Project no: **502687**

NEEDS

New Energy Externalities Developments for Sustainability

INTEGRATED PROJECT

Priority 6.1: Sustainable Energy Systems and, more specifically,
Sub-priority 6.1.3.2.5: Socio-economic tools and concepts for energy strategy.

Working Paper RS2, WP2.3

Key Drivers for Energy Trends in EU; Specification of the Baseline and Policy Scenarios

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1 Introduction

For policy evaluation studies with TIMES, a first task is to construct a baseline scenario for which all exogenous assumptions around drivers, energy prices and policies are specified following a rather business as usual trend. It is important for the baseline scenario to be on line with the assumptions used in similar projects or energy projections at the European Commission. The scope of this report is to first elaborate a critical review of the existing energy trends projections and the policy issues of interest for the EC. Then, with the help of the general equilibrium model GEM-E3 the exogenous assumptions for the baseline scenarios can be derived. Finally, other scenarios will be followed to address specific energy and environmental policies and measures using the same macroeconomic assumptions as in the baseline scenario.

The policy scenarios will illustrate the capabilities/possibilities of the models and approaches to analyze energy/environmental/research issues and will evaluate policies which are under discussion by the stakeholders at national and the EU level.

These policy scenarios can be either elaborated with the help of GEM-E3 as variants of the baseline scenario based on alternative growth and efficiency assumptions and on alternative international energy prices or they can be evaluated in a partial equilibrium framework, keeping the macroeconomic assumptions for the drivers as in the baseline scenario. The second approach will be used in this project.

1.1 Drivers for the Baseline scenario

The general equilibrium model GEM-E3 (EU22 countries) allows getting a consistent set of the various exogenous to TIMES data needed for the different modeling teams. Though not specifically a projection tool, it ensures a global consistency in the macroeconomic development of countries and sectors which is used to derive the demand for energy services. The model has been applied various times for policy analysis for the European Commission and for issues related to energy taxation, local pollution policy and long term climate policy. Exogenous input for GEM-E3 is:

- population growth
- technical progress, energy intensity and labor productivity evolution
- policy assumptions, e.g., Kyoto related policies, general taxation
- GDP growth target: an average EU GDP growth of 2 to 2.5% seems reasonable and in line with recent EC target and past growth rates

The growth path evaluated with the help of the GEM-E3 simulation should be comparable with those in other EC projects. The drivers generated by GEM-E3 to be used in the TIMES model are the following:

- GDP and GDP per head growth
- Private consumption as a proxy for disposable income

- sectoral production growth with a distinction between energy intensive sectors (e.g., ferrous and non-ferrous metals, chemical sector, etc.), other industries and services.

Moreover there are common assumptions such as population growth, fuel prices evolution or reference policy assumptions.

1.2 The policy scenarios

The policy scenarios should have two objectives. First to illustrate the capabilities of the model following the integration approach developed within NEEDS and secondly to contribute to policy analysis for issues which are on the table at the EC policy level. These scenarios could be within the following scope:

- Extensions of the Kyoto Protocol;
- CCS options for Europe;
- Air quality Improvement;
- Enhancement of endogenous energy resources.
- Efficiency and Renewables standards;
- Nuclear Acceptance;

The scenarios above will be analyzed capitalizing on advanced NEEDS methodologies and data that combine scenario generation techniques (i.e., based on partial equilibrium) with LCA and the internalization of externalities related to local/regional pollution and to global climate change.

Finally, the scope of this report can be summarized as follows:

- To critically review and summarize the main assumptions on key drivers determining the European Commission's Baseline Scenario "*Trends to 2030*" (EU, 2003) and "*Scenarios on key drivers*", (EU, 2004).
- To define an adjusted to recent developments Baseline Scenario that follows business as usual (BAU) trends in parallel with other EC studies
- To select other Policy Cases of interest for the EC stakeholders e.g., Extensions of the Kyoto; Air quality Improvement; Efficiency and Renewables standards; Nuclear Acceptance; Enhancement of endogenous energy resource availability, etc.
- To specify the needed information to project energy demand for the baseline and to specify the first list of common policy scenarios to be evaluated with TIMES.

2 DGTREN Scenarios-Underlying Assumptions and Review

2.1 General Issues- Overview

The DGTREN energy projections "*Trends to 2030*" (EU, 2003) are still the main energy projections available and at the base of many EU studies. This overview will illustrate the type of assumptions behind such a projection exercise.

- The Baseline scenario reflects the most likely development of the energy system in the future in the context of current knowledge, policy objectives and measures.
- Includes existing trends and of policies in place and/or in the process of being implemented by the end of 2001.
- The implementation of the renewables Directive of 2001 is not included
- Tax rates are as of July 2002 in EU-15, new members will gradually converge their taxes towards those in EU-15
- Excludes all additional policies and measures that aim at further reduction of CO2 emissions
- Weather conditions, which are important in determining energy use, are assumed to remain unchanged over the projection period.

The scenarios "*Scenarios on key drivers*", (EU, 2004) look at the impact of more specific assumptions, such different oil price evolution or economic growth, energy efficiency, acceptability of nuclear.
Hereafter we give an overview of the assumptions in the different scenarios; the main results are given in the annex.

2.2 Baseline scenario

2.2.1 Demographics

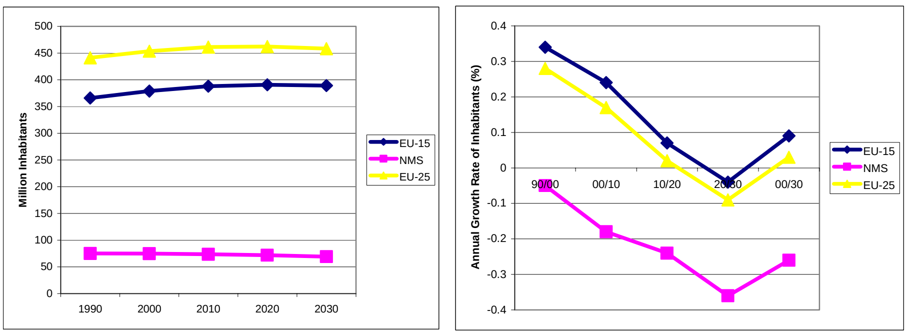

Fig. 1: Population in the baseline and growth rates
EU-25 population is projected to remain relatively stable, peaking in 2020 at some 462 million, but thereafter declining to 458 million by 2030, while New-Member states (NMS) account for 15.1% of the EU-25 population by 2030, down from 16.5% in 2000

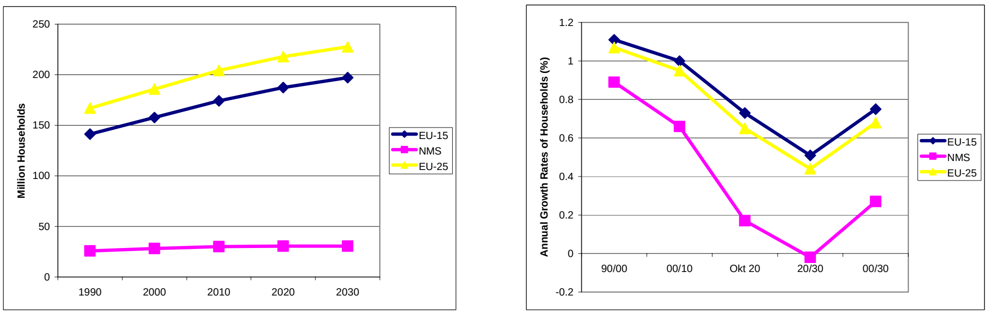

Fig. 2: Number of Households in the baseline and growth rates

Rising life expectancy, combined with declining birth rates and changes in societal and economic conditions are the main drivers for a decline in average household size but significant growth in the number of households takes place. Average household size will decline in EU-15 to 1.97 persons in 2030 (-0.65% p.a.) per household in NMS to 2.27 persons in 2030 (-0.52% p.a.) per household while the number of households will increase by 42 million between 2000 and 2030.

Remarks on Demographics: The above assumptions are exogenous to GEM-E3 and can be adopted as such for our analyses. The latest EU population projections will be used for NEEDS;

2.2.2 Macroeconomic Assumptions; *Gross Domestic Product:*

GDP projections for EU-25 Member States are based on the Economic and Financial Affairs DG forecasts of April 2002 for the short-term (2001-2003); and macroeconomic forecasts from WEFA, adjusted to reflect recent developments, for the horizon to 2030. Also, on Member States' stability programs and long-term projections for additional inputs for the EU-15, as well as stakeholders' consultation and the results of the GEM-E3 model. It is assumed that:

- The recent economic slow-down is transitory, and the longer-term global economic climate is assumed to remain generally positive.
- Economic growth is not uniformly distributed across countries, but the convergence of Member States' economies is assumed to continue.
- The Baseline economic outlook of EU-25 is dominated by the evolution of the EU-15 economy, while the integration of new Member States into the European Union is assumed to generate accelerated growth for their economies.
- Increases in commodity prices and inflation are assumed to remain modest.
- The slowdown in economic growth for NMS between 1990 and 2000 (+1.7% p.a. compared to +2.0% p.a. for EU-15) largely reflects the major reforms of political and economic structures that Central and eastern European countries (CEEC) have experienced since the early 1990s.

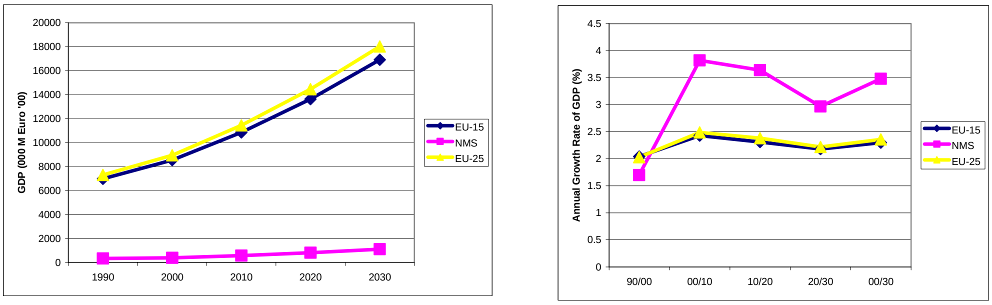

Fig. 3: GDP development and growth rates
EU-25 is projected to benefit from economic and monetary unification as well as from a continued increase in world trade. Average growth rates are around 2.3% for EU-15 and 3.5% for NMS

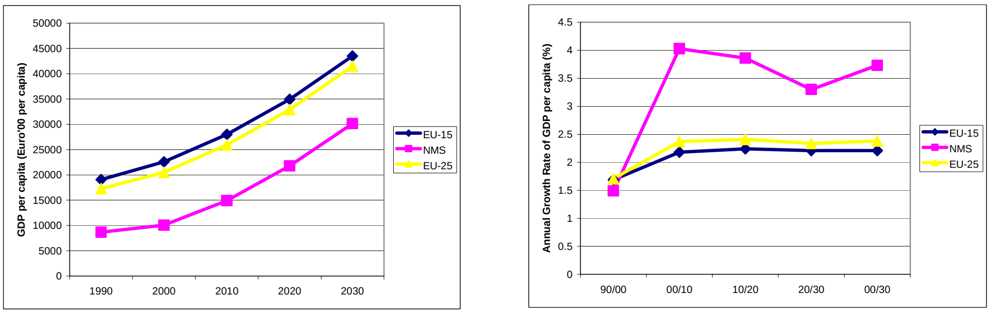

Fig. 4: Per capita GDP development and growth rates
The per capita growth is higher approaching 43000 € in EU-15 and 30000 € in NMS. The Baseline assumptions for economic growth of the EU-25 Member States reflect the long established trend of structural changes in developed economies, away from the primary and secondary sectors and towards services and high value-added products (less material and energy-intensive products). However, the pace of change is expected to decelerate in the long run.

Remarks on GDP development: The above assumptions and results concerning the GDP development remain valid for our analyses with the exception of the international oil and gas prices. We need to adjust price assumptions to recent developments and estimated the economic growth changes and this will be done with GEM-E3.

2.2.3 Evolution of sectoral value added in EU-25

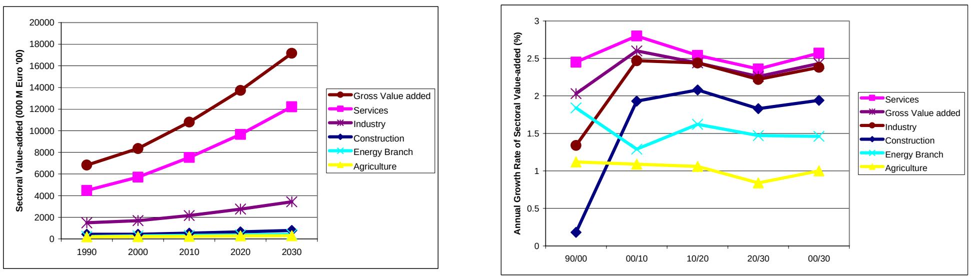

Fig. 5: Evolution of Sectoral value added and growth rates

- Services value added increases over the projection period above average, implying a continuous increase of its share in total economic activity (from 68.4% in 2000 to 71.1% in 2030).
- Market share of industrial activity grows at rates slightly below average, and therefore declines by 0.3% from 20.3% in 2000 to 20% in 2030.
- Agriculture is projected to experience the lowest economic growth of +1.0% p.a. between 2000 and 2030, but energy branch and construction sector are also projected to significantly decline in terms of market share, growing by 1.5% p.a. and 1.9% p.a. respectively.
- Despite faster growth of services, NMS' economies are projected to remain more reliant on industry and agriculture than the EU-15 to 2030.

2.2.4 International fuel prices

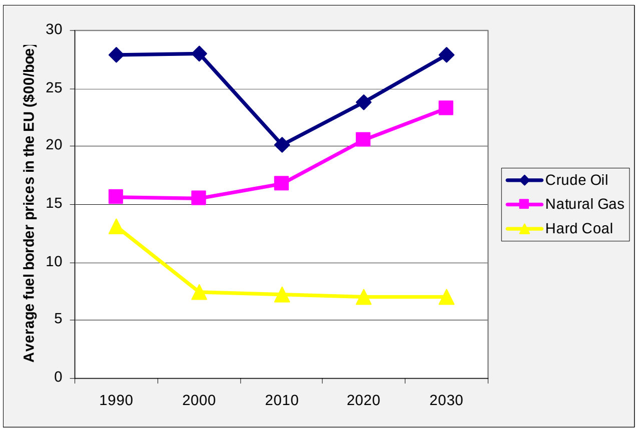

Fig. 6: Evolution of *International fuel prices*

Baseline projections are based on the assumption that global energy markets will remain well functioning throughout the projection period. Primary energy prices reflect the consensus that no major supply constraints are likely to be felt in the period to 2030. Future discoveries of new oil and gas field are assumed as well as further advances in extraction technologies. Oil prices are assumed to decrease over the next few years (!!) while gas prices are decoupled from oil prices in the second part of the projection period. Coal prices remain essentially stable in real terms.

2.2.5 Policy Related Assumptions

- Technological progress, induced both by economic growth and by modernization of installations in all sectors of the economy, thereby improving the efficiency of the energy system.
- The restructuring of the sectoral pattern of economic growth, which gradually shifts away from traditional energy-intensive sectors and concentrates on high value added activities, thereby reducing energy intensity.
- The effects from restructuring of markets through the liberalization of electricity and gas in the EU, which proceeds in line with EC directives; liberalization is assumed to be fully implemented in the period to 2010. Completion of the internal electricity and gas markets is also assumed to take place in the new Member States.
- The restructuring in power and steam generation, which is enabled by mature gas-based power generation technologies that are efficient, involve low capital costs and are flexible regarding plant size, co-generation and independent power production.
- Changes in primary energy production patterns (especially in many new Member States), characterized by the closure of unprofitable coalmines that took place in the 1990s and which is expected to continue to some extent over the next few decades.
- Energy policies that aim at promoting renewable energy (wind, small hydro, solar energy, biomass and waste) and co-generation are assumed to continue, involving subsidies on capital costs and preferential electricity selling prices. Rather than imposing the indicative targets of the EC renewables electricity Directive for each Member State, the Baseline includes policy measures in view of higher renewables deployment in individual countries.
- Ongoing infrastructure projects involving the introduction of natural gas. These are assumed to be completed in the next few years.
- Differences in current policies of EU-25 Member States as regards nuclear capacity, taking into account policy decisions as regards nuclear phase out in Belgium, Germany and Sweden; and plans concerning nuclear plant refurbishment/closure, as already agreed or under negotiation with the European Commission for new Member States.
- The effects arising from the voluntary agreement reached between the European Commission and the European automobile industry on specific CO2 emissions from new cars (followed in 1999 by similar agreements with Korean and Japanese car manufacturers).
- Concerning the use of biofuels in transportation, it was assumed that all countries would follow EU rules sooner or later. The impact of blending gasoline and diesel with biofuels on final consumer prices was assumed to be negligible, since higher fuel production costs will probably be offset by tax reductions scheduled to be implemented on these fuel blends.
- Policy initiatives related to climate change are included only to the extent that they are agreed policy measures. For the purposes of the study it is assumed that no specific new policies and measures aimed at meeting Kyoto targets in 2008-2012, and possible more severe ones in the future, are implemented over the next 25 years.

- However, it is assumed that stringent regulation for acid rain pollutants continues, especially for large combustion plants. Similarly, other clean air policies are assumed to continue.
- All capacity expansion and decommissioning plans in power generation, already decided, takes place as indicated in the EURPROG report of EURELECTRIC and other statistical sources (e.g. EPIC). Beyond 2010 plant decommissioning occurs on the basis of technical lifetimes and agreed policies on nuclear phase-out.

Three (real) discount rates are currently used within the model.

- The first, used mostly for large utilities, is set at 8%;
- the second, used for large industrial and commercial entities, is set at 12%;
- the third, used for households in determining their spending on transportation and household equipment, is set at 17.5%.

These different policy and efficiency evolution assumptions will have to be reviewed in line with the policy decisions at the EU and the economic context.

Table 1: Summary of the Development of key driving forces under the Baseline Scenario 'Trends to 2030' (European Commission, 2004)

	1990	2000	2010	2020	2030	90/00	00/10	10/20	20/30	00/30
	Million inhabitants					Annual Growth Rate (%)				
Population	441.13	453.41	461.23	462.11	458.16	0.28	0.17	0.02	-0.09	0.03
	Million households					Annual Growth Rate (%)				
Number of households	166.97	185.78	204.24	217.86	227.58	1.07	0.95	0.65	0.44	0.68
	1000 Million €$_{2000}$					Annual Growth Rate (%)				
Gross Domestic Product	7315	8939	11433	14462	18020	2.03	2.49	2.38	2.22	2.36
	€/capita					Annual Growth Rate (%)				
Per capita GDP	17303	20502	25917	32898	41479	1.71	2.37	2.41	2.34	2.38
	1000 Million €$_{2000}$					Annual Growth Rate (%)				
Gross value added	6833	8351	10793	13730	17165	2.03	2.6	2.44	2.26	2.43
Industry	1486	1698	2168	2758	3436	1.34	2.47	2.44	2.22	2.38
Energy intensive	430	495	620	771	931	1.40	2.28	2.21	1.90	2.13
Non Energy intensive	1055	1203	1548	1987	2505	1.32	2.55	2.53	2.34	2.47
Construction	431	439	532	653	783	0.18	1.93	2.08	1.83	1.94
Services	4482	5709	7525	9667	12210	2.45	2.80	2.54	2.36	2.57
Agriculture	198	222	247	275	298	1.12	1.09	1.06	0.84	1.00
Energy branch	236	283	322	377	437	1.84	1.29	1.621	1.47	1.46
Average order prices	$\$_{2000}$/boe					Annual Growth Rate (%)				
Crude oil	27.9	28.0	20.1	23.8	27.9	0.03	-3.27	1.74	1.59	
Natural gas	15.6	15.5	16.8	20.6	23.3	-0.06	0.80	2.06	1.25	
Hard coal	13.1	7.4	7.2	7.0	7.0	-5.60	-0.25	-0.22	-0.01	

2.3 Main assumptions for alternative scenarios

2.3.1 "Energy efficiency and 12% renewables in 2010"

- *Energy efficiency*: this scenario investigates the effects of actions along the lines of the EC Action Plan for Energy Efficiency in the EU-15 system. The Action Plan outlines policies and measures for the removal of exiting barriers to, and the realisation of the existing potential for, investment in energy efficiency. It is assumed that consumer obtain a better understanding of the benefits of adopting more efficient technologies, which in turn leads to faster deployment of improved and advanced technologies compared to the Baseline. Efficiency standards force the least efficient energy consumer items out of the market. The supply side also shifts towards more efficient equipment. The share of CHP is increased. (EC, 2004)

- *“12% renewables in 2010”*: it is assumed that additional incentives are provided so that the indicative target of a 12% contribution set out in the Renewables Electricity Directive is reached. Penetration of renewables on the demand side (biomass, solar thermal collectors) is achieved through promotional policies. On the supply side, targets are achieved through support schemes that provide subsidies for electricity generation from renewables. (EC, 2004)

2.3.2 “New nuclear technology accepted”

The “New nuclear technology accepted” scenario assumes that new nuclear designs, such as the European Pressurised Water Reactor (EPR) and the Westinghouse AP technology become mature by 2010. These reactors possess passive safety features, which reduce core fusion probability from 10^{-5}/year for existing nuclear plants to less than $5x10^{-7}$/year. It is assumed that this characteristic would ease public opinion concerns towards nuclear energy. In this case, those Member States with declared nuclear phase out policies, or where nuclear generation ceases in the period up to 2030, are assumed to re-evaluate their decisions and to permit new investment in these improved nuclear power plants. (EC, 2004)

2.3.3 Alternative Scenarios on world energy prices

Compared to the baseline scenario which describes a world of abundant oil and gas resources and relatively moderate international fuel price increases in the period to 2030, the alternative cases describe scenarios contrasting oil and gas price profiles (EC, 2004):

- PS1: ‘High oil and gas price scenario’ corresponds to a world with higher economic growth and lower oil and gas resources.
- PS3: ‘De-linking of oil and gas price’ illustrates the consequences of a higher relative availability of gas compared to oil; this case shows a decrease in the relative price of gas to oil.
- PS4: ‘Soaring oil/gas prices’ assumes a very sharp and prolonged oil and gas price increase. Oil and gas prices after 2010 are 100% higher than their Baseline level.

2.3.4 Alternative Scenarios on economic development

In view of the large uncertainties regarding the future economic evolution, two alternatives scenarios are examined in (EC 2004) in addition to the baseline scenario:

- The “low growth rate” case assumes a continuation of recent trends as regards the observed economic slowdown in the European Union. GDP growth is limited to 2.0%/a in 2000-2010, 2.1%/a in 2010-2020, and 1.9%/a in 2020-2030.
- The “high growth” case reflects the ambitions for high economic growth following the Lisbon and subsequent summits, i.e. 3%/a economic growth for the EU up to 2010. (2.7%/a in 2010-2020, 2.5%/a in 2020-2030).

3 Scenarios to be generated with the TIMES model for NEEDS

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3.1 The reference scenario

The EC-2003 and EC-2004 studies are good starting points for our analyses aiming to define a reference case that follows business as usual trends. Perhaps a better and more convenient procedure for the project is to follow the new DGTREN projection as recent developments in the oil and gas markets have been taken already into account. The Kyoto climate policy will be implemented for the reference case. After 2012, we should assume constant and moderate tax levels as the definition of the appropriate Post-Kyoto tax it will be the main subject of policy scenarios. For nuclear energy, we will adopt the country decisions as part of the Reference case.

3.2 The Policy issues addressed

We will mainly consider environmental issues linked to energy (e.g., climate policy and local pollution) and Energy independence issues aiming to reduce the dependency of European Union on energy imports

The scenarios

1. *Post Kyoto climate policy* with a long term target between 450-550ppm of CO2-equivalent concentration is proposed, where emission reduction targets can be derived from a study with IMAGE, POLES and GEM-E3 for DGENV, called "*Greenhouse gas reduction pathways in the UNFCC process up to 2025"*.
   With information taken from the above DGENV study, it should be possible to define a global CO2-eq emission target for 2050 compatible with the long term EU target of 2° C average, post-industrial temperature change. Imposing this constraint in TIMES we will evaluate the appropriate CO2/GHG tax necessary to reach the long term 2° C policy target. The level of the tax will partly depend on the World fuel prices assumed in the reference case (a high oil price will already have an impact on the energy consumption and thus will reduce the effort needed). TIMES can also consider (exogenous) impacts of climate policy on World prices for fossil fuels and the associated feed-back on demands using the partial equilibrium option.
2. *Enhancement of endogenous energy resources* such as renewables and bio-fuels and energy conservation options through a combination of policies (renewables standards, energy efficiency standards, R&D policy). By imposing a general constraint on input dependency, TIMES allows determining in which sectors and on which technologies the effort has to be concentrated to enhance energy independence for Europe and will eventually justify the imposed standards.

3. *Local pollution policy* targets for air quality to be derived from stream RS1b and a discussion at the EU level in a special workshop around this issue, as:
   RS1b could specify for TIMES policy targets in terms of emissions (derived from their atmospheric models). TIMES could also use the targets derived by the CAFÉ paper of DG environment. Another approach would be to internalize the external cost (by adding to TIMES the cost per ton of emissions from RS1b or from the CAFE study) and then see what emission reductions this implies and where the reduction is imposed.

Scenario Variants: Some scenarios variants can be considered regarding

- oil price
- the internalization or not of external cost in the first two scenarios (in all scenarios the cost or benefits in terms of external cost is always an output of the model)
- nuclear availability or not
- a combination of scenario 1 and scenario 3 to estimate the secondary benefits of carbon policy to local pollution targets.

The total number of scenarios will be limited to three with three variants altogether (i.e., the reference and six more cases at maximum).

The exact specification of these policy scenarios and their modalities will be defined later on in a special conference including stakeholders and Stream leaders of NEEDS.

3 References

European Commission (2003): European Energy and Transport – Trends to 2030. European Commission, Directorate-General for Energy and Transport, 2003. ISBN 92-894-4444-4

European Commission (2004): European Energy and Transport – Scenarios on key drivers. European Commission, Directorate-General for Energy and Transport, 2004. ISBN 92-894-6684-7

4 Appendix A: From macroeconomic assumptions to TIMES baseline input

4.1 General overview

The projection derived with GEM-E3 will give the evolution of demand driver needed to generate the demand projections for energy services. The key relation defining the useful energy demand projections EU_{rtj} by region (r), and sector (j) is following the relation (App-B1):

$$EU_{rtj} = EU_{r0j} \cdot \left(\frac{D_{r,t,j}}{D_{r,0,j}}\right)^{\alpha_j} \cdot \left(\frac{P_{r,t,j}}{P_{r,0,j}}\right)^{\varepsilon_j} \cdot \prod_{\tau=1}^{\tau=t} (1-aeei_{rj})^{ypp_\tau} \qquad \text{(App-A1)}$$

The drivers by demand category $D_{r,t,j}$ and their elasticities are defined in Table 2. The initial value of energy services $EU_{r,0,j}$ will be elaborated with the help of the calibration to the Eurostat energy data for each country and the efficiencies of the existing end-use technologies, in accordance with the database of the regional models.

Prices $P_{r,t,j}$ (i.e., in our case the marginal cost of energy services) are not known a-priori but we could start by assuming a given time path of prices[1], generated by GEM-E3 to estimate the first guess of the equilibrium reference demand projections based on equation (App-A1). Then, the partial equilibrium version of the model will define the equilibrium prices and demands simultaneously.

Finally, the last term defines the price independent demand change due to autonomous efficiency improvement. As in our database efficiencies are explicitly defined and demands are adjusted when an end-use technology is introduced in the markets the use of the AEEI factors can lead to double counting effects[2]. Thus, if demands for energy services are defined for homogeneous markets, like for example cars or buildings, the model itself will change the efficiency including explicit conservation measures. On the other hand, if demands refer to sectors like e.g., chemical industry then, intra-sectoral structural changes can be included in these factors explicitly. The implicit assumption is that the more energy intensive subsectors are declining compared to the other subsector. As detailed analyses by country and sector are outside the scope of NEEDS, it is proposed to assume that either the $aeei_{rj}$ factors are equal to zero or that this effect is included in the income elasticity.

The computation of the growth of the drivers $drgr_{rj}$ and the evolution of prices pgr_{rj} will derived from GEM-E3. Given the assumption that $aeei_{rj} = 0$, the relation can be written as

[1] Relative price changes in GEM-E3 will be applied to the marginal prices estimated in TIMES for the first period and define a price path and based on that and App-A1 to estimate the corresponding the demand projections. The simplest approach is to assume constant prices as in the first period and define demands according to that.

[2] *Life style changes can be integrated in the autonomous efficiency improvement to generate price independent demand projections*

$$EU_{rtj} = EU_{r0j} \cdot \left(\prod_{\tau=1}^{\tau=t} (1 + drgr_{rj}) \right)^{\alpha_j} \left(\prod_{\tau=1}^{\tau=t} (1 + pgr_{rj})^{ypp_\tau} \right)^{\varepsilon_j}$$

This gives the baseline demand for TIMES for the horizon considered which is exogenous in the baseline scenario.

4.2 Specific demand categories

4.2.1 Space heating:

The demand for energy services in the building market (e.g., space heating in residential and commercial buildings) needs to account for the balance of existing buildings over time that could be demolished, or renovated but as well as the construction of new buildings. Thus, the energy use for space heating and water heating is based on the existing housing stock, the demolition and retrofitting rates and the construction of new buildings.

The specific energy consumption is computed with the help of statistical analysis for the past developments (and the calibration for the year 2000) and the building code applied for a country. The building code subjects to policy changes and depends on scenario specifications.

First, the building balance is estimated for each category of buildings, i.e., demolition buildings (DB), Retrofitted buildings (RB) and new buildings NB, by assuming demolition, renovation rates for existing housing stock and growth rates for new buildings. The useful energy of existing buildings, per building category $E_{i,t}$, is defined based on the number of buildings $B_{i,t}$, their surface $F_{i,t}$, and their specific useful consumption per unit of surface $SE_{i,t}$.

Demolition balance per category of buildings, i.e. age and type:

$$DB_{i,t} = B_{i,t-1} \bullet (1.-e^{\Delta T_t \cdot DR_{i,t}})$$

Retrofit balance:

$$RB_{i,t} = B_{i,t-1} \bullet (1.-e^{\Delta T_t \cdot RR_{i,t}})$$

Old buildings available at time t:

$$B_{i,t} = B_{i,t-1} - DB_{i,t} - RB_{i,t}$$

Energy of unmodified old buildings:

$$E_{i,t} = B_{i,t-1} \bullet F_i \bullet SEO_{i,t}$$

Energy of retrofitted buildings at time t:

$$ER_{i,t} = \sum_{k=1,t} RB_{i,k} \bullet F_i \bullet SER_{i,k}$$

Energy of new buildings[3]:

$$EN_{i,t} = \sum_{k=1,t} NB_{k,i} \bullet F_{k,i} \bullet SEN_{k,i}$$

Water heating, old[4]:

$$WH_{i,t} = (B_{i,k} + \sum_{k=1,t} RB_{i,k}) \bullet F_i \bullet SWO_{i,k}$$

Water heating, new:

$$WHN_{i,t} = \sum_{k=1,t} NB_{i,k} \bullet F_{i,k} \bullet SWN_{i,k}$$

Process heating for the commercial sector and electricity use for commercial appliances are defined either as specific values per floor area or per value added based upon statistical analyses and the calibration for the year 2000. The interface to MARKAL/TIMES needs the selection of appropriate building categories which assume similar specific investment costs per annual useful energy consumption. The **conservation supply curve** for space and water heating in TIMES must be defined as explicit technologies. This refers to conservation options that go above the **reference** development by assuming gradual improvements of the building envelope, heat recovery and solar passive systems.

4.2.2 Energy use in Appliances:

The relations below represent one of the possibilities to formulate the demand for appliances. The approach followed in the GAMS code explained later on is based on the application of different drivers with different elasticities. The electricity consumption of secondary appliances of the households is defined on the specification of their ownership probability, which is supposed to follow a logistic curve, and an exponential decaying curve describing the energy consumption per appliance. This function saturates to a theoretical value, SE_∞ with a half-life time, τ. Both parameters are policy dependant. There are different types of appliances to be considered.

Ownership f :

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[3] The number of new buildings and retrofitted buildings depend on new families and their disposable income.

[4] Water heating per building depends on family size

$$f_t = \frac{Sat}{1 + e^{-\alpha \bullet (\sum_t \Delta T_t - t_0)}}$$

The specification of the constants needs first to assume a saturation level (e.g., 100%) and two known pairs of time and ownership.

Specific annual consumption:

$$\frac{(SE_t - SE_0)}{(SE_\infty - SE_0)} = 1 - e^{-0.693 \bullet \sum_t \Delta T_t / \tau}$$

The energy consumption of appliances could be correlated and normalized to the results of an econometric model for a **reference** case. Any farther reduction of energy consumption below to the values assumed in the reference development should be the result of investments on conservation. For that purpose, (and when enough information can be made available), the model should define either a **conservation supply curve,** (i.e., the conservation potential *versus* cost), for the set of the appliances consuming electricity or individual and explicit technological options.

4.3 Price and Income Elasticities for TIMES

4.3.1 Income elasticities

The development of the demand for energy services are linked to the drivers' projections through elasticities. These elasticities are meant to reflect changing patterns in energy service demand in relation to economic growth, such as saturation in some energy end-use demand, increased urbanization or changes in consumption patterns once the basic needs are satisfied. The elasticities chosen for this scenario are summarized in Table 2.

Table 2: Demand drivers and elasticities

Demand Category	**Driver**	**Driver Elasticity**
Transportation demand		
Passenger transport		
Autos	GDPP	1.2
Buses	POP	0.7
Two/three wheelers	POP	0.7
Passengers rail transportation	POP	0.8
Domestic aviation	GDP	1.3
International aviation	GDP	1.3
Freight transport	GDP	1
Trucks	GDP	0.7
Freight rail transportation	GDP	1
Internal navigation	GDP	1
International navigation (bunkers)	GDP	1

Residential demand		
Space heating	HOU	0.8
Space cooling	HOU	1
Hot water heating	POP	1
Lighting	GDPP	1
Cooking	POP	0.7
Refrigerators and freezers	HOU	1
Cloth washers	HOU	1
Cloth dryers	HOU	1
Dish washers	HOU	1
Miscellaneous electric energy	GDPP	1
Other energy uses	HOU	1
Commercial demand		
Space heating	Service sector production	0.5
Space cooling	Service sector production	0.8
Hot water heating	Service sector production	0.5
Lighting	Service sector production	0.8
Cooking	Service sector production	0.8
Refrigerators and freezers	Service sector production	0.8
Electric equipments	Service sector production	0.8
Other energy uses	Service sector production	0.5
Agriculture	Agriculture production	0.8
Industrial demand		
Iron and steel	Sectoral production	0.7
Non ferrous metals	Sectoral production	0.8
Chemicals	Sectoral production	0.8
Pulp and paper	Sectoral production	0.8
Non metal minerals	Sectoral production	0.8
Other industries	Sectoral production	0.8

HOU: # of households growth
POP: population growth
GDP: growth domestic product
GDPP: growth GDP per head
* climate sensitive

The assumptions behind these figures are briefly described hereafter.

Passenger transport: there is shift from public transport towards private car with increasing income; the greater urbanization would also contribute to a lesser increase in the passenger-km demand.

Freight transport: accompanies more closely the growth of GDP with a slight shift away from road transport.

Residential demand: for the basic needs, the drivers are either the evolution in the number of household or the population growth, for the other demand categories, the evolution in income is the dominant factor. In the long run, certain saturation and changes in consumption patterns will lessen this link.

Commercial demand: follows the sectoral activity but with a decreasing link

Industrial and agriculture demand: the demand follows the sectoral production evolution

These assumptions are clearly disputable given the great uncertainty around the possible future development patterns.

4.3.2 Price elasticities

There are no studies on the price elasticities of energy service demand, except for transport demand but then they do not cover the whole world. Therefore elasticities are proposed based on energy demand price elasticities. The passage from energy demand price elasticity to energy service demand price elasticities is based on the following relation between the two elasticities.
At an aggregate level, energy demand is equal to the energy service demand times the energy efficiency of the process used to satisfy the demand. Depending on the substitution possibilities between inputs and processes, the relation between the two price elasticities will be different.

Energy demand

$$ED = ES * UE$$

where *ED*: energy demand (final)
ES: energy service demand
UE: final energy demand per unit of energy service demand; a function of capital and energy
Assuming a fix relation between capital and energy in the production function of energy services (Leontieff structure), then the price elasticity of energy demand is a function of the price elasticity of energy demand and the share of energy in the total cost:

$$pelas_{ED} = pelas_{ES} * share\, of\ E\, in\, PES$$

where *PES*: cost of the energy service (i.e., the marginal cost of energy service demand)
$pelas_{ED}$: price elasticity of energy demand
$pelas_{ES}$: price elasticity of energy service demand

Assuming substitution possibilities between capital and energy in the production function (e.g. a CES production function, then the price elasticity of energy demand will also depend on the substitution elasticity:

$$pelas_{ED} = pelas_{ES} * share\, of\ E\, in\, PES - \sigma(1 - share\, of\ E\, in\, PES)$$

or $pelas_{ES} = (pelas_{ED} + \sigma \cdot (1 - share))/share$

where σ: elasticity of substitution in the CES function.

The greater the share of energy in the total cost, the closer the two elasticities is while the greater the substitution possibilities the greater the distance between the two elasticities. Based on these relations and assumptions regarding the energy demand price elasticities and substitution possibilities, energy services demand price elasticities were derived, which are reproduced in Table 3.

Table 3: Price elasticities and elasticities for energy services

Demand			Demand						
Residential Heating/cooling/ hot water	EDelas	-0.45	cooking/	EDelas	-0.35	other	EDelas	-0.5	-0.5
	SUBelas	0.7	refrigerator	SUBelas	0.4		SUBelas	0.3	0.3
	Share EN	0.8		Share EN	0.8		Share EN	0.6	0.9
	ESelas	-0.39		ESelas	-0.34		ESelas	-0.63	-0.52
Commercial Heating/cooling/ hot water	EDelas	-0.55	cooking/	EDelas	-0.4	other	EDelas	-0.5	-0.5
	SUBelas	0.7	refrigerator	SUBelas	0.4		SUBelas	0.3	0.3
	Share EN	0.8		Share EN	0.8		Share EN	0.6	0.9
	ESelas	-0.51		ESelas	-0.40		ESelas	-0.63	-0.52
Industrial energy intensive	EDelas	-0.7	other	EDelas	-0.4				
	SUBelas	1		SUBelas	0.4				
	Share EN	0.7		Share EN	0.8	depends on the cost included in MARKAL/TIMES			
	ESelas	-0.57		ESelas	-0.40				

For transport there are estimations of the demand for transport price elasticities, though they don't cover all the regions and are sometimes related to the cost of energy and not the total transport cost. Average figures for long term elasticities in OECD countries are given in 4.

Table 4: Price elasticities for transport demand

Passenger		**Freight**	
Private car	-0.7	Trucks	-0.9
Bus	-0.2	Train	-0.2
Train	-0.2	Navigation	-0.2
Motorized two-wheelers	-0.3		
Navigation	-0.1		
Air	-0.7		

5 Appendix B: Defining the Demand multipliers for Belgium and Switzerland

Based on the relations explained before, the tables given in the Appendix of EC-2004 the demands and elasticities defined in Appendix B, the following GAMS code is written to generate the demands multipliers for Belgium which is also presented in the subsequent tables and figures. Clearly the code can be used for any country and the AEEI factors or alternative and exogenous growth rates can be easily applied to take into account life-style scenario assumptions[5].

The main conclusions of this work are the following:

- The demand projections for buildings must improve to take into account demolition and renovation rates together with construction rates for new buildings and the building code. Construction rates could be linked to the drivers.
- The demand projection for commercial services should be better disaggregated following the activities of the individual sub-sectors in services.
- Life style changes are important for some sectors with very high demand projections and needs approval by stakeholders
- NMS are not defined with the same details in terms of their socio-economic data and a modified interface was developed.

The subsequent GAMS code compute from the GEM-E3 results the drivers and the demand evolution for TIMES.

```
$TITLE  DEMAND PROJECTIONS FOR NEEDS  July 2005 PSI

*BELGIUM:key demographic and economic assumptions as in EC-2004

$inlinecom{ }
SETS
TP          time periods /1990,2000,2010,2020,2030/
SECTORS     economic sectors /irst, nfm,petro, drugs, nmetm, pulpr, printing, food,
textile, engineer, otheri, construct, markets, nmser, trade, agri, energy/

POPECO      general data    /pop, size, hou, gdp, yhouse, gva/;

scalar      runaeei    run aeei  if one         /0/;

table gdeco(popeco, tp)
       1990   2000   2010   2020   2030
pop    10     10.2   10.4   10.6   10.6    { population (million)            }
size   2.6    2.4    2.3    2.2    2.1     { household   size (persons)      }
```

[5] Similar results are also given for Switzerland while the code is modified to reflect the restricted socio-economic data given for NMS and EFTA countries.

```
hou     3.9     4.2     4.6     4.9     5.1     { number of households (million)      }
gdp     199.8   248.3   308.1   367.4   432.1   { gross domestic product (in 000 meuro  }
yhouse  105.5   128.9   157.4   190.1   225.6   { households expenditure (in 000 meuro  }
gva     187.7   230     288.3   346.5   409.4   { gross value added (in 000 meuro'00)}

table ysector(sectors,tp)
                1990    2000    2010    2020    2030
irst            3.8     2.8     2.6     2.3     2.1     { iron and steel}
nfm             1.1     0.8     1       1.2     1.4     { non ferrous metals   }
{       chemicals                       }
petro           3.4     6.2     8.3     9.1     9.4     { petroche.fertilisers,others    }
drugs           1.7     3       5       7.2     10      { pharmaceuticalscosmetics    }
nmetm           2.4     2.6     2.9     3.3     3.7     { non metallic minerals         }
{       paper.pulp.printing             }
pulpr           1       0.6     0.7     0.8     0.9     { paper and pulp production    }
printing        2       2.8     3.4     4.1     4.8     { printing and publishing        }
food            3.4     6.2     7.5     8.8     9.7     { food.drink.tobacco             }
textile         3.3     2.8     3       3.1     3.1     { textiles and leather           }
engineer        14      15.1    19.3    23.9    28.9    { engineering                    }
otheri          6.4     4.3     5.4     6.6     7.9     { other industries               }
construct       10.1    11.5    13.8    16.2    18.7    { construction            }
{       services                        }
markets         43.8    63.5    90      115.5   146.8   { market services                }
nmser           45.1    52.2    58.9    65.6    71.1    { non-market services            }
trade           40      43.9    52.1    62.1    72.5    { trade                          }
agri            2.6     3.6     3.8     3.9     4       { agriculture                    }
energy          3.7     7.9     10.7    12.7    14.7    { energy sector                  }      ;

display gdeco, ysector;
parameter checkgva(tp);
checkgva(tp)=sum (sectors  , ysector(sectors,tp));
display checkgva;
set drivers /gdpp, pop, gdp, hou, sva, agri, irst , nfm, petro,  pulpr, nmetm, otheri /
parameter vdriver(drivers, tp);

vdriver("gdpp", tp)=gdeco("gdp", tp) /gdeco("pop", tp);
vdriver("pop", tp)=gdeco("pop", tp);
vdriver("gdp", tp)=gdeco("gdp", tp);
vdriver("hou", tp)=gdeco("hou", tp);
vdriver("sva", tp)=ysector("markets", tp) +ysector("nmser", tp)  +ysector("trade", tp) ;
vdriver("agri", tp)=ysector("agri", tp);
vdriver("irst", tp)=ysector("irst", tp);
vdriver("nfm", tp)=ysector("nfm", tp);
vdriver("petro", tp)=ysector("petro", tp);
vdriver("pulpr", tp)=ysector("pulpr", tp);
vdriver("nmetm", tp)=ysector("nmetm", tp);
```

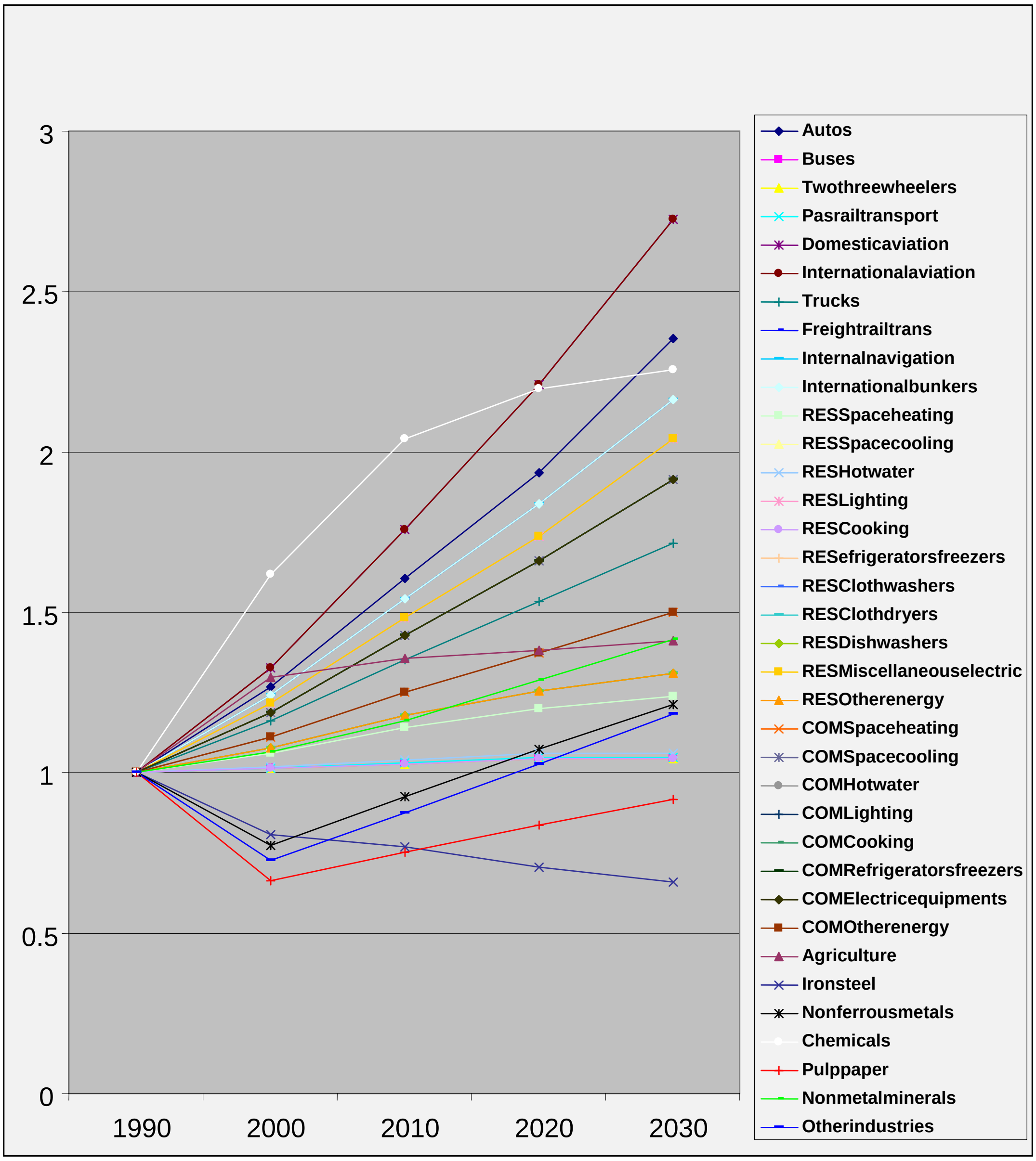
```
vdriver("otheri", tp)=ysector("otheri", tp);

set demand
/autos
buses
twothreewheelers
pasrailtransport
domesticaviation
internationalaviation
trucks
freighttrailtrans
Finternalnavigation
internationalbunkers
resspaceheating
resspacecooling
reshotwater
reslighting
rescooking
resefrigeratorsfreezers
resclothwashers
resclothdryers
resdishwashers
resmiscellaneouselectric
resotherenergy
comspaceheating
comspacecooling
comhotwater
comlighting
comcooking
comrefrigeratorsfreezers
comelectricequipments
comotherenergy
agriculture
ironsteel
nonferrousmetals
chemicals
pulppaper
nonmetalminerals
otherindustries
/;
*define demands categories drivers and income elasticity
parameters demands(demand,tp), grdriver(drivers,tp);
parameter demand2driver(demand, drivers)
* Passenger transport
/
Autos.GDPP                    1.2
```

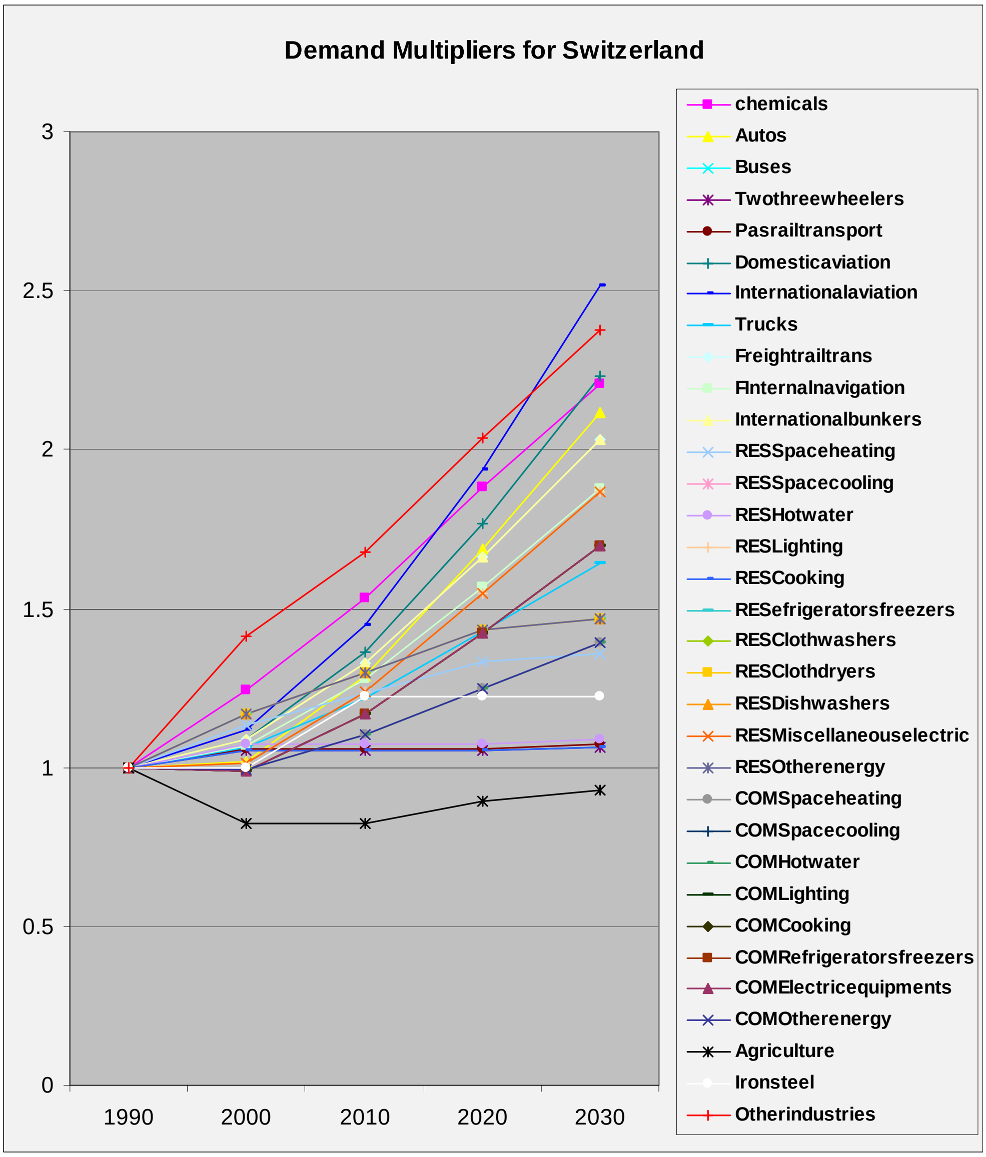
```
Buses.POP                          0.7
Twothreewheelers.POP               0.7
Pasrailtransport.POP               0.8
Domesticaviation.GDP               1.3
Internationalaviation.GDP          1.3
* Freight transport
Trucks.GDP                         0.7
Freightrailtrans.GDP               1
FInternalnavigation.GDP            1
Internationalbunkers.GDP           1
*Residential demand
RESSpaceheating.HOU                0.8
RESSpacecooling.HOU                1
RESHotwater.POP                    1
RESLighting.GDPP                   1
RESCooking.POP                     0.7
RESefrigeratorsfreezers.HOU        1
RESClothwashers.HOU                1
RESClothdryers.HOU                 1
RESDishwashers.HOU                 1
RESMiscellaneouselectric.GDPP      1
RESOtherenergy.HOU                 1
*Commercial demand
COMSpaceheating.SVA                0.5
COMSpacecooling.SVA                0.8
COMHotwater.SVA                    0.5
COMLighting.SVA                    0.8
COMCooking.SVA                     0.8
COMRefrigeratorsfreezers.SVA       0.8
COMElectricequipments.SVA          0.8
COMOtherenergy.SVA                 0.5
Agriculture.AGRI                   0.8
*Industrial demand
Ironsteel.IRST                     0.7
Nonferrousmetals.NFM               0.8
Chemicals.PETRO                    0.8
Pulppaper.PULPR                    0.8
Nonmetalminerals.NMETM             0.8
Otherindustries.otherI             0.8   / ;
loop (tp, grdriver(drivers,tp+1)= log(vdriver(drivers,tp+1)/vdriver(drivers,tp))/10. ;
grdriver(drivers,tp+1)=100*(exp(grdriver(drivers,tp+1))-1);
);
loop (drivers, demands(demand,tp) $(demand2driver(demand, drivers))  =
(vdriver(drivers,tp)/vdriver(drivers,"1990"))**demand2driver(demand, drivers)
);
display demands, grdriver;
```

Table Appendix B1: Basic Socioeconomic data for Belgium

BELGIUM:KEY	DEMOGRAPHIC	AND	ECONOMIC	ASSUMPTIONS	
	1990	2000	2010	2020	2030
Demographic Assumptions					
Population (Million)	10	10.2	10.4	10.6	10.6
Average household size (persons)	2.6	2.4	2.3	2.2	2.1
Number of households (Million)	3.9	4.2	4.6	4.9	5.1
Gross Domestic product (in 000 MEuro'00)	199.8	248.3	308.1	367.4	432.1
Households expenditure (in 000 MEuro'00)	105.5	128.9	157.4	190.1	225.6
Gross Value Added (in 000 MEuro'00)	187.7	230	288.3	346.5	409.4
Industry	42.6	47.3	59.2	70.4	81.6
iron and steel	3.8	2.8	2.6	2.3	2.1
non ferrous metals	1.1	0.8	1	1.2	1.4
chemicals	5.1	9.2	13.3	16.3	19.3
petrochemicals fertilisers and others	3.4	6.2	8.3	9.1	9.4
pharmaceuticals and cosmetics	1.7	3	5	7.2	10
non metallic minerals	2.4	2.6	2.9	3.3	3.7
paper. Pulp .printing	2.9	3.4	4.2	4.9	5.6
paper and pulp production	1	0.6	0.7	0.8	0.9
printing and publishing	2	2.8	3.4	4.1	4.8
food. drink. tobacco	3.4	6.2	7.5	8.8	9.7
textiles and leather	3.3	2.8	3	3.1	3.1
engineering	14	15.1	19.3	23.9	28.9
other industries	6.4	4.3	5.4	6.6	7.9
Construction	10.1	11.5	13.8	16.2	18.7
Services	128.8	159.6	200.9	243.2	290.4
market services	43.8	63.5	90	115.5	146.8
non-market services	45.1	52.2	58.9	65.6	71.1
trade	40	43.9	52.1	62.1	72.5
Agriculture	2.6	3.6	3.8	3.9	4
Energy sector	3.7	7.9	10.7	12.7	14.7
Source: PRIMES to be replaced by GEM-E3					

Figure B1: Demand multipliers for Belgium and Switzerland

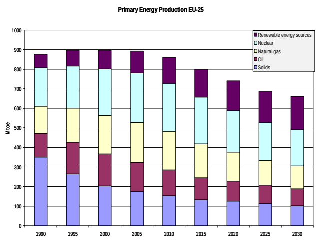


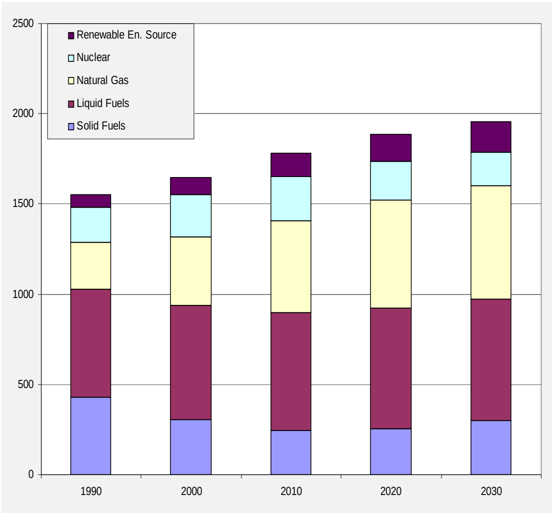


Demand Multipliers for Switzerland
3
2.5
2
1.5
1
0.5
0
1990
2000
2010
2020
2030
chemicals
Autos
Buses
Twothreewheelers
Pasrailtransport
Domesticaviation
Internationalaviation
Trucks
Freightrailtrans
FInternalnavigation
Internationalbunkers
RESSpaceheating
RESSpacecooling
RESHotwater
RESLighting
RESCooking
RESefrigeratorsfreezers
RESClothwashers
RESClothdryers
RESDishwashers
RESMiscellaneouselectric
RESOtherenergy
COMSpaceheating
COMSpacecooling
COMHotwater
COMLighting
COMCooking
COMRefrigeratorsfreezers
COMElectricequipments
COMOtherenergy
Agriculture
Ironsteel
Otherindustries

6 Appendix C: Scenario Results

6.1 Baseline

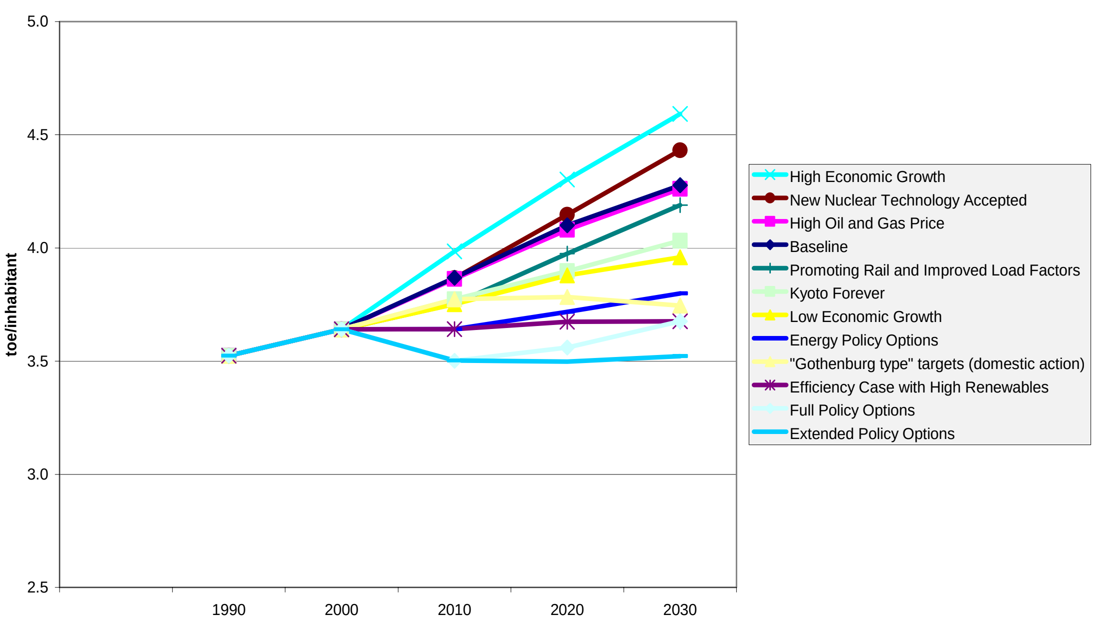




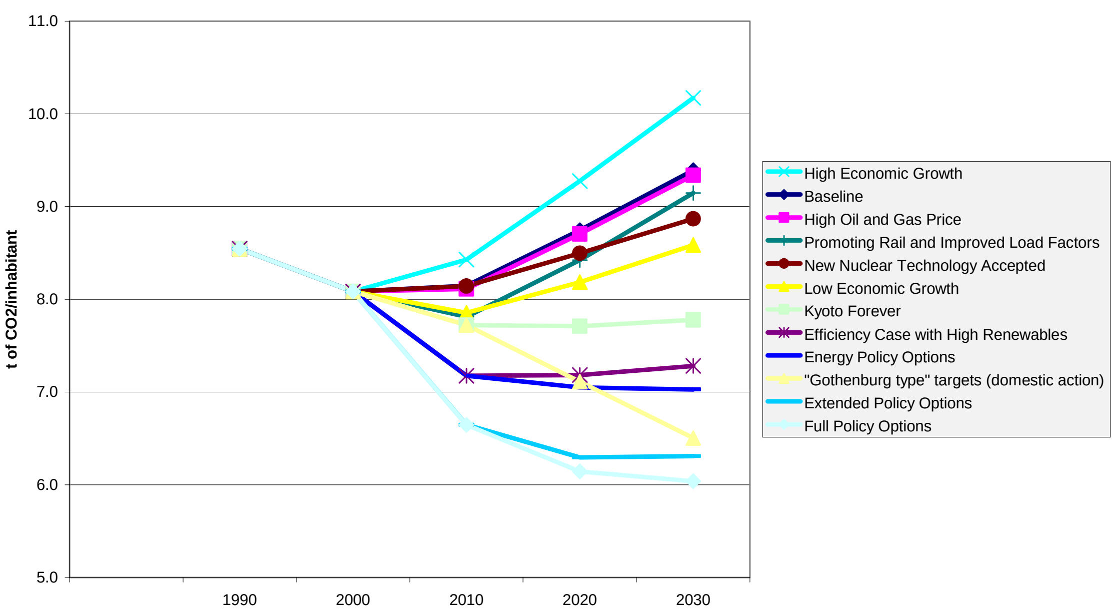
Indigenous production is around 50% of consumption while the adjusted to new oil prices primary energy demand could grow at 0.5 %/yr = -0.25(pop) +2(GDP/pop) -1.25(E/GDP)

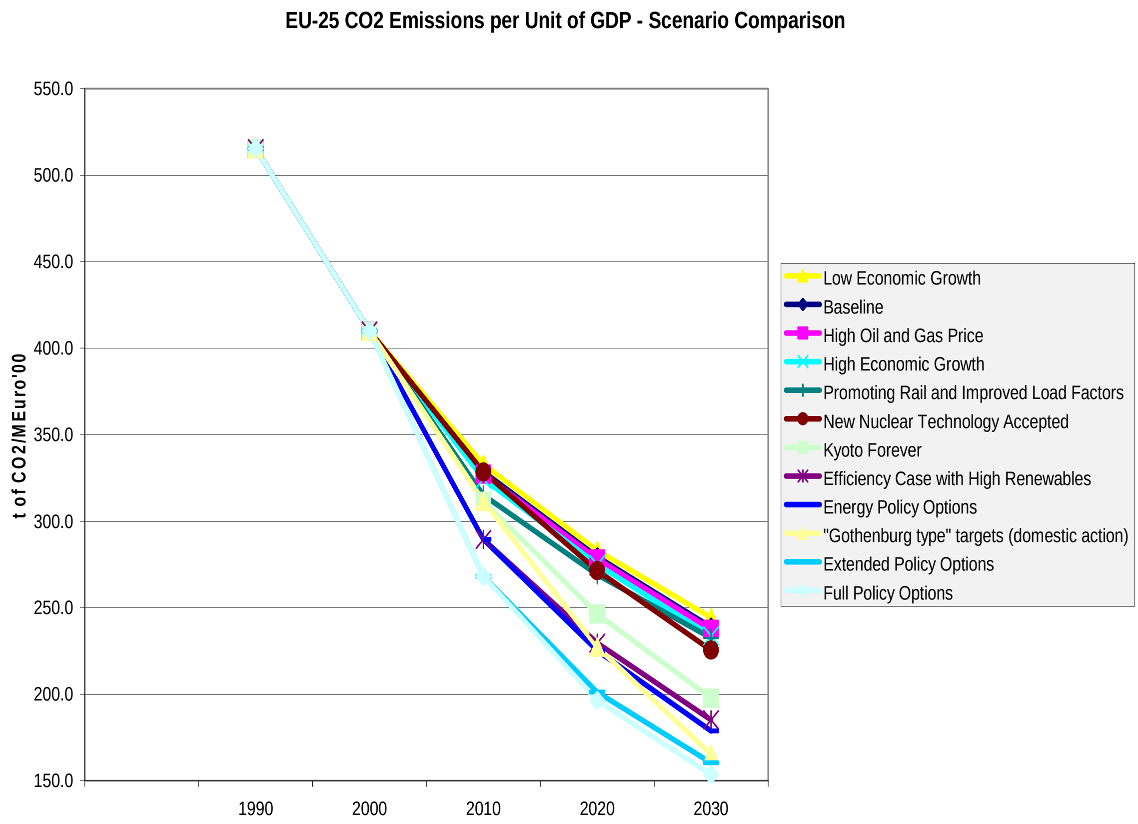
Remarks on Indigenous energy production and use: The results above reflect the key vulnerability of the European energy system. Energy production is around 50% of energy consumptions with decreasing trends. Policy efforts are needed to improve energy efficiency, to enhance endogenous production and to establish strategic partnerships and diversification of energy imports. The subsequent graph explains how a proper policy could reduce Gross-Inland Consumption and CO_2 emissions per capita.

EU-25 Gross Inland Consumption per Capita - Scenario Comparison



EU-25 CO2 Emissions per Capita - Scenario Comparison





Remarks on CO2 Emissions per Unit of GDP: The results above conclude that the 1990-2010 trends can be extrapolated in the future only when proper policies apply, otherwise CO2 emissions will be less successfully de-coupled to economic growth as it was the case in the past.