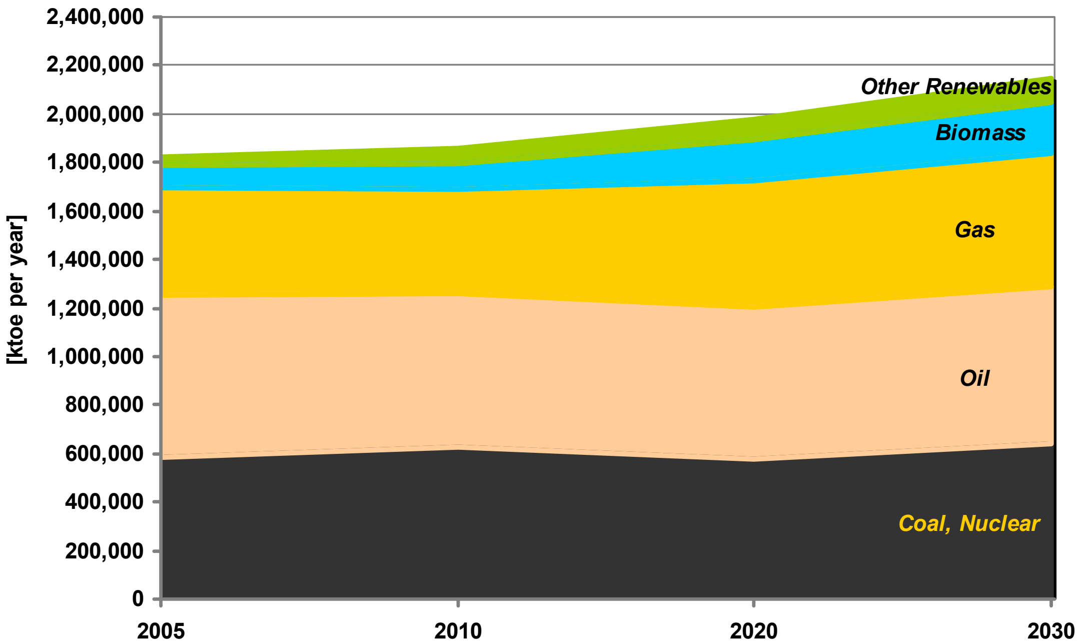
Table 1: Final energy demand per transport mode

Final energy demand [Mtoe]	**2005**	**2010**	**2020**	**2030**
Transport – all modes	375	389	427	451
Road transport cars	201	221	230	246
Road transport freight	108	108	125	125
Rail	9	10	11	12
Aviation	51	46	56	63
Other transport	6	5	5	5

Source: iTREN-2030 – POLES model

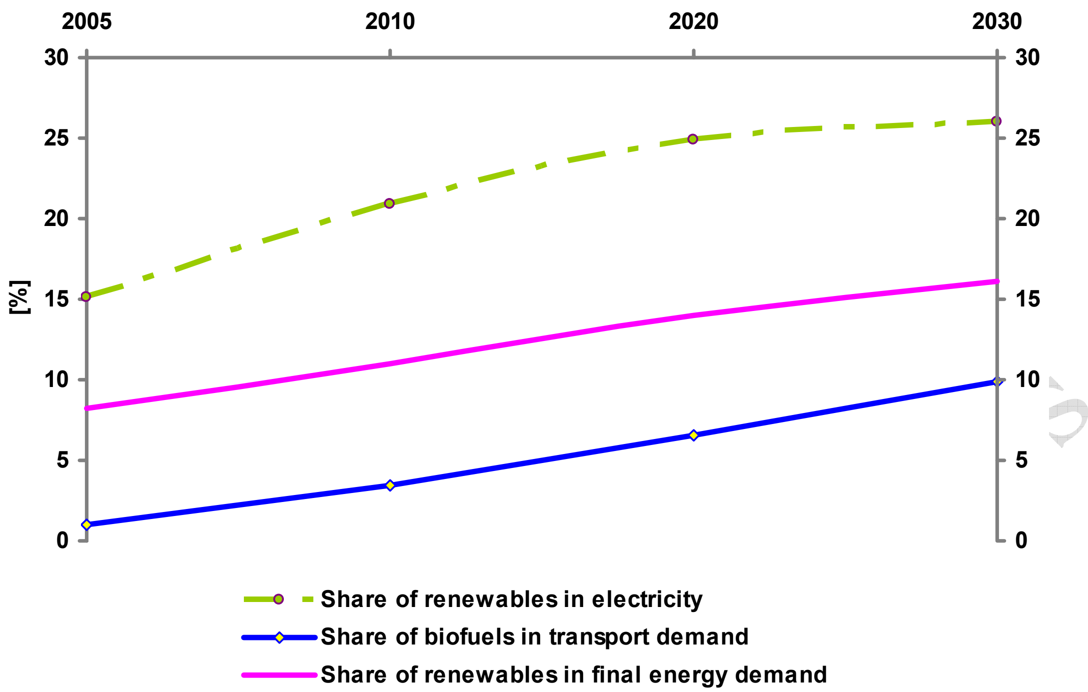
Among the fossil fuels a shift from oil and coal towards gas is foreseen such as the share of gas on gross inland consumption might increase from 24% to 26% in 2030. Remarkably is also the increase of the share of biomass and of renewables to gross inland consumption from 5% respectively 2% in 2005 to almost 10% respectively 5% in 2030. Under the given conditions for biofuels in the Reference Scenario its share is expected to increase. However, we assume that in 2010 the biofuels share will be around 3.4%, falling short of the 5.75% target of the biofuels Directive. Nevertheless, we expect the biofuels consumption to increase to 6.6% in 2020 and to almost 10% in 2030. The increase of biofuels consumption is based on the high oil prices and on a decrease of production cost of biofuels, whose price is however ultimately forecasted to increase under demand pressure.

In comparison with other studies like the European Energy and Transport – Trends to 2030 (European Commission 2008a) the results are quite comparable. Minor differences emerge as we consider in POLES oil prices between 75 and 95 €$_{2005}$/bbl, while in PRIMES the oil price increase from 55$/bbl to 63$/bbl. This leads to a stronger shift from oil towards gas, biomass and renewables in POLES. Hence, their share of primary energy reaches higher levels. The share of energy imports is affected from this shift as well. Due to gas, biomass and renewables the energy imports remain at a level of about 50% in POLES, whereas PRIMES assumes rising energy imports.



Source: iTREN-2030 – POLES model

Figure 6: Gross inland energy consumption by source in EU27 countries



Source: iTREN-2030 – POLES model

Figure 7: Shares of alternative energy sources in EU27 countries

The trends of energy consumption by source and of final energy demand by consuming sector in the iTREN-2030 Reference Scenario are shown in Table 2 and, respectively, Table 3 below compared to the European Energy and Transport - Trends to 2030.

As far as energy consumption is concerned, the iTREN-2030 Reference Scenario is slightly more optimistic in terms of renewable sources, whose growth rate is larger than in the Energy and Transport Trends to 2030. However, in both studies renewable sources develop faster than any other energy sources. Also, in both studies the contribution of oil, coal and nuclear is rather stable while gas is the second most dynamic source. In the iTREN-2030 Reference Scenario the total energy consumption is expected to grow at a faster pace than in the other study, but the two projections are comparable.

Also regarding final energy demand, the iTREN-2030 Reference Scenario and Energy and Transport Trends to 2030 are largely similar. The overall growth rate is the same and the only remarkable difference is that in iTREN-2030 energy demand of the transport sector is expected to grow slightly less than the average, in the other study it is expected to grow above the average.

Table 2: iTREN-2030 Reference Scenario energy consumption growth rates compared to European Energy and Transport Trends to 2030

Energy source	**iTREN-2030**	**EET trends**
Oil	-0.1%	0.2%
Gas	0.9%	0.6%
Coal – Nuclear	0.4%	-0.3%
Biomass	3.5%	2.7%
Other renewable	4.1%	
Total	*0.7%*	*0.4%*

Source: iTREN-2030 on various data

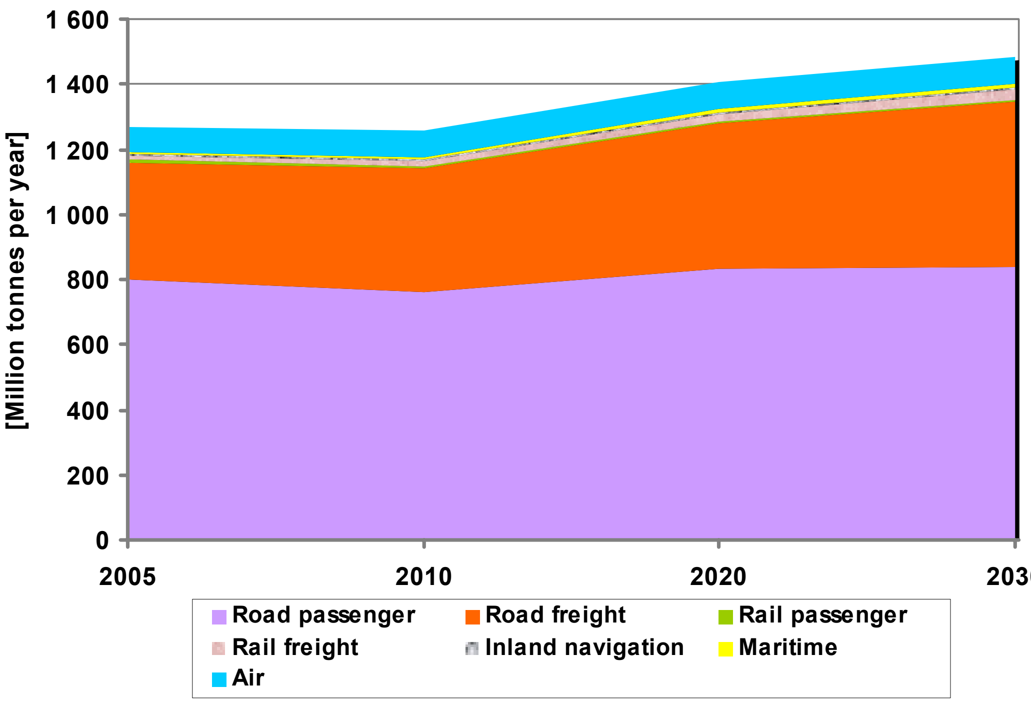
Table 3: iTREN-2030 Final energy demand growth rates compared to European Energy and Transport Trends to 2030

Energy source	iTREN-2030	EET trends
Passenger transport	0.8%	1.0%
Freight transport	0.6%	
Residential and Services	0.5%	0.6%
Industry	0.8%	0.7%
Total	*0.6%*	*0.7%*

Source: iTREN-2030 on various data

CO_2 emissions of transport in EU27 countries slightly increase between 2005 and 2030 in the iTREN-2030 Reference Scenario. This forecast is in line with respect to the projections of the European Energy and Transport – Trends to 2030 (European Commission, 2008a), where an increase of transport CO_2 emissions is envisaged as well.

The bulk of the emissions comes from road passenger mode followed by road freight and air modes. The road passenger emissions are basically stable and the share of this mode in total emissions decreases slightly from 63% to 57%. Road freight emissions increase by an average of 0.8% between 2005 and 2010 then by an average of 1.5% between 2010 and 2030. The share of this mode's emission increases from around 29% in 2005 to 34% in 2030. Emission share of air mode remains relatively constant at around 6% during the 25 year period. It is worth to note that rail freight is the mode that has the highest growth rate of CO_2 emissions: it increases by an average of 5.4% between 2005 and 2010 and by an average of 3.9% between 2010 and 2030 driven by the strongest demand growth. The share of rail freight CO_2 emissions increases from around 1% in 2005 to around 2% in 2030.



Source: iTREN-2030 – ASTRA model

Figure 8: CO_2 transport emissions in EU27 countries by mode of transport

Observation on EU15 and EU12 gives different panorama on the evolution of CO_2 emissions in relation to that of EU27. Total CO_2 emissions in EU15 increase by around 14% during 25 years, while the total CO_2 emissions in EU12 increase by around 38% during the same period. Increase in the rail freight CO_2 emissions in EU12 is significant which is also the principle cause of the increase of total CO_2 in EU12: its share increases twofold from 6.4% (11 Mtonnes) in 2005 to 13.2% (31 Mtonnes) in 2030. It is also important to note how in absolute term the CO_2 emissions from rail freight mode in EU12 are two (in 2005) to three times (in 2030) bigger than those in EU15.

3.2 The Integrated Scenario

3.2.1 Policies and measures considered in the Integrated Scenario

At the current stage results of the Integrated Scenario are not finally finished. But preliminary results of the Integrated Scenario can already be discussed.

The Integrated Scenario incorporates an ambitious energy and climate policy while at the same time it takes into account the economic downturn. In more details, the following elements are incorporated in the scenario:

- It incorporates the effects of the economic crisis: the GDP forecasts and associated value added of the various economic sectors reflect the recent economic downturn. This lowers energy demand and tends to lower energy-related CO_2 emissions.
- It endorses an ambitious climate change policy: it is assumed that the binding unilateral European greenhouse gas reduction target for 2020 (i.e. -20% below 2020 levels) is reached. The scenario results show that the target will even be over-fulfilled. In the model, these targets are achieved through a sector- and time-dependent carbon price, following the example of the emission trading scheme (ETS). We assume an imperfect carbon market across sectors and countries, resulting in different abatement and thus different carbon costs. With respect to trading sectors, we assume that a carbon market is created for energy-intensive industrial use (including the power sector), with other sectors joining later. The transport and residential sectors belong to the non-trading sectors. In these sectors the implementation of emission reduction policies is simulated by introducing a specific carbon value in 2013. In the Integrated Scenario these policies should establish an incentive similar to that of the carbon price in the industrial sectors by 2018. The carbon price would rise from 6 $€_{2005}$ per tonne of CO_2 in 2005 to 27 $€_{2005}/t_{CO2}$ in 2020 and 28 $€_{2005}/t_{CO2}$ in 2030.
- It takes an active renewable energy policy for granted: the Integrated Scenario will meet the European target of a 20% share of renewables in final energy demand. For model-related reasons, the target share of renewable energies in final energy consumption was set at around 18.7% instead of 20%, as the POLES model in its current version does not consider some emerging technology options[5]. The renewable energy policy has been approximated by assuming harmonised technology-specific renewable energy support premiums across the EU, which are based on information from the Green-X model [Resch et al., 2009].
- Energy efficiency policies: following the energy efficiency action plan, important improvements in energy efficiencies are assumed, which lead to an increase of energy efficiency by 1% annually.

[5] In a comparison between renewable energy scenarios done with the POLES and the GreenX models, it was found that these missing categories account for 1.2-1.3% of renewables in final demand by 2020 [Resch et al., 2009].

- Support for carbon capture and sequestration (CCS): support of R&D and demonstration sites for CCS so that first large-scale plants can be built around 2030.
- Increased fossil fuel prices: even though fossil fuel prices have been decreasing since their peak at about 150$/bbl in 2008, supported by the global economic downturn, rising demand from fast developing regions and uncertainty about the future availability of cheap resources are suggesting that crude oil prices will not fall back to the low levels observed before 2007. It is therefore assumed that they rise from present prices and then remain at high levels at around 80 $€_{2005}$/bbl in 2020 and almost 90 $€_{2005}$/bbl in 2030.

Even though the focus of the present analysis lies on the development of the European power sector, global developments cannot be ignored due to their interactions via fuel prices or technological learning that is triggered by global capacities etc. In line with the trends assumed for the EU, it has been assumed that an active renewable energy and climate change policy will be implemented also in many other world regions. Assumptions for non-European macro-economic trends and the related CO_2 values build on the global emission reduction pathway scenario (GRP4) that was developed with the POLES model and is documented in Russ et al. [2007].

3.2.2 Results of the Integrated Scenario

(a) Energy prices

After more than a decade of cheap oil at around 20 US$/barrel, prices have steeply risen to peak at about 150$/bbl in 2008. After 2008, fossil fuel prices decreased, supported by the global economic downturn, to less than 50$/bbl. Currently they are rising again to 80$/bbl based on better economic outlooks and expected oil demand.

There is a general consensus among the experts that the rise of energy prices should be regarded as a structural condition due to the foreseeable trend of demand and supply. The rising demand from fast developing regions and uncertainty about the future availability of cheap resources suggest that crude oil prices will not fall back to the low levels observed before 2007. It is therefore assumed that they rise from present prices and then remain at high levels at around 80 $€_{2005}$/bbl in 2020 and almost 90 $€_{2005}$/bbl in 2030. The oil price in the INT Scenario follows the trend in the IEA World Energy Outlook (WEO). The WEO projects an oil price of around 74 $€_{2005}$/bbl in 2020 and 85 $€_{2005}$/bbl in 2030 [IEA, WEO 2009][6].

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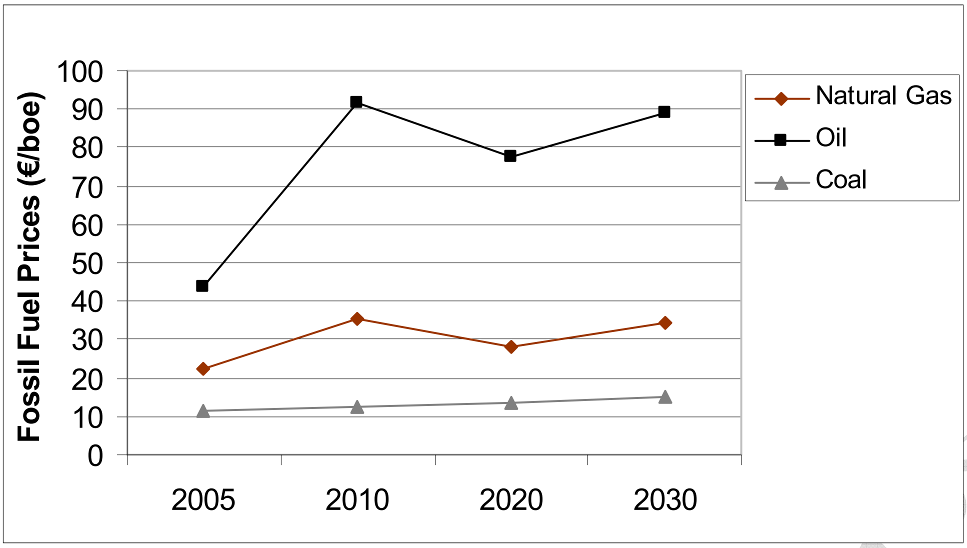
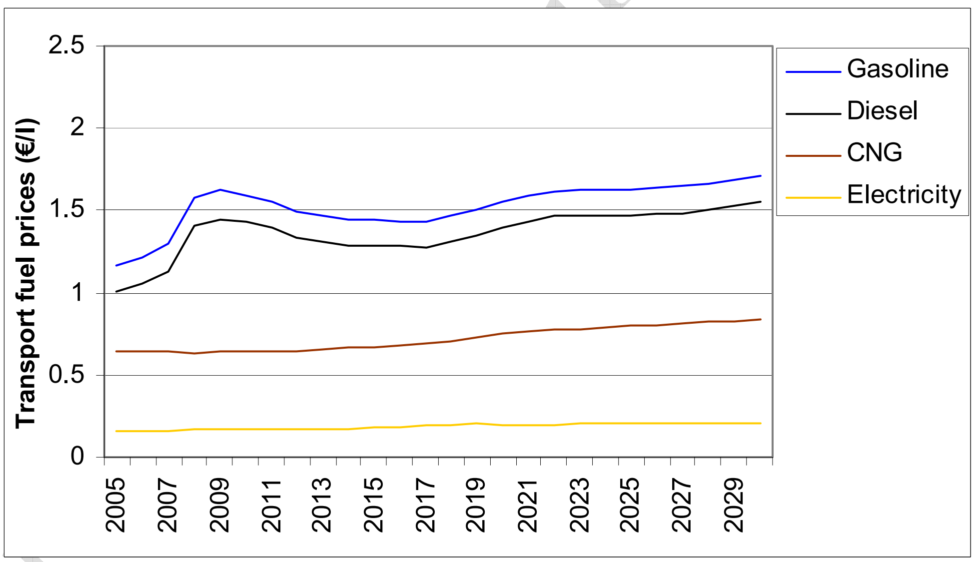
[6] The original values from IEA are expressed in $ of 2008. They were 100 $\$_{2008}$/bbl respectively 115 $\$_{2008}$/bbl in 2020 and in 2030 [IEA, WEO 2009].



Source: iTREN-2030 – POLES model

Figure 9: Fossil fuel prices [in €$_{2005}$]

Gas prices are assumed to increase in a similar pattern but at a lower pace, reflecting the dynamics of the inter-fuel competition and the rising supply costs. Over the whole time period, gas prices are expected to increase by 56%. Coal prices increase by only 33% due to the ample reserves.



Source: iTREN-2030 – POLES model

Figure 10: Transport fuel prices [in €$_{2005}$]

In addition to the high prices for oil and gas we have to consider the development of fuel taxes. The rising carbon value and the harmonization of fuel taxes lead to a further increase of transport fuel prices (see Figure 10). It is expected that the gasoline and diesel prices reach the levels of the peak year 2008 by 2020 and increases slightly further thereafter. Gas prices are following this trend at a lower price level while electricity prices remain quite stable[7].

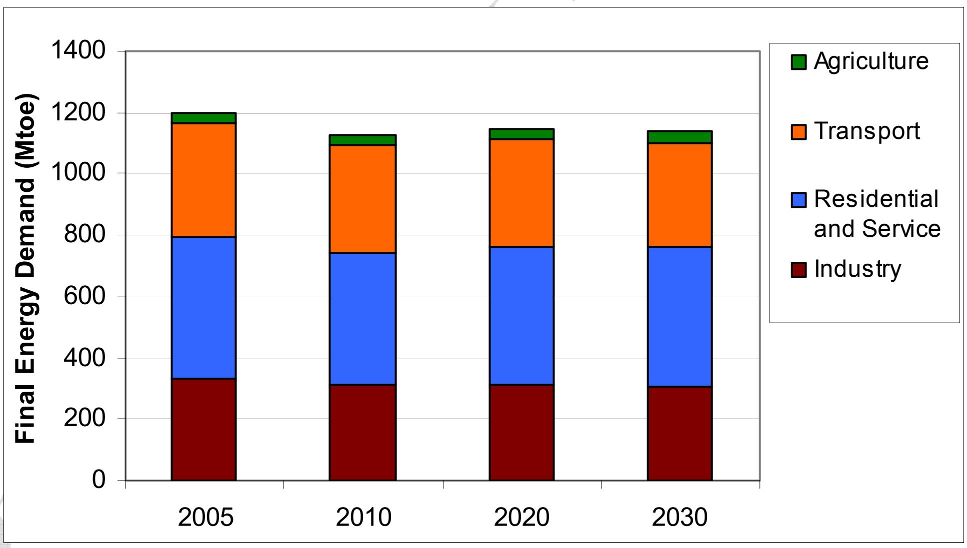
[7] Gas and electricity prices are expressed in terms of energy content.

(b) Energy demand

The above assumptions have a dampening effect on the total European energy demand. Unlike the steadily rising energy consumption observed over the past decades, the INT Scenario will remain close to 2005 levels by 2030. The stabilization of energy consumption is largely achieved by a break in the historic trend of a continuously growing transport energy demand in the INT Scenario, transport energy consumption may even experience some slight reductions after 2010 due to lower transport activities and the introduction of new technologies. The economic crisis also largely affects industrial activities and so lowers the final energy demand of industry, while the residential and service sectors are expected to further increase their energy consumption (see Figure 11).

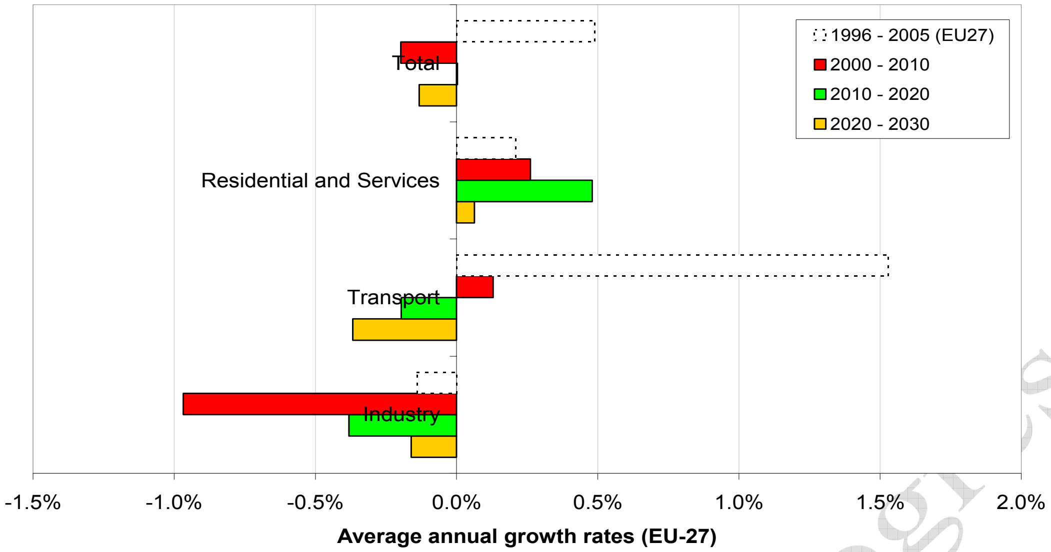
Overall, the policies introduced in the Integrated Scenario would manage to achieve a trend break in most sectors and consequently limit the overall consumption of energy in the EU (see Figure 12). In the integrated scenario the average annual growth rate in total energy consumption dropped from around 0.5% observed between 1996 and 2005 to levels between 0% and -0.2%.

The biggest change can be identified for the transport sector, where high growth rates (+1.8% p.a. between 1996 and 2005) turned into slightly negative ones. This effect becomes even more pronounced towards the end of the time horizon because of delays related to the vehicle fleet. In the industrial sector the small decline in energy demand is expected to continue, only coming a bit later in the decade 2000 to 2010 due to the impacts of the economic downturn. After 2010 it seems that the economic recovery offsets the increase of higher carbon values and higher production costs due to higher renewable shares.



Source: iTREN-2030 – POLES

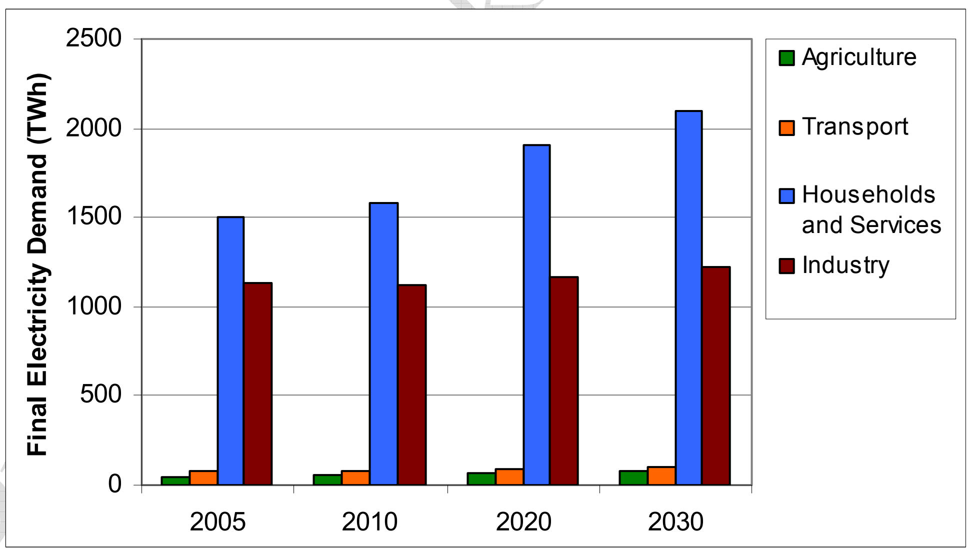
Figure 11: Trends in final energy demand in the INT Scenario (EU27)



Source: iTREN-2030 – POLES, Eurostat

Figure 12: Average annual growth rates of energy demand of economic sectors

Unlike final energy consumption, the demand for electricity will continue to rise throughout all sectors, following the development in the past years. The fastest growth is expected for the household and services sector, given the trend towards more and bigger appliances in private households and the rising economic importance of the tertiary sector.



Source: iTREN-2030 – POLES

Figure 13: Trends in final electricity demand in the INT Scenario (EU27)

Looking at the energy consumption of the transport sector in more detail reveals that the decrease largely stems from lower energy demand in road passenger transport and road freight transport (see

Table 4). Road mode energy consumption decreases by around -14% for freight and passenger transport. Air transport experiences a significant drop until 2010 due to the economic crisis, but recovers and finally increases by +10% over the whole time period from 2005 to 2030.

Table 4: Final energy demand per transport mode

Final energy demand [mtoe]	2005	2010	2020	2030
Transport – all modes	375	356	350	339
Road transport cars	201	194	180	172
Road transport freight	108	106	105	95
Rail	9	9	10	10
Aviation	51	41	50	56
Other transport	6	5	5	5

Source: iTREN-2030 – POLES model

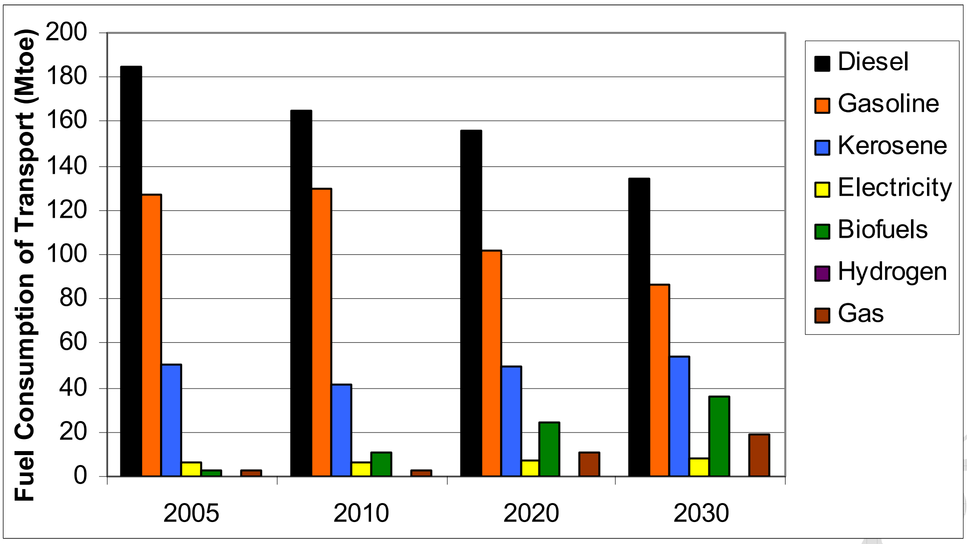
Also regarding final energy demand, the Reference and the Integrated Scenario differ most in the transport sector (see Table 5). Overall, the annual growth of 0.7% in the Reference Scenario turns into a negative growth of -0.4% in the Integrated Scenario. This reduction is largely caused by the changes in road transport and to a minor extent from the changes in air transport. Both types of road transport are expected to decrease, with an annual growth rate of about -0.5%, while they experienced an increase in the Reference Scenario.

Table 5: Final energy demand growth rates between 2005 and 2030

Average annual changes in final energy demand [%]	Integrated Scenario	Reference Scenario
Transport – all modes	**-0.4**	**0.7**
Road transport cars	-0.6	0.8
Road transport freight	-0.5	0.6
Rail	0.4	1.2
Aviation	0.4	0.8
Other transport	-0.7	-0.7

Source: iTREN-2030 POLES model

The development of fuel consumption in transport reflects the overall decrease of energy demand and the trends of the vehicle fleet (see chapter 6). Gasoline and diesel consumption is decreasing, while kerosene experiences a slight increase due to the continued growth of air transport (see Figure 14).



Source: iTREN-2030 – POLES model

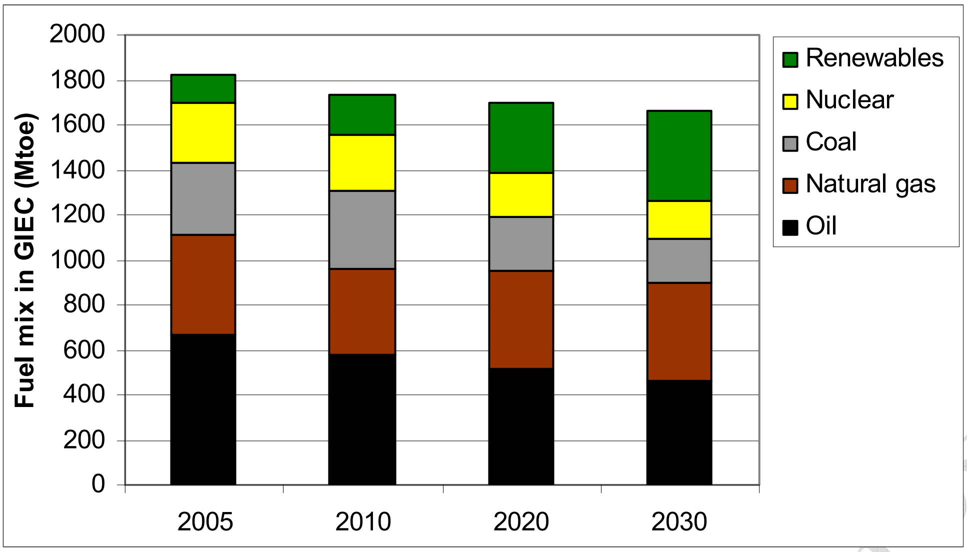
Figure 14: Fuel consumption in transport

Alternative transport fuels like biofuels, gas and electricity will play a more important role. Among alternative fuels, biofuels will experience the strongest growth, in particular in the Integrated Scenario. Despite their uptake, the biofuels share will be around 3.4% by 2010, thus falling short of the 5.75% target of the Biofuels Directive. Thereafter, however, the favourable conditions of the Integrated Scenario imply a further increase in the share of biofuels to gasoline and diesel consumption, to reach 9.8% by 2020 and around 15% by 2030. The increase of biofuels consumption is supported by the high oil prices, on the one hand, and a decrease of the production cost of biofuels with the entry of more advanced technologies, on the other.

Gas demand for transport experiences substantial growth as well. The trend towards gas can be explained by the development of gas and gasoline/diesel prices (see Figure 10). Although the number of hybrid and electric vehicles reaches 30 million vehicles, the electricity consumption of transport remains quite low as the fuel efficiency is quite high with respect to electricity of electric and hybrid vehicles.

(c) Energy supply

On the supply side, the energy sector in general, and the power sector in particular, strongly reacts to the rising carbon dioxide price and the renewable energy policy by substituting carbon-intensive fuels with low-carbon alternatives (see Figure 15).



Source: iTREN-2030 – POLES model

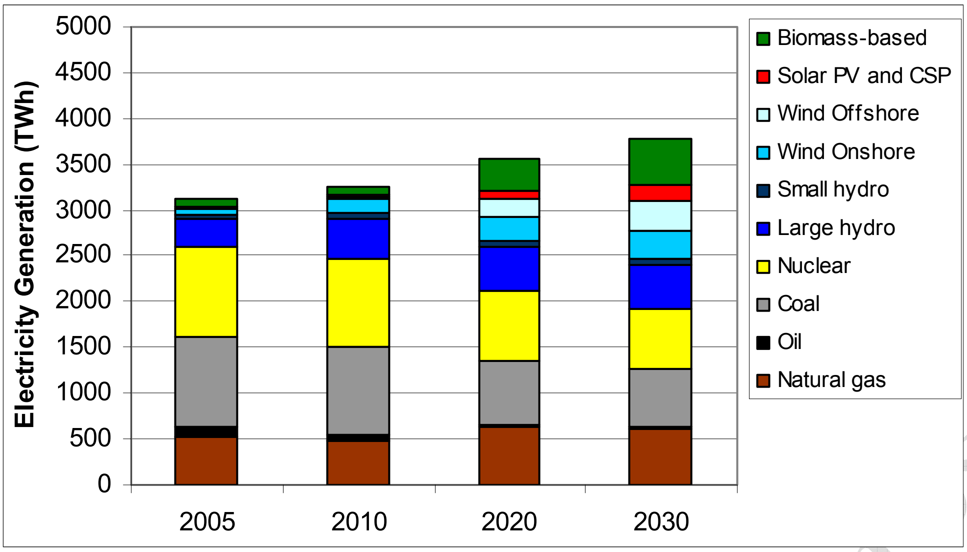
Figure 15: Fuel mix in Gross Inland Consumption (GIEC) in mtoe

Among the fossil fuels, a shift from oil and coal towards gas can be observed: oil and coal consumption will decrease by 30% until 2020, respectively 40% until 2030, compared to their 2005 levels. At the same time, gas consumption remains stable which leads to an increase of the share of gas in gross inland consumption from 24% to 26% in 2030. Remarkable is also the increase of the share of biomass and of other renewables to gross inland consumption from 5% respectively 2% in 2005 to almost 16% respectively 8% in 2030.

This picture differs quite strongly from the development of the fuel mix in the reference scenario. Unlike the Integrated Scenario, in the reference case gross oil and coal consumption remain stable at around 650 mtoe, respectively 350 mtoe and the share of biomass and of other renewables to gross inland consumption increases much more slowly (to reach only 5%, respectively 3%, by 2030).

In the power sector, coal-based power generation would be reduced by around one third between 2005 and 2030 in the Integrated Scenario. Oil-based power generation decreases even more strongly, while gas-based power generation remains stable. Together these trends illustrate the fossil fuel switch which is propelled by the increase of the carbon value.

At the same time, electricity generated by renewable energy generation (without large hydropower) increases by a factor of 5 (see Figure 16). The increasing trend of biomass and wind-onshore will continue and they will reach 10%, respectively 8%, in 2030 (see Figure 16). Wind-offshore and solar energy are expected to enter the market before 2020 with a presumable share. They will reach 5%, respectively 2%, in 2020 and may increase towards 9% respectively 5% in 2030.

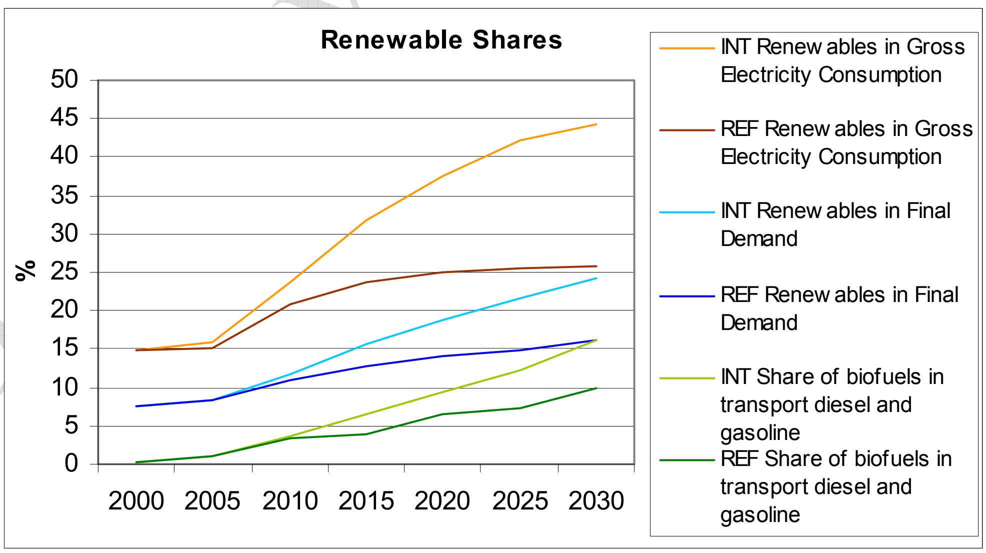


Source: iTREN-2030 – POLES

Figure 16: Electricity generation by fuel in the INT Scenario (EU27)

Consequently, in the Integrated Scenario renewable sources account for 37% of total electricity generation by 2020 in the EU, rising further to 44% by 2030 (see Figure 17), while in the Rference Scenario renewable sources reach 25% by 2020 and remain almost stable thereafter. A similar trend across the scenarios can also be observed for biofuels, which experience a continuous rapid increase in the Integrated Scenario (see (b)), whereas they would grow at a much slower pace in the Reference Scenario.

Overall, the share of renewables in final energy demand reaches 18.7% instead of 20% in 2020, as the POLES model in its current version does not take some emerging technology options into consideration [8] (see Figure 17). In the Reference Scenario where the renewable target was not implemented it reaches only 14% in 2020.



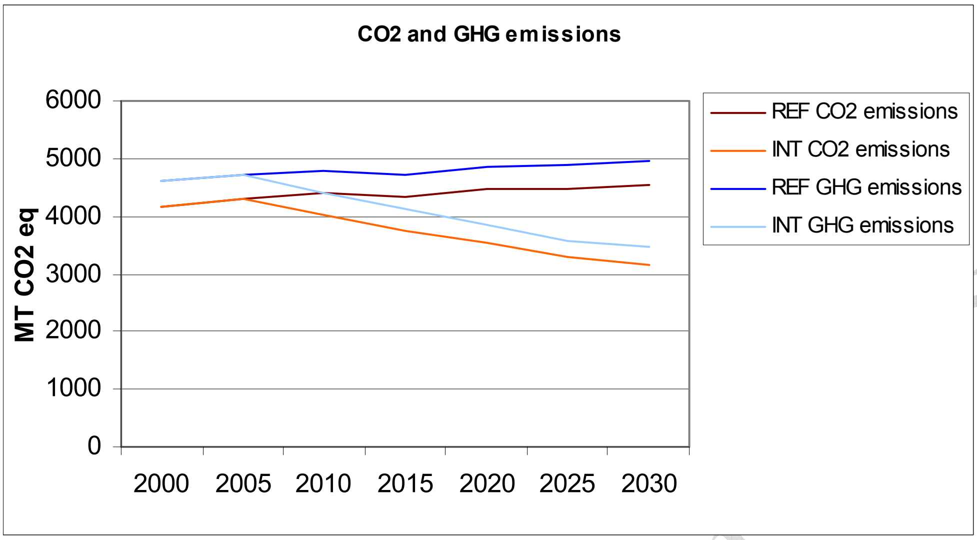
Source: iTREN-2030 – POLES

Figure 17: Shares of renewables in electricity, transport demand and final energy demand

8 In a comparison between renewable energy scenarios done with the POLES and the GreenX models, it was found that these missing categories account for 1.2-1.3% of renewables in final demand by 2020 [Resch et al., 2009].

(d) Emissions

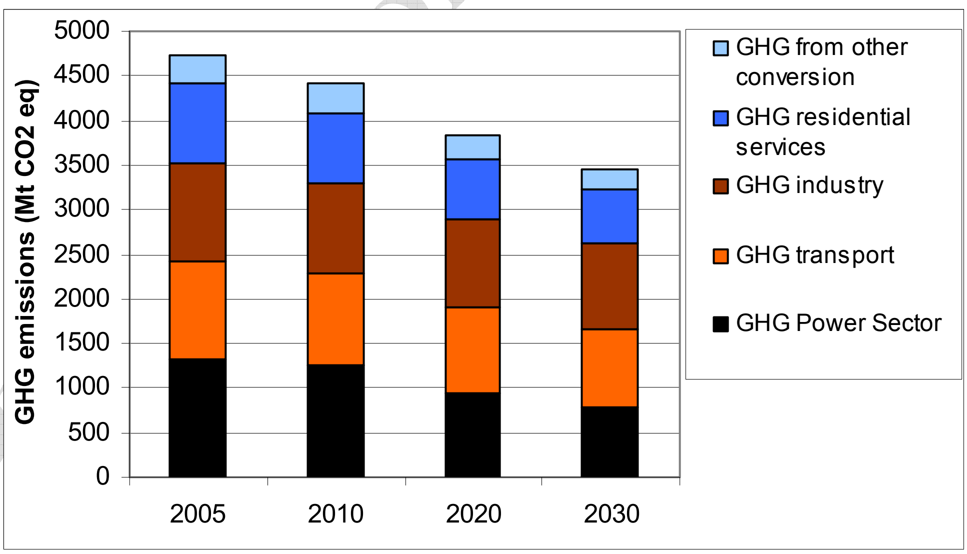
The combination of stagnating energy demand and the decreasing carbon intensity of power generation leads to substantial reductions in the emission of greenhouse gases, both compared to a baseline and the 1990 levels (see Figure 18).



Source: iTREN-2030 – POLES

Figure 18: Comparison of emissions between reference and integrated scenario

By 2020, the energy-related GHG emissions would be 21.9 % below the emissions in 1990 (see Figure 19) in line with the targets set for the scenario. The reduction of energy-related GHG emissions is slightly higher compared to the envisaged target because of the fact that the Integrated Scenario has to reach the renewable target as well. The renewable target is more difficult to meet than the GHG emission reduction target, especially due to the GDP crisis.



Source: iTREN-2030 – POLES

Figure 19: Development of GHG emissions (EU27)

The lower levels of GDP make it easier to reach the GHG emissions as they cause lower energy demand. The feed-in tariff and the carbon price that is necessary to meet the renewable target causes slightly higher GHG emission reductions. The GHG emissions will fall further, to 31% below 1990 levels by 2030. Major parts of the emission reductions are realized in the power sector (-36% between 2005 and 2030) and in the residential sector (-34% over the same period). But also greenhouse gas emissions of transport are declining, achieving a reduction of -7% until 2020 and of -12% by 2030 compared with 2005.

4 Conclusion

Several conclusions can be drawn from iTREN-2030. These refer to the applied methodology of linking and integrating various models and achieving consistency, on the results of the scenario projections integrating the impacts of the economic crisis, and on policies regarding their impacts as a policy, and their fit into the general European policy framework.

However, this paper focuses on the energy aspects of transport in the Integrated Scenario. At the current stage results of the Integrated Scenario are not finally finished. But preliminary results of the Integrated Scenario can already be discussed. Under the scenario conditions of a high oil price and the policies implemented in the Integrated Scenario changes in final energy demand can be expected. The biggest change can be identified for the transport sector, where high growth rates (+1.8% p.a. between 1996 and 2005) turned into slightly negative ones (see Figure 11). This effect becomes even more pronounced towards the end of the time horizon because of delays related to the vehicle fleet (see Figure 12). Looking at the energy consumption of the transport sector in more detail reveals that the decrease largely stems from lower energy demand in road passenger transport and road freight transport (see Table 4). Also regarding final energy demand, the Reference and the Integrated Scenario differ most in the transport sector (see Table 5). Overall, the annual growth of 0.7% in the Reference Scenario turns into a negative growth of -0.4% in the Integrated Scenario.

Alternative transport fuels like biofuels, gas and electricity will play a more important role. Among alternative fuels, biofuels will experience the strongest growth, in particular in the Integrated Scenario. Despite their uptake, the biofuels share will be around 3.4% by 2010, thus falling short of the 5.75% target of the Biofuels Directive. Thereafter, however, the favourable conditions of the Integrated Scenario imply a further increase in the share of biofuels to gasoline and diesel consumption, to reach 9.8% by 2020 and around 15% by 2030.

With respect to emissions the combination of stagnating energy demand and the decreasing carbon intensity of power generation leads to substantial reductions in the emission of greenhouse gases. Major parts of the emission reductions are realized in the power sector (-36% between 2005 and 2030) but also in the residential sector (-34% over the same period).

Consequently, the greenhouse gas emissions of transport are also declining, achieving a reduction of -7% until 2020 and of -12% by 2030 compared with 2005. However, the objective of reducing these emissions from transport by -10% by 2020 has failed, even though the economic crisis contributed towards reducing energy and transport demand growth.

Overall, the Integrated Scenario can be summarized as an ambitious development of the European (and global) energy system that encounters the challenges of drastic emission reductions and higher fossil fuel prices with a further switch towards low-carbon fuels and higher energy efficiency. At the same time, the consequences of the present economic downturn play an important role in reducing energy demand, especially over the coming decade.

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