REPORT

Long term energy and emissions' projections for Belgium with the PRIMES model

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Table of contents

List of figures

I. Introduction

In the Royal Decree de dato December 6, 2005 (published in the Belgian Official Journal[1] of December 19, 2005) the installation of a Commission Energy 2030 was officialised: the Commission is made up of a number of Belgian and foreign experts who will carefully scrutinize the energy future of Belgium on a long term horizon (2030). In order to fulfil this task, it was decided to start from a quantitative, scientific base. Because of the long expertise in modelling and analysing of long term energy projections, the Federal Planning Bureau (FPB) was asked to take up the task of providing the Commission with the necessary input. This input will subsequently be studied by the Commission, as well as complemented with analyses and other activities executed in its bosom.

This report aims at gathering the work carried out by the FPB in the above framework. The heart of the analysis of the Belgian energy outlook to 2030 is provided by a set of energy scenarios. These scenarios provide a quantitative basis for the analysis of environmental, energy and economic challenges Belgium will be faced with in the coming years. Doing so, the analysis gives a valuable input to the report the Commission Energy 2030 has to deliver to M. Verwilghen, the federal Minister of Energy.

However, numbers do not tell the whole story and modelling tools have their limitations. Consequently, this quantitative analysis needs to be (and is in most cases) complemented and enlarged by additional analyses carried out by experts within the Commission or by other relevant studies. All the more so that, given the strict timing of the study, only a limited number of energy policy options and environmental or economic challenges have been examined in detail. The FPB is fully aware of these limitations. As such, the focus of the analysis is put on policy options in the power generation sector, as was specifically requested by the Commission Energy 2030[2].

In this overall context, it is worth noting that, in parallel with this study, the FPB has completed another study for M. Tobback, the federal Minister of Environment. The principal objective of this study is to elaborate on and analyse greenhouse gas (GHG) emission reduction scenarios in Belgium to 2020 and 2050. This study was conceived in the light of the international preliminary climate discussions in which Belgium is involved for the period after 2012 as new commitments have to be formulated for this period. Belgium has expressed its wish to properly prepare itself for these new discussion rounds and wants to secure itself by quantitatively estimating the consequences different GHG emission reductions have on an environmental and socio-economic level.

Main differences between the two studies (the present one and the study for Minister Tobback) can be found in the divergence in time horizon (2030 vs. 2020 for the energy outlook) and the general framework that is used to perform the analyses. The latter can be shown by two illustrating examples:

- While the present study, on the specific request of the Commission Energy 2030, investigates some options concerning a nuclear come-back, the study for the Minister of Environment precludes the use of nuclear energy and subscribes itself within the legal framework of the Law holding the progressive phase-out of nuclear energy for industrial electricity production;
- The perspective concerning emission reductions followed in both studies is different. The present study chooses to look at it on a national stand-alone basis and to deal with energy related CO_2 emissions only: Belgium needs to reduce its energy CO_2 emissions by 15% and 30% compared to the CO_2 emissions achieved in the year 1990. The study for Minister Tobback, on the other hand,

1 *Belgisch Staatsblad, Moniteur Belge, Belgisches Staatsblatt*

2 This choice results also from the limitations of the model to cope, in an exhaustive manner, with the cost impacts of specific options in the demand side.

subscribes itself in a European system that leads to equalisation of marginal costs of the reduction constraint imposed on all GHG by 2020.

At the start of the study, it is important to pinpoint that a number of hypotheses as well as policy scenarios and variants were defined by the Commission Energy 2030 in collaboration and after discussion with the DG Energy from the FPS Economy, SMEs, Self-Employed and Energy and with the Federal Planning Bureau (FPB). As such, decisions on potentials of renewable energy sources, deployment of nuclear energy and carbon capture and storage were debated and decided on within this working group.

The present report starts with a short description of the PRIMES model, the model that was used in order to generate the quantitative results, and the scenarios discussed (chapter II), and by the main hypotheses used for the analysis (chapter III.A). After that, results of the baseline (or reference scenario) are being described (chapter III.B), followed by the outcome of a price sensitivity analysis (chapter IV). Next, a number of alternative scenarios are presented and analysed in chapter V. Chapter VI contains the main conclusions.

II. Methodology

A. The PRIMES model

In this study, the PRIMES model is used in order to quantitatively examine the energy outlook of Belgium in the period 2005-2030. For the analysing of PRIMES projections, one starts from a baseline scenario in which recent policy and current trends are being taken up. Next to the baseline, sensitivity analyses and/or policy scenarios are defined in order to study the effect of uncertainty existing around one parameter and scrutinize the impact of a different policy on the national energy system respectively.

PRIMES then generates long term energy and emissions' projections (horizon 2030) on the supranational (European) and national (e.g. Belgian) level. For a number of years, European Commission's DG TREN makes use of the PRIMES model in order to elaborate energy projections for the EU25, next to individual nation's projections. The PRIMES model is being developed and managed in the University of Athens (NTUA) by a team under the coordination of Prof. P. Capros. For some of the hypotheses, the NTUA makes use of the output of other universities or scientific institutions, like for example international energy prices (on the basis of POLES, supplemented by the world energy model PROMETHEUS and revised by a number of experts) and the modelling of the transport activity (on the basis of SCENES, a European transport network model).

PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the European Union (EU) member states. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match the quantity consumers wish to use. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships. PRIMES can be run with perfect foresight[3]; the model is behavioural but also represents in an explicit and detailed way the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market economics, industry structure, energy/environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing. PRIMES is a general purpose model. It is conceived for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies.

More information about the PRIMES model is provided in annex F. A more elaborate description of the PRIMES model can be found in "*The PRIMES Energy System Model, Summary Description*" by NTUA[4].

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[3] PRIMES is run with perfect foresight in this study.

[4] Downloadable via http://www.e3mlab.ntua.gr/, the model is run at NTUA.

B. The scenarios

1. Baseline

The baseline (or *reference scenario*) simulates current trends and policies as implemented in Belgium by the end of 2004. While informing about the development of policy relevant indicators such as the renewables shares in 2010, the baseline does not assume that indicative targets, as set out in the Directives, will be necessarily met. The numerical values for these indicators are outcomes of the modelling; they reflect implemented policies rather than targets. This also applies for CO_2 emissions. The baseline thus describes what the Belgian energy future could look like if no additional actions are taken.

In addition to its role as reference projection, the baseline also serves as a standard for sensitivity analyses and alternative scenarios, next to which they can be placed in order to measure the impact of a change in one exogenous variable or a different policy setting respectively.

2. Sensitivity analysis

Sensitivity analyses study the effect one single exogenous parameter can have on the energy system. Traditionally, this single exogenous parameter is a variable around which a lot of uncertainty exists, like e.g. international fuel prices or the growth of the (inter)national economy. With the exception of this one parameter, the baseline setting is not touched upon and hypotheses and presumed trends are identical to the ones reported in the baseline.

This study performs sensitivity analyses on fuel prices.

3. Alternative or policy scenarios

Policy or alternative scenarios are different from sensitivity analyses in that the former do entail a new policy setting and philosophy. Not a single one, but a whole mindset of variables is changed compared to the baseline. Such a setup makes it possible to examine -among other things- the achievement of energy or environmental policy targets. Issues such as renewable energy sources, nuclear energy, energy efficiency, alternative fuels in transport or climate change can then be studied with reference to the baseline.

The evolution of the Belgian energy system described in the baseline accounts for policies and measures implemented by the end of 2004. Needless to say that additional policies and measures having an impact on energy developments are likely to occur in the coming years in order to cope with three important issues: climate change, the security of our future energy supply and the competitiveness of our economy. These policies and measures can either be additional or constitute changes in current energy policy orientations.

This study is not aimed at covering all possible alternatives in terms of energy policy options or climate change strategies. Its objective is to shed light on the above issues through a limited set of alternative or policy scenarios that nevertheless cover a large range of possibilities. As regards the climate change issue, all alternative scenarios introduce constraints on energy related carbon dioxide emissions at the horizon 2030 (CO_2 is the principal GHG in Belgium). Further to discussion within the Commission Energy 2030, it was decided to consider two targets, namely reductions in energy related CO_2 emissions of 15% and 30% in 2030 from 1990 levels. Concerning specific policy options, the Commission Energy 2030 has asked to examine the repercussions that a come-back of nuclear on the electricity scene would generate for Belgium. Finally, given the large uncertainty associated to the commercial availability and technical feasibility of the promising CO_2 emission reduction technology of carbon capture and storage, it was proposed to subdivide the scenarios into two categories: those that include this technology as a possible option and those that do not.

III. Baseline

For the baseline, the reference scenario that was published by the DG TREN in 2006[5] and that also includes Belgian projections is being used. The same reference scenario was also chosen as baseline in the study for Minister Tobback (cf. Introduction). This baseline gives a coherent view of the long term evolution of the Belgian energy system. It is based on a number of hypotheses on the demographic and economic context (activity of the sectors, international fuel prices …) and on the existing policy measures on energy, transport and environment. Recent trends and structural changes are assumed to continue. This baseline thus enables to pinpoint the long term challenges in the fields of energy, transport and environment, as well as to identify the actions that have to be taken in order to solve potential problems. The baseline then examines what could happen if no new action in the field of energy, climate or transport is installed. It also allows to evaluate the impact of new propositions or alternative policy measures on the evolution of the Belgian energy system and its emissions[6].

A. Hypotheses

The hypotheses used relate to a number of variables like international fuel prices, the economy, demography, the transport activity and the implemented policy measures. They are described briefly below. More information, in particular on assumptions that are not Belgium specific but relate to the European policy context or international framework, can be found in the DG TREN publication of May 2006.

1. International fuel prices

a. Recent evolution

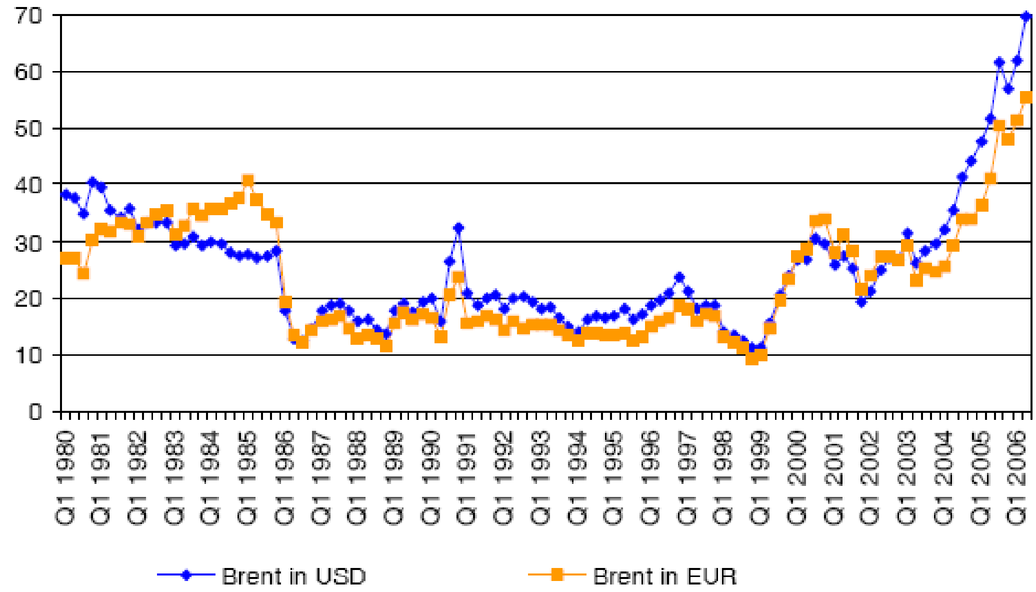
Over the last years, the international energy prices have embarked on an impressive growth path. The prices of oil are a good example[7]. Starting in the mid eighties until the end of the nineties, the Brent crude oil price fluctuated around 20 dollars per barrel. By the turn of the century, this situation changed drastically. For the first time in years, the price of the Brent reached a level of more than 30 dollars per barrel. In 2002 the situation looked like it was going to normalize, but this turned out to be an illusion. The price of crude oil continued its upward journey to reach record heights in 2005 of 55$. Today, values of 70$ per barrel are common.

5 European Commission, Directorate-General for Energy and Transport, *European Energy and Transport, Trends to 2030-update 2005*, prepared by NTUA with the PRIMES model, May 2006.

6 The PRIMES model focuses on energy related CO_2 emissions.

7 Furthermore they play the role of catalyst as oil and gas prices are coupled. In other words, the price of gas follows the evolution of the price of oil, although with some delay.

Figure 1: Brent oil spot prices in US dollars and euros per barrel



Source: Thomson Datastream

b. Forecasts

Given these recent sound fluctuations, the exercise of drawing up international energy price projections then becomes subject to a strong sense of insecurity (and disagreement) amongst the experts. To illustrate this point, a table is cited in which the long term projections for oil prices in nominal terms ($2000) according to a number of renowned sources are being given. The strongly diverging figures are telling.

Table 1: Comparison of long term oil price projections according to different institutions ($2000)

Source	2010	2020	2030
IEA	22	26	29
EIA	23.3	25.1	
EC	27.7	33.4	40.3
OPEC	19.3	19.3	
IEEJ	24	27	
CGES	20.5	15.1	

Source: IEA, World Energy Outlook 2004, p.529

c. Price forecasts used in the baseline

In order to make up the PRIMES' baseline, the hypotheses of the future fuel prices of figure 2 are being used. This figure is produced by the University of Athens (NTUA) with the use of POLES [8] and PROMETHEUS (also a NTUA model) and has been revised by a number of experts[9]. Assumptions on fuel prices are higher than the projections elaborated in the years before 2004 (see table 1). In fact, they take

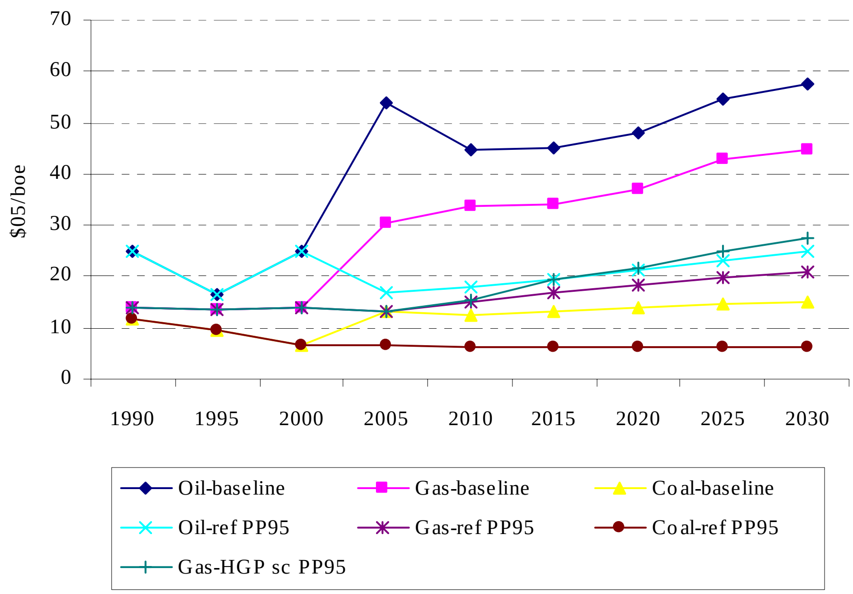
[8] The POLES model is a global sectoral model of the world energy system. The development of the POLES model has been partially funded under the Joule II and Joule III programmes of DG XII of the European Commission. Since 1997 the model has been fully operational and can produce detailed long-term (2030) world energy and CO2 emission outlooks with demand, supply and price projections by main region. The model splits the world into 26 regions. For the model design see the model reference manual: *POLES 2.2. European Commission, DG XII, December 1996.*

[9] For a more elaborate description on the modelling of oil and gas prices and the energy price outlook, see annex A.

into account the rather high price levels seen up to mid 2005 (when the modelling of the baseline started). For comparison, oil prices in this baseline are similar to those used in the DG RTD funded WETO-H_2 project (World Energy and Technology Outlook), but slightly higher than those used in the 2005 IEA World Energy Outlook. In order to take the uncertainty on the energy prices into account, the baseline is complemented with a price variant in which the oil and gas prices are considerably higher than in the baseline. This variant will be discussed in part IV (Sensitivity analysis).

In order to further underline the uncertainty associated with price forecasts, they are depicted together with the ones taken from a publication of the FPB on long term energy forecasts for Belgium which appeared in 2004, named PP95 ('refPP95'): oil and gas prices of the new run are obviously higher than the ones used in the PP95.

Figure 2: Comparison of international energy prices present baseline vs. scenarios in the PP95, 1990-2030 ($05/boe)



Source: NTUA (2005), PP95

refPP95: reference scenario in the PP95

HGP sc PP95: High Gas Price scenario in the PP95

2. Economic activity and demography

Next to hypotheses on price, hypotheses on the evolution of the national macro-economic situation and on demography are indispensable[10]. In table 2, absolute values of these indicators are given next to the annual growth rate of a couple of key variables of the Belgian economy. First, projections of the total number of people living on Belgian soil and the average household size for the period 2000-2030 are given, followed by the GDP and the average household revenue. After, value added is depicted, divided per (sub)sector. The table concludes with the hypotheses on the Belgian iron and steel production according to the 2 production processes: these are expressed in kton.

[10] Demographic and macroeconomic assumptions are described more extensively in NTUA (2005). The principal sources of these hypotheses are Eurostat, Global Urban Observatory and Statistics Unit of UN-HABITAT, Economic and Financial Affairs DG of the European Commission, Member States' stability programmes and the results of the GEM-E3 and PRIMES models.

Table 2: Macro-economic assumptions for Belgium, 2000-2030

	2000	2010	2020	2030	'90-'00	'00-'10	'10-'20	'20-'30
					Annual % Change			
Population (in Million)	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
Household size (inhabitants per household)	2.42	2.28	2.16	2.08	-0.6	-0.6	-0.5	-0.4
Gross Domestic Product (in MEuro'00)	247924	302858	370146	431665	2.2	2.0	2.0	1.5
Household Income (in Euro'00/capita)	12904	14887	17226	19396	1.8	1.4	1.5	1.2
SECTORAL VALUE ADDED (in MEuro'00)	231229	280534	339665	393763	2.0	2.0	1.9	1.5
Industry	46407	53371	62492	71457	1.7	1.4	1.6	1.3
iron and steel	2630	2714	2753	2757	-3.1	0.3	0.1	0.0
non ferrous metals	1028	1295	1436	1477	-0.4	2.3	1.0	0.3
chemicals	9553	12219	14866	17565	4.5	2.5	2.0	1.7
non metallic minerals	2134	2125	2455	2691	0.2	0.0	1.5	0.9
paper, pulp and printing	3268	3927	4672	5345	1.1	1.9	1.8	1.4
food, drink and tobacco	5137	6107	7011	7764	-0.1	1.7	1.4	1.0
engineering	16236	18257	21593	25114	2.4	1.2	1.7	1.5
textiles	2587	2232	2200	2194	-0.3	-1.5	-0.1	0.0
other industries	3835	4495	5507	6548	2.8	1.6	2.1	1.7
Construction	11622	13123	14985	16653	1.4	1.2	1.3	1.1
Tertiary	162581	203552	250349	292506	2.2	2.3	2.1	1.6
market services	62659	78140	96924	115204	3.6	2.2	2.2	1.7
non market services	52285	64005	75402	81171	1.5	2.0	1.7	0.7
trade	43967	57722	74027	92013	1.1	2.8	2.5	2.2
agriculture	3669	3685	3997	4118	3.7	0.0	0.8	0.3
Energy sector and others	8509	7936	8762	9553	2.0	-0.7	1.0	0.9
INDUSTRIAL PRODUCTION								
iron and steel (in ktn)	11636	11924	12040	11970	0.2	0.2	0.1	-0.1
integrated steelworks	8910	8376	8250	7846	-1.5	-0.6	-0.2	-0.5
electric processing	2726	3548	3790	4124	10.0	2.7	0.7	0.8

Source: NTUA (2005)

3. Transport activity

The projections for the transport activity are being depicted in table 3. The figures were generated by the SCENES model, a European transport network model. The transport of people as well as goods keeps growing in the period 2000-2030, but at a slower pace than in the period 1990-2000.

Table 3: Projections of the transport activity in Belgium, 2000-2030

	2000	2010	2020	2030	'90-'00	'00-'10	'10-'20	'20-'30
					Annual % Change			
Transport activity								
Passenger transport activity (Gpkm)	**135.8**	**155.6**	**173.1**	**189.1**	**2.0**	**1.4**	**1.1**	**0.9**
Public road transport	13.2	13.0	12.1	11.3	2.0	-0.1	-0.7	-0.6
Private cars	106.3	121.7	135.5	147.6	1.8	1.4	1.1	0.9
Motorcycles	1.0	1.2	1.4	1.5	-1.6	1.4	1.4	1.2
Rail	8.6	9.4	9.9	10.3	1.7	0.9	0.5	0.4
Aviation	6.5	10.0	13.8	17.9	8.2	4.4	3.3	2.6
Freight transport activity (Gtkm)	**65.9**	**78.9**	**92.1**	**103.5**	**3.2**	**1.8**	**1.6**	**1.2**
Trucks	51.0	62.1	74.0	84.2	4.1	2.0	1.8	1.3
Rail	7.7	7.8	8.0	8.1	-0.9	0.2	0.2	0.2
Inland navigation	7.2	9.1	10.2	11.2	2.8	2.3	1.1	1.0
Travel per person (km per capita)	13258	14742	16039	17218	1.7	1.1	0.8	0.7
Freight activity per unit of GDP (tkm/000 Euro'00)	266	261	249	240	1.0	-0.2	-0.5	-0.4

Source: SCENES model (information received from NTUA)
Gpkm: billion of passenger-kilometres
Gtkm: billion of ton-kilometres

4. Other hypotheses

Some other hypotheses were necessary in order to run the different scenarios.

- The number of degree-days is assumed to be fixed over the entire projection period and equals the number reached in the year 2000 (i.e. 2097 degree-days, 16.5 equivalent).
- The discount rate plays an important role within the PRIMES model. It is a crucial element in the determination of investment decisions by economic agents regarding energy using equipment. Three (real) 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 transport and household equipment, is set at 17.5%.
- The emission factors used in the calculation of energy emissions are the following (expressed in ton CO_2 per toe): 3.941 for coal, 2.872 for gasoline, 3.069 for gasoil and 2.336 for natural gas.
- The most recent energy balances used in order to draw up the baseline date from 2004.
- As regards renewable energy sources, the Commission Energy 2030 looked into the issue of achievable contributions in the Belgian energy system by 2030. Potentials were provided for wind power and solar photovoltaics (PV). These potentials represent reasonable maximum achievable “technical” potentials at the horizon 2030. These are the following: 2026 MW for on-shore wind, 3800 MW for off-shore wind and 10000 MW for solar PV. Supply cost curves are associated to all three power technologies to account for cost increases according to the level of capacity installed. These increases reflect e.g. additional costs related to less favourable production sites or additional investments required in the electricity grid to absorb the increase in renewable capacities. As far as biomass is concerned, no limit is put on its supply on the Belgian territory (total supply combines domestic production and imports). However, a supply cost curve is associated to biomass reflecting supply cost increases when the demand for biomass rises (see J. De Ruyck, *Renewable energies*, September 2006).

5. Greenhouse gases other than energy related CO_2

The present study only focuses on energy related CO_2 emissions (as PRIMES is an energy model). Energy related CO_2 emissions, however, are not the only damaging emissions in the biosphere: there also exist other greenhouse gases (GHG). Knowledge of the amount and appearance of those other GHG is crucial since general (international) objectives on emission reductions are defined in terms of total GHG. Next to energy CO_2, GHG consist of non-energy CO_2 (emitted through industrial processes, fugitive and waste), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (HFC, PFC and SF_6). Together, these GHG other than energy related CO_2 account for approximately 21% of the total, since energy CO_2 makes up 92% of the total of CO_2 emissions and total CO_2 emissions take up a share of 85.5% in the GHG (see National Climate Commission, *Fourth National Communication on Climate Change*, 2006).

It is also important to be more specific about what is meant by energy related CO_2 emissions in this study. According to the Eurostat statistical convention on which the PRIMES model is based, aviation bunkers are included in the final energy consumption of transport whereas maritime bunkers are not. Maritime bunkers are put into the export category of the energy balances. The rationale behind this choice comes from the fact that this consumption has, in most cases, no link with the economic activity of the country. Consequently, CO_2 emissions from aviation bunkers are included in the analysis whereas those from maritime bunkers are not. From an environmental perspective, the consumption of maritime bunkers is however crucial as it is a major contributor to climate change. In 1990, the base year for the Kyoto Protocol, maritime bunkers represented no less than 10% of total GHG emissions in Belgium (i.e. comparable to the contribution of agriculture). Furthermore, its consumption follows an increasing trend: + 80% between 1990 and 2004.

Both aviation and maritime bunkers are excluded from the scope of the Kyoto Protocol. Nevertheless, there is some question of them being part of the game in future GHG reduction commitments. The exclusion of maritime bunkers in the analysis should therefore be borne in mind when discussing the results of the different scenarios.

6. Policy context

The baseline includes agreed policies addressing economic actors as known by the end of 2004. It presumes that all current policies and those in the process of being implemented at the end of 2004 will continue in the future. However, in the baseline, it is not assumed that the indicative targets, as set out in various EC Directives, will necessarily be met. The numerical values for these indicators are outcomes of the modelling; they reflect implemented policies rather than targets.

- The establishment of an emission trading regime in Europe is included in the baseline assuming a permit price of 5 €'00/t CO_2 for those sectors covered by the EU Emission Trading Scheme (ETS).
- The baseline integrates effects from the restructuring of markets through the liberalisation of electricity and gas in the EU, which proceeds in line with EC Directives (e.g. decreases in producers' mark-ups and in regulated transport and distribution tariffs). Liberalisation is assumed to be fully implemented in the period to 2010.
- Concerning the use of biofuels in transport, it is assumed that Belgium will follow EU rules sooner or later. The impact of blending gasoline and diesel with biofuels on final consumer prices is assumed to be negligible, since higher fuel production costs will probably be offset by tax reductions scheduled to be implemented on these fuel blends.
- On transport, the baseline assumes that the targets agreed for 2008 with the car industry on the reduction of specific CO_2 emissions for new cars[11] are achieved without assuming a further strengthening of targets thereafter.
- The Law on the progressive phase-out of nuclear energy is taken up in the baseline. The baseline, in other words, takes into account the decommissioning of nuclear power plants once they turn 40,

[11] 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).

conform the Law on the progressive phase-out of nuclear energy for industrial electricity production which was consented on January 31, 2003[12].

- The system on green and heat certificates is part of the baseline. In agreement with the European Directive on the promotion of electricity generation from renewable energy sources, the Belgian Regions have decided to make use of green certificates. Concerning the combined heat and power (CHP), the Regions have fixed regional objectives in order to stimulate the production of electricity on the basis of CHP.

B. Results

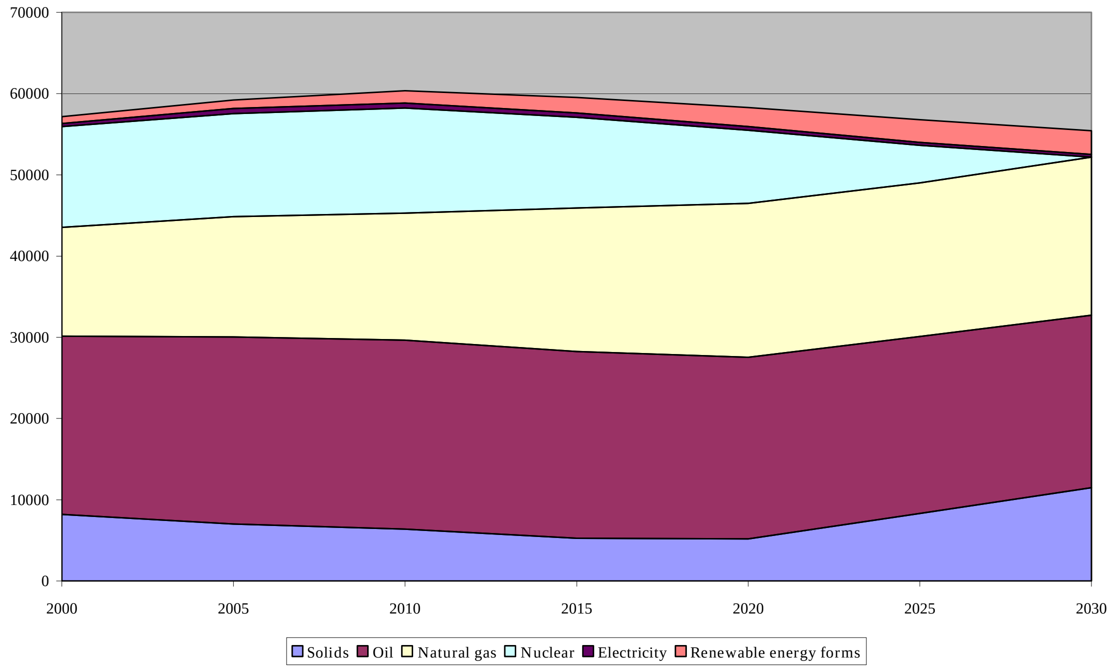
1. Primary energy demand

The primary energy demand (also referred to as *gross inland consumption* or *GIC*), an indicator that describes a nation's total energy consumption and that consists of primary production (energy sources that are exploited on the nation's soil, e.g. wind and hydro) and net import (energy sources that are imported by the country, e.g. oil), follows an inverse U-shaped path. In 2000, a total gross inland consumption (GIC) of 57 Mtoe is reached. After 2000 a slow growth is set in (0.5% per year) to reach a peak in 2010 of 60 Mtoe. During the period 2010-2020 the indicator declines at a rhythm of -0.3% annually, followed by a further decrease in the next decennium (-0.5% yearly). In 2030 the GIC reaches 55 Mtoe.

The evolution of primary energy demand should be interpreted with caution, though, at least at the end of the projection period when the share of nuclear decreases steadily. The decreasing trend does not only reflect overall improvements in energy efficiency (both at final energy demand level and energy transformation level) but also the impact of the statistical convention used since many years for nuclear heat. According to this statistical convention, an average efficiency of 33% is given to nuclear power plants in order to calculate the primary energy requirements corresponding to nuclear electricity. Given that current and future fossil fuel based power plants as well as those using renewable energy sources have conversion efficiencies considerably higher than 33%, the progressive retirement of nuclear plants translates into comparatively lower primary energy inputs.

[12] Belgian Official Journal (Belgisch Staatsblad, Moniteur Belge or Belgisches Staatsblatt), February 28, 2003, pp. 9879-9880. This law was already announced in the governing agreement of July 7, 1999.

Figure 3: Composition of the primary energy demand, baseline (ktoe)



Source: PRIMES

Next to the evolution of the GIC, it is also interesting to study its composition. Oil is head of the class during the entire period. In 2000, the dominance of oil is crystal clear, in 2030 it still ranks first in the fuel order, but the relative relations between the different energy sources have shuffled. Especially the "dash for gas" is threatening the strong position of oil, leading to an almost equal share of the two fuels in the GIC at the end of the projection period (oil: 38%, natural gas: 35%).

From 2015 onwards, nuclear energy is being phased out because of the law stipulating the progressive retirement of nuclear plants after a lifetime of 40 years[13]. Whereas the gross inland consumption of nuclear energy still reaches 12 Mtoe in 2000, it disappears from the GIC scene by 2030. Solid fuels start off from a position of 8 Mtoe in 2000, then loose weight to only reach 5 Mtoe in 2015, but after that, they start to rise again towards the end of the projection period to arrive at 11 Mtoe. Together with natural gas, these solids fill up the gap left by the nuclear void.

Renewable energy sources follow a spectacular growth path, mainly during the first projection period (2000-2010) when their consumption climbs by 6% per year. In 2030, it then reaches a level of approximately 3 Mtoe.

Still remaining: a small level of electricity that is being imported[14]. This imported electricity sharply increases during the first decennium (2000-2010), to decrease again in the 2 subsequent periods. In the end, a level is obtained that comes close to the level at which it all started (325 ktoe).

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13 See the law on the progressive phase-out of nuclear energy for industrial electricity production, Belgian Official Journal, February 28, 2003.

14 The new version of PRIMES (that is used in order to perform the present analysis) integrates a country-by-country modelling which focuses on the dynamics of the energy system within a country, while considering trade in fuels between countries. The analysis has fully taken into account the economic opportunities of electricity and gas trade within the EU Internal Energy Market as well as the engineering and operating constraints of the European transmission system as this evolves in relation to the completion of new interconnectors as planned in the context of the Trans-European Energy Networks. The extension and stabilization of the UCTE system has also been considered. The endogenous treatment of electricity and gas imports and exports is a new feature of the PRIMES model (PRIMES ver.2005).

The table below gives an overall picture of the evolution of the primary energy demand in the baseline. It also describes the evolution of several indicators, namely the energy intensity of the GDP (i.e. GIC divided by the GDP), the primary energy consumption per capita and the import dependency (i.e. the share of net imports in the GIC).

Table 4: Primary energy demand and related indicators

	2000	2010	2020	2030	10//00 (%)	20//10 (%)	30//20 (%)
Gross inland consumption (Mtoe)	57.2	60.4	58.3	55.4	0.5	-0.3	-0.5
- Solids	8.2	6.4	5.2	11.5	-2.5	-2.1	8.3
- Oil	21.9	23.4	22.4	21.2	0.6	-0.4	-0.5
- Natural gas	13.4	15.5	18.9	19.5	1.6	1.9	0.3
- Nuclear	12.4	12.9	9.0	0.0	0.4	-3.6	-
- Electricity	0.4	0.6	0.4	0.3	5.2	-3.2	-3.2
- Renewable energy forms	0.9	1.5	2.3	2.9	5.9	4.4	2.2
Energy intensity of the GDP (toe/M€'00)	230.6	199.3	157.5	128.4	-1.4	-2.3	-2.0
GIC/capita (toe/inhabitant)	5.6	5.7	5.4	5.1	0.2	-0.6	-0.7
Import dependency (%)	77.7	78.2	82.4	95.3			

Source: PRIMES
//: average annual growth rate

2. Production of electricity

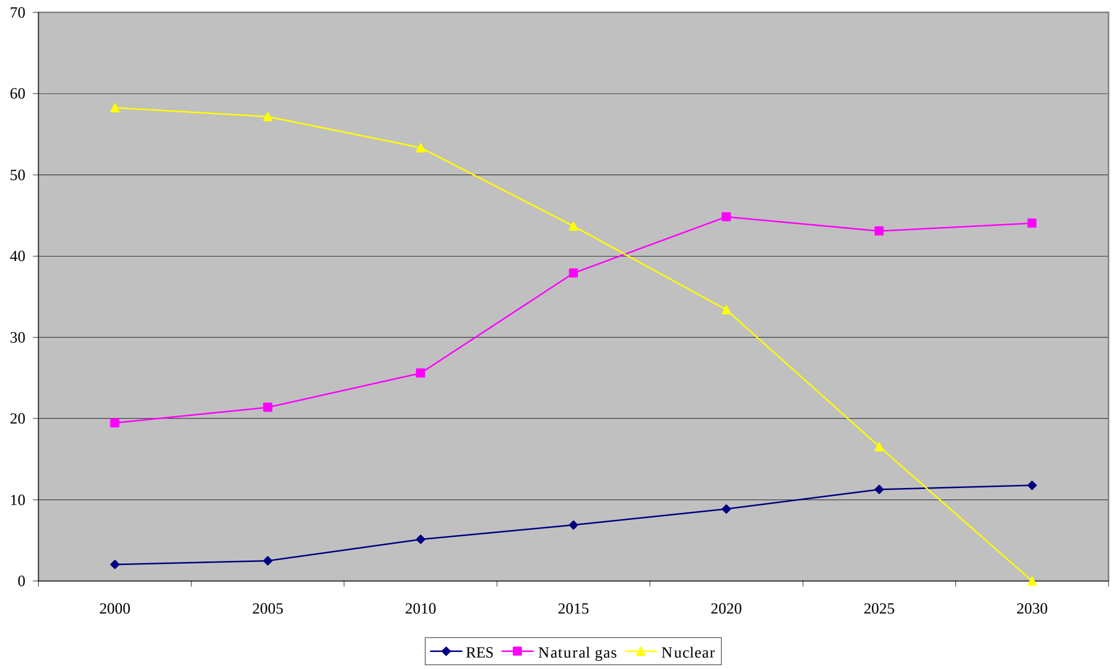
A second indicator of interest is the generation of electricity. As for the previous indicator, we first look at the evolution of the total production, and then we turn to the structure or composition of this parameter.

The production of electricity is mounting throughout the entire projection period. During the first period (2000-2010) it increases at 1.3% per annum, reaching a total of 94 TWh by the year 2010 (in 2000, it was still 82.6 TWh). During the next decennium this increase keeps pace and the production of electricity grows at 1.1% per annum. It is only in the last period that the pace of growth will slow down and reach 0.7% per year: in 2030 then, 112 TWh of electricity will be generated.

The generation capacity is provided by nuclear power stations, renewable units (especially hydro and wind) and thermal production units (including biomass). In 2000, the supremacy of nuclear electricity is still obvious: 48 TWh is being generated by nuclear power stations. Thermal units take up the rest of the national production (34 TWh), as renewables only stand for 0.5 TWh. At the end of the projection period, this situation changes considerably. Because of the nuclear phase-out, nuclear power disappears from the electricity scene, which, in turn, forces the thermal units to catch up for the difference: in 2030 they will account for 106 TWh. Generation through renewables will also increase: spectacularly during the first period ('00-'10) at a rate of 20,4% per year; followed by more modest percentages (3,1% and 4,1% per annum respectively) in the next decennia. In 2030, renewables will provide 6 TWh of electricity.

Figure 4 complements the above analysis per category of power production units; it shows the evolution of electricity generation in the baseline according to the different energy forms, namely nuclear energy, natural gas and RES (incl. biomass). The balance gives the share of coal.

Figure 4: Composition of the electricity generation, baseline (%)



Source: PRIMES

The evolution of the electricity production and fuel mix described above can be complemented by the presentation of several indicators that enlarge the scope of the analysis.

Table 5: Indicators related to the production of electricity in the baseline

	2000	2010	2020	2030
Efficiency of thermal electricity production (%)	37.1	42.1	55.1	52.6
Net import ratio [1] (%)	4.97	7.10	4.74	3.27
% of electricity from CHP	7.9	14.3	18.5	18.2
Share of non fossil fuels in electricity production (%)	60.3	58.5	42.3	11.8
Installed power capacity (GW)	14.9	16.8	19.6	23.0
Carbon intensity (t CO_2/GWh)	246	212	213	395
Electricity (final demand) per capita (kWh/capita)	7566	8618	9265	9583

Source: PRIMES
[1]: Net import of electricity divided by total electricity supply.

The evolution of the average efficiency of thermal electricity production is closely related to the technology mix. The remarkable increase in 2000-2020 has to do with the investments in combined cycle gas turbines (CCGT) that are characterised by high conversion efficiencies (close to 60% for new generation), while the slight decrease in 2020-2030 comes from the progression of supercritical coal power plants in the power technology mix; this technology has a lower conversion efficiency than CCGT (around 50%).

The significant penetration of coal based power plants beyond 2020 also helps to explain the jump in the carbon intensity and in the CO_2 emission index in 2030.

The share of non fossil fuels in electricity production combines two elements: nuclear on the one hand, renewable energy sources on the other. The share of nuclear electricity decreases steadily further to the decommissioning of nuclear plants after an operating lifetime of 40 years. On the contrary, the share of renewable energy sources goes up: representing only 2% in 2000, it reaches almost 12% in 2030. Similarly, the share of CHP in electricity generation goes up steadily up to 2020 after which it stabilises at 18% for the next 10 years.

The installed power capacity increases by 54% in 2000-2030. This increase is required to meet the growth in electricity consumption. However, the power capacity increases at a higher pace than electricity demand. One reason is the decrease in net electricity imports; another is the decrease in the average utilisation rate of electrical capacities: in 2000, it was close to 63%; in 2030, it is estimated to be 55%[15]. The evolution of electricity imports and exports is determined endogenously by the model[16] given a certain number of assumptions regarding the declared strategy of the neighbouring countries. The progressive decrease in net electricity imports in 2005-2030 results, among other things, from the decline of surplus capacities in France and Germany. In 2030, net electricity imports are projected to be slightly less than 4 TWh.

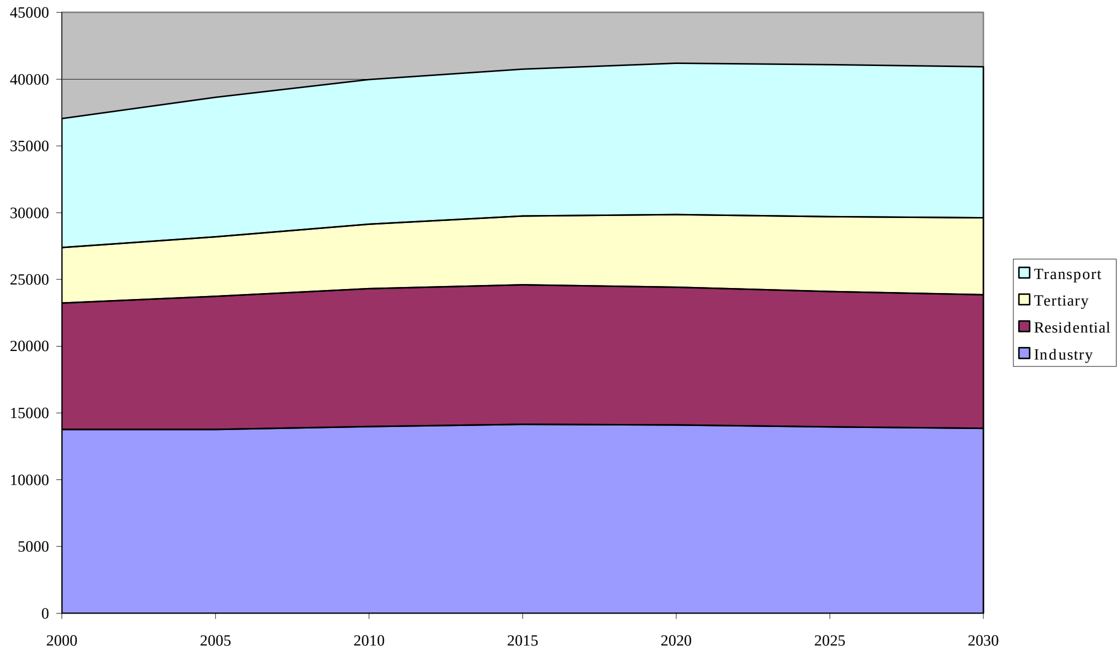
3. Final energy demand

The final energy demand is the demand for the different end forms of energy (e.g. gasoline) by different consumers (e.g. the transport sector). Traditionally, one makes a distinction between the final energy demand by sector (or consumer) and the final energy demand by fuel (or energy form).

[15] The decrease in average utilisation rate (i.e. generation/(installed capacity x 8760 hours)) is due to the higher share of power capacities based on intermittent energy sources.

[16] The new version of PRIMES used for this scenario analysis includes a set of improvements notably in the electricity and steam sub-model where optimal flow analysis and investment expansion over a set of regional electricity markets are explicitly modelled, see also footnote 6.

Figure 5: Sectoral composition of final energy demand, baseline (ktoe)



Source: PRIMES

Taking a look at each sector separately we can conclude that the largest end consumer of energy in 2000 is also the largest consumer in 2030: the industry is consuming the biggest part of the final energy demand. Nevertheless, it can be noticed that the final industrial energy demand in 2030 shows a status quo with demand in 2000. This is due to the energy intensive industries that constantly diminish their final energy demand.

During the first decennium, the residential sector gains territory: every year, its final energy demand increases with 0.9% on average. After 2010, final demand stabilizes and between 2020 and 2030, a slight decrease in final energy demand can be noted.

The transport sector, on the other hand, continues to satisfy her energy appetite by an enlarged consumption. Its final demand grows in the period 2000-2010; it keeps on growing in 2010-2020 but at a slower pace and finally stabilizes in the last decennium. This causes the transport sector to maintain its second place in the final energy consumption (11 Mtoe in 2030).

The tertiary sector consumes the least energy, but shows the strongest growth. During the 3 decennia under consideration, it grows on average at 1.5%, 1.2% and 0.6% per annum, reaching a final energy demand of 6 Mtoe in 2030.

The table below describes the evolution of the final energy consumption in each sector, the changes in the sectoral share in the total final energy demand and the increment/decrease in consumption between 2000 and 2030 (in ktoe and in %).

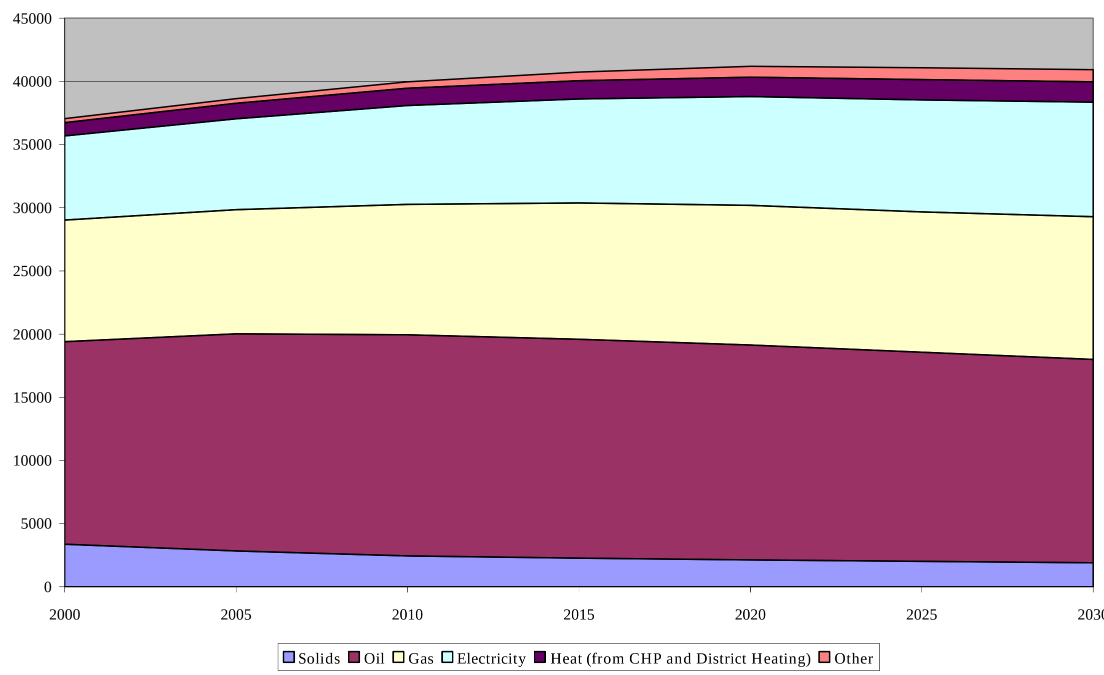
Table 6: Evolution of the final energy demand in the baseline (per sector)

	2000		2010		2020		2030		Increment 2000-2030	
	ktoe	share	ktoe	share	ktoe	share	ktoe	share	ktoe	%
Industry	13769	37%	13993	35%	14102	34%	13851	34%	82	1%
Residential	9465	26%	10311	26%	10314	25%	10008	24%	543	6%
Tertiary	4158	11%	4848	12%	5446	13%	5763	14%	1605	39%
Transport	9662	26%	10816	27%	11336	28%	11308	28%	1645	17%
Total	37055		39968		41197		40930		3876	10%

Source: PRIMES

Next to a subdivision of the final energy demand into consuming sectors, there also exists a subdivision in fuels.

Figure 6: Fuel composition of final energy demand, baseline (ktoe)



Source: PRIMES

Taken this subdivision, we see that oil is the fuel that is the most consumed. Although its pole position, the demand for oil does not change much during the whole projection period: the consumption level in 2000 is identical to the level in 2030 (16 Mtoe in 2000 and in 2030) causing its relative share in the final energy demand to shrink from 43% down to 39%.

Natural gas and electricity, on the other hand, are in for a climb: natural gas reaches 11 Mtoe in 2030, electricity 9 Mtoe. Both of them are able to raise their relative share during the projection period: natural gas climbs from 26 to 28%, electricity grows from 18 to 22%.

Solid fuels have become much less popular and plunge from 3 Mtoe in 2000 to somewhat less than 2 Mtoe in 2030, leading to a relative share of 5% of final demand. The decrease is mainly due to the iron and steel sector (production decreases in integrated steelworks).

Heat use increases fast: in 2000, heat demand was only 1 Mtoe, in 2030, it already climbed up to 1.6 Mtoe.

The consumption of RES more than triples in the period 2000-2030. The major share of the increase can be subscribed to biofuels: its demand reaches slightly more than 700 ktoe in 2030, which equals 8% of total gasoline and diesel consumption in transport.

The table below describes the evolution of the final energy consumption per fuel, the changes in the share of each fuel in the total final energy demand and the increment/decrease in consumption between 2000 and 2030 (in ktoe and in %).

Table 7: Evolution of the final energy demand in the baseline (per fuel)

	2000		2010		2020		2030		Increment 2000-2030	
	ktoe	share	ktoe	share	ktoe	share	ktoe	share	ktoe	%
Solids	3373	9%	2453	6%	2143	5%	1907	5%	-1466	-43%
Oil	16038	43%	17497	44%	17003	41%	16091	39%	54	0%
Nat. Gas	9615	26%	10312	26%	11052	27%	11300	28%	1686	18%
Electricity	6667	18%	7822	20%	8597	21%	9052	22%	2385	36%
Other	1362	4%	1883	5%	2402	6%	2580	6%	1218	89%
Total	37055		39968		41197		40930		3876	10%

Source: PRIMES
"Other" includes heat and RES

4. Energy related CO_2 emissions

Using different forms of energy to satisfy the final energy demand is not an action without consequences: the consumption of most of these energy vectors initiates a harmful effect on the environment in the form of greenhouse gas emissions. A national energy consumption pattern as described in the previous paragraphs will have a negative impact in terms of polluting greenhouse gas emissions. In the output of the PRIMES run, only the energy related CO_2 emissions get calculated. In what follows, their evolution is discussed.

In the year 2000, a total of 114.7 Mt of CO_2 emissions was registered. Every year this amount grows further, first rather slowly (0.1% per annum in the period 2000-2020), then very fast (at a yearly rate of 1.8% in the period 2020-2030). Remarkable is that the biggest CO_2 pollutant in 2000 (namely, industry) passes on her bad reputation to the sectors of electricity production and transport, which, from 2020 onwards, take the lead in polluting. The electricity production emits 23.5 Mt of CO_2 in 2000, a figure which more than doubles by 2030 (to 52.4 Mt). Transport takes in the second place with 31.3 Mt in 2030, while industry still reaches a value of 23.5 Mt in 2030, meaning a decrease compared to the year 2000 (when the level was up to 29.1 Mt). In 2030, households exhaust 18.3 Mt in CO_2 emissions, while the tertiary sector is the smallest polluter at 10.2 Mt of CO_2 emissions. The residential sector declined its emissions by 1.7 Mt compared to 2000, the tertiary sector did the opposite and gained 2 Mt.

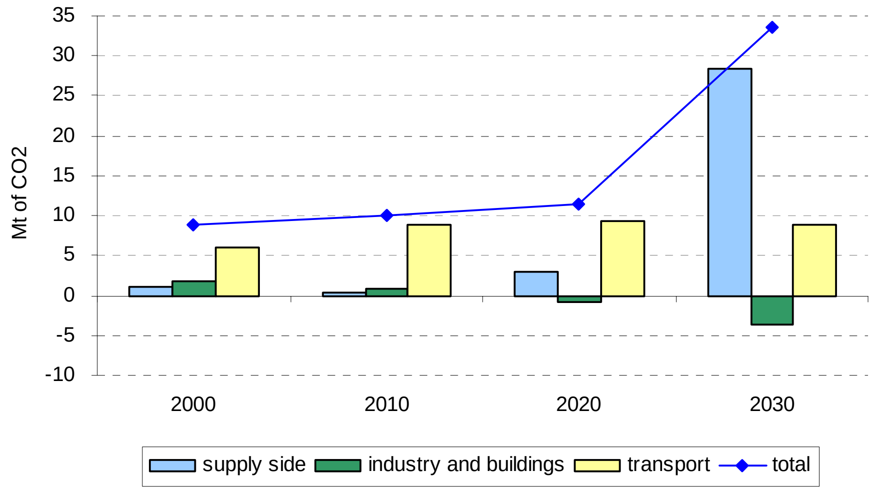
In the context of the Kyoto Protocol and of current discussions on reduction targets for the post-2012 period, it is also useful to present the evolutions described above in another perspective, namely in comparison with 1990 emission figures (1990 is the base year for CO_2 emissions in the Kyoto Protocol). The graph below shows the differences in CO_2 emissions compared to 1990, by sector category and for the total energy-related CO_2 emissions. The key messages are the following:

Given the current policies and measures and assumptions underlying the baseline, total energy-related CO_2 emissions will increase by 32% in 2030 compared to 1990. The increase is particularly sharp beyond 2020, while CO_2 emissions are in the range of 8 to 11% above the 1990 level in the period 2000-2020.

Up to 2020, the increase mainly comes from the transport sector. By contrast, CO_2 emissions from industry and buildings (i.e. residential and tertiary sectors) decline steadily.

Beyond 2020, the supply side (mainly the power sector) provides the bulk of the increase in total CO_2 emissions. This trend results from significant investments in coal-fired power plants. On the other hand, the emissions from the transport sector decrease slightly.

Figure 7: Changes in CO_2 emissions compared to 1990 levels



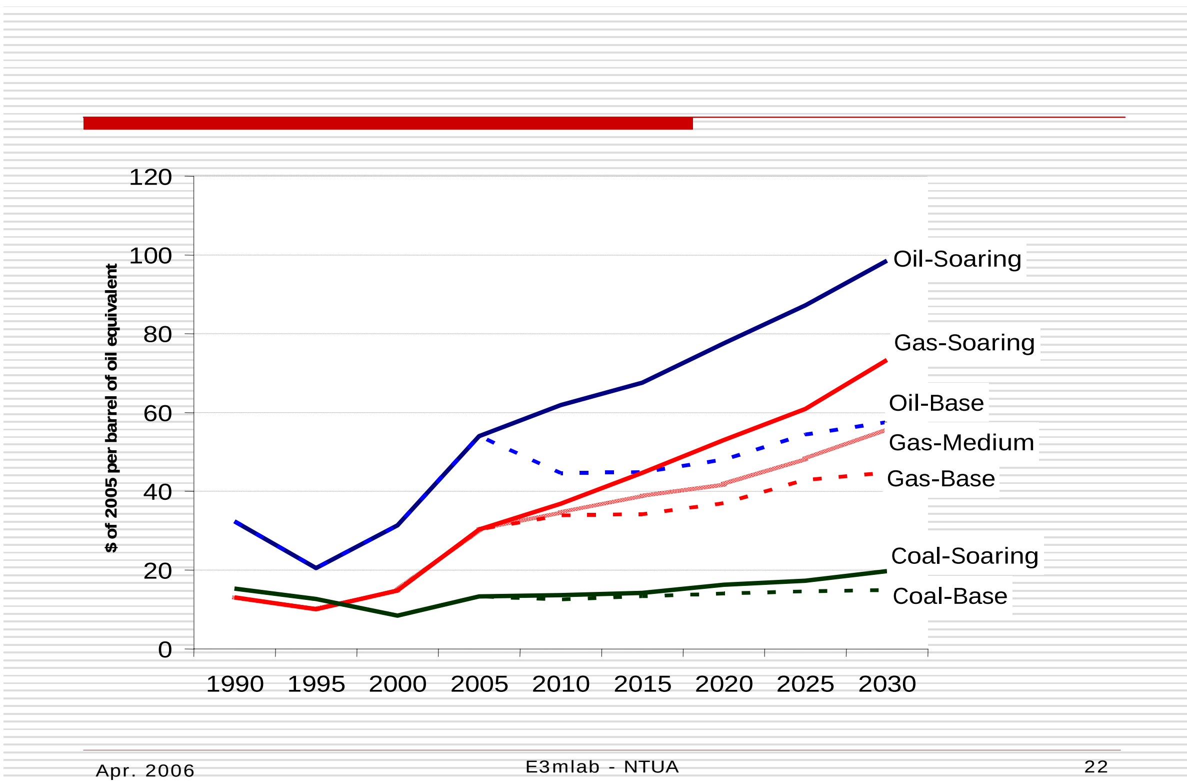
Source: PRIMES

Supply side = power and steam sector + other energy transformation sectors

IV. Sensitivity analysis

Next to the baseline, a sensitivity analysis is performed on “international energy prices”, more specifically, on the prices for oil, gas and coal. In this analysis, a coupled evolution of oil and gas is assumed. The rationale behind this price analysis is that in this ‘higher-oil-higher-gas’ variant energy prices are pushed upwards by a strong economic growth in China, India and other Asian countries in development (+10% compared to the baseline) and oil and gas reserves are less abundant than they are presumed to be in the baseline. In other words, oil and gas reserves will be depleted sooner, which will initiate a rise in prices. The ‘alternative’ (-Soaring) and ‘baseline’ (-Base) prices for oil, gas and coal are depicted in figure 8.

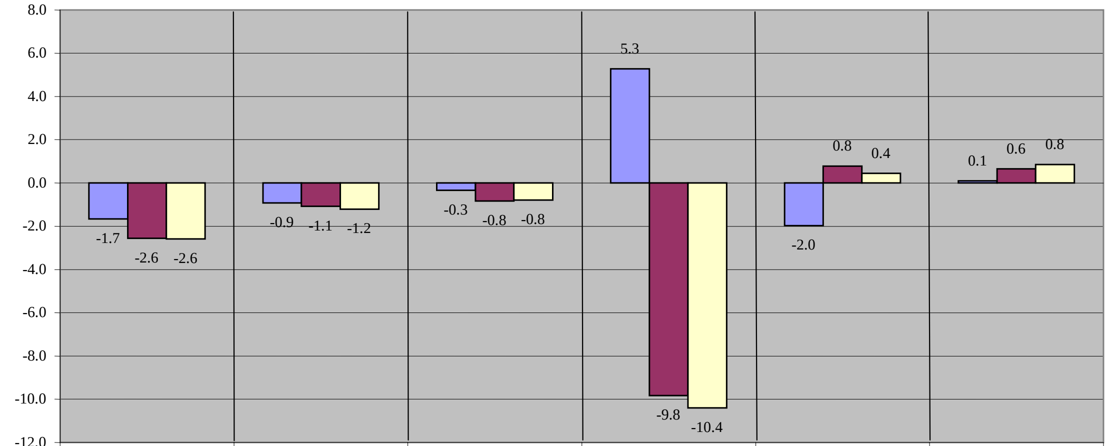
Figure 8: Comparison forecasts international energy prices for baseline and price variants (1990-2030)



Source: NTUA

The higher oil and gas prices assumption will have immediate repercussions on the indicators described for the baseline as common economics dictate that a price rise will cause a decrease in demand. A decrease in demand (a lower consumption) entails a decrease in emissions, except when a ‘fuel switch’ takes place which can upset the situation. This fuel switch occurs when another, more competitive fuel (rendered more competitive because of the new price situation) will take the place of a more expensive fuel (oil or gas), but that this cheaper fuel in itself is more polluting (e.g. coal). Even in the generation of electricity, this fuel switch caused by higher prices can play: the electricity fuel mix will change in the sense that coal will, where possible, take the place of the more expensive fuels. Some parameters that will experience an impact from the higher fuel prices are shown in the graphs below. On the X-axis, the evolution throughout the projection period is depicted; on the Y-axis, the difference with the baseline expressed in percentages is being shown.

Figure 9: Primary energy related indicators for the higher-oil-higher-gas variant, evolution, difference with the baseline (%)



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
2010	-1.7	-0.9	-0.3	5.3	-2.0	0.1
2020	-2.6	-1.1	-0.8	-9.8	0.8	0.6
2030	-2.6	-1.2	-0.8	-10.4	0.4	0.8

Source: PRIMES
(*): expressed in percentage points

Figure 9 presents a couple of general energy indicators. Starting with the net import of energy, this will, due to higher fuel prices, shrink. In 2030, a decrease in net imports of 3% can be noted, which in fact hides 2 opposite movements: on the one hand, the net imports of oil and gas will shrivel (respectively with -6% and -11% in 2030); on the other hand, more coal will be imported (a rise of 22% in 2030). Summed up, this leads to a total impact in net imports of -3%. The decrease in net imports will have an influence on the primary energy demand, which will in its turn slightly decline (with -1.2% in 2030). This modest decrease is due to the partial substitution of the net imports by an increase in primary production (more specifically, in renewable energy sources).

The price variant will lead to a complementary decrease in the energy intensity of the GDP (in the baseline, one could already notice a yearly decline in the energy intensity) and it will bring along a lessened national dependence on strategically sensitive import.

The need for gas declines as a result of the less competitive prices: by the end of the projection period, gas demand decreases by more than 10% compared to the baseline.

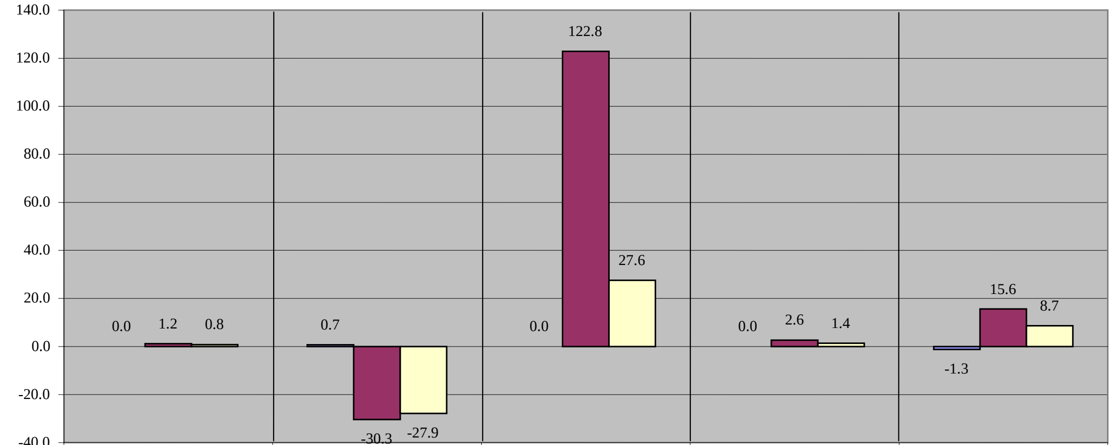
CO_2 emissions are lower in 2010, but carefully climb above the baseline level in 2020 and 2030 (0.8% in 2020 and 0.4% in 2030). This is the result of the emissions being subject to an opposite movement: on the one hand, a lower energy consumption which puts a downward pressure on the emissions (the dominant effect in 2010), on the other hand, the higher consumption of coal in the price variant replacing the expensive gas. Since coal emits more CO_2 per unit output than gas does, this movement pulls the emissions back up again. The relative strength of these effects changes through time and it is only from 2020 onwards that the use of more polluting coal gets the upper hand and that CO_2 emissions are slightly higher compared with the baseline.

Finally, we see that the share of renewable energy sources in the gross national consumption is slightly higher than the baseline level, in 2010 only 0.1 percentage points, in 2020 and 2030 the difference boils down to 0.6 and 0.8 percentage points respectively.

2. Production of electricity

The second figure contains information on the electricity production. For the electricity generation, five parameters are being examined, namely the carbon free share in power generation, the share of gas and coal, power capacity expansion and CO_2 emissions per MWh produced.

Figure 10: Electricity production related indicators for the higher-oil-higher-gas variant, evolution, difference with the baseline (%)



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
2010	0.0	0.7	0.0	0.0	-1.3
2020	1.2	-30.3	122.8	2.6	15.6
2030	0.8	-27.9	27.6	1.4	8.7

Source: PRIMES

(*): expressed in percentage points

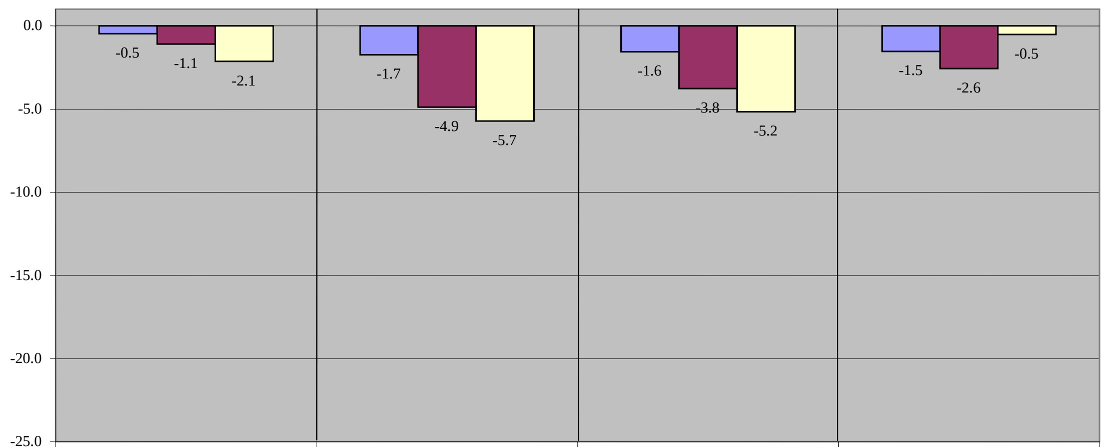
The carbon free share is somewhat higher than in the baseline (0.8 percentage points in 2030). This increase is entirely due to a larger use of renewable energy sources in electricity generation since the nuclear branch, as in the baseline, is gradually being phased out. In 2030, the share of the renewable energy sources in the electricity production in the price variant reaches 12%.

As could be expected, the higher price of gas translates into a lower use of this fuel in the generation of electricity, a void that for the major part is being filled up by coal. The use of coal is particularly high in 2020: it has more than doubled compared to the baseline. These changes in fuel mix lead to an electricity production that emits more CO_2 per MWh produced than is the case in the baseline.

3. Final energy demand

Next to the impact on the gross inland consumption and the electricity production, the effect of higher fuel prices on the final energy demand is studied as well.

Figure 11: Changes in sectoral final energy demand for the higher-oil-higher-gas variant, evolution, difference with the baseline (%)



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
2010	-0.5	-1.7	-1.6	-1.5
2020	-1.1	-4.9	-3.8	-2.6
2030	-2.1	-5.7	-5.2	-0.5

Source: PRIMES

All the end sectors undergo an impact from the higher energy prices as higher prices lower demand. The effect is highest in the residential sector, shrinking its consumption by almost 6% relative to the baseline by the end of the projection period. Industry and transport, on the other hand, seem to be the least affected. This can be attributed to, in the case of industry, the limited medium term flexibility for structural changes and to important efficiency gains already reached in the baseline. The low impact on final transport demand then is due to the high motor fuel taxes which curb the impact of higher oil import prices.

Box 1: An alternative price variant

Another possible price variant that will not be discussed in this study, though, is an analysis in which oil prices are still assumed to be high, but the evolution of the gas prices does no longer follow the oil price progression. Gas nevertheless shows a slight price increase (as is shown in figure 8 as 'Gas Medium'). This 'higher-oil-medium-gas-price variant' starts from the same hypotheses as the previous variant (stronger GDP growth in the East and smaller oil and gas reserves), but introduces a relatively slower growth in the gas price compared to oil (but still stays above the level obtained in the baseline). This variant allows to test the hypothesis that the most nearby suppliers of gas in Europe (Russia, Iran and the Caspian Sea) could sell their gas at a price slightly under the price determined by the market fundamentals so as to maintain a share in this region of the world.

Main lessons to be drawn from this variant is that at more moderate gas prices (but still skyrocketing oil prices), total gas needs will be higher than in the baseline (and much higher than in the higher-oil-higher-gas variant). This can be subscribed to the relative price proportions (gas is far less expensive than oil). Nonetheless, gas is slightly more expensive than in the baseline, which leads to a small decrease in primary energy demand. This lower primary energy consumption combined with a further penetration of natural gas will entail lower CO_2 emissions.

When it comes to electricity production, coal is more competitive than gas so coal is the preferred fuel, gas occupies the second place. This leads to a power generation sector that is somewhat more polluting than the baseline power sector (but less polluting than the higher-oil-higher-gas variant).

Due to the higher energy prices, final demand is being reduced, although not as drastically as in the higher-oil-higher-gas variant. This can be explained by the moderate gas prices in the higher-oil-medium-gas variant which limit the impact on energy consumption. Interesting to remark is that the demand reduction in the transport sector is exactly identical to the higher-oil-higher-gas variant, due to the fact that this sector does not consume natural gas and that the price hypotheses for oil are the same as the ones described in the higher-oil-higher-gas variant.

V. Alternative scenarios

A. Definition

Next to an obligatory baseline and a sensitivity analysis on international fuel prices to take into account the uncertainty surrounding future energy prices, the FPB was also asked to study the impact of a number of alternative scenarios. Alternative scenarios are constructed in order to investigate a particular policy line or policy measures of which one wants to know the impact on the national energy system and its emissions. These alternative scenarios differ from sensitivity analyses in that they do not study the effect one single exogenous parameter has on the outcome, rather the whole context of the scenario is being changed. In this way, through the definition of the alternative scenario, a new policy background is chosen, in such a way different from the baseline that it becomes possible to compare the two scenarios (reference and alternative) and to investigate how a different outset (as stipulated in the alternative scenario) can change the national energy and emission system.

Further to the request of the Commission Energy 2030, three main policy issues are put forward in this report and assessed in different combinations: first, the impact of a CO_2 emission constraint is being studied[17], second, the reappearance of nuclear on the electricity scene will be scrutinized, third, the uncertainty related to the availability of a particular emission reduction technology, namely carbon capture and storage, is assessed. A detailed description of the way the scenarios were designed and of the rationale behind these choices is provided in annex C.

Finally, the alternative scenarios are complemented with a sensitivity analysis on soaring oil and gas prices (identical to the one tested on the baseline). This adds up to 12 new scenarios and associated variants.

[17] The emission constraint is achieved in modelling the energy economy so as to obtain equal marginal abatement costs across the sectors.

Box 2: Definition of alternative scenarios and sensitivity analyses on the alternative scenarios

Alternative:
- **Bpk15**: scenario in which Belgium reduces its energy CO_2 emissions by 15% in 2030 compared to the 1990 level, decommissioning of nuclear plants takes place and CCS is available in the period 2020-2030
- **Bpk15n**: scenario in which Belgium reduces its energy CO_2 emissions by 15% in 2030 compared to the 1990 level, lifetime extension of existing nuclear plants + possibility of having 1 new nuclear unit of 1700 MW after 2020 and CCS is available in the period 2020-2030
- **Bpk15s**: scenario in which Belgium reduces its energy CO_2 emissions by 15% in 2030 compared to the 1990 level, decommissioning of nuclear plants and CCS is not available in the period 2020-2030
- **Bpk15ns**: scenario in which Belgium reduces its energy CO_2 emissions by 15% in 2030 compared to the 1990 level, lifetime extension of existing nuclear plants + possibility of having 1 new nuclear unit of 1700 MW after 2020 and CCS is not available in the period 2020-2030

Sensitivity analysis:
- **Bpk15h**: scenario in which Belgium reduces its energy CO_2 emissions by 15% in 2030 compared to the 1990 level, coupled with soaring oil and gas prices, CCS is available in the period 2020-2030
- **Bpk15nh**: scenario in which Belgium reduces its energy CO_2 emissions by 15% in 2030 compared to the 1990 level, lifetime extension of existing nuclear plants + possibility of having 1 new nuclear unit of 1700 MW after 2020 coupled with soaring oil and gas prices, CCS is available in the period 2020-2030

Alternative:
- **Bpk30**: scenario in which Belgium reduces its energy CO_2 emissions by 30% in 2030 compared to the 1990 level, decommissioning of nuclear plants takes place and CCS is available in the period 2020-2030
- **Bpk30n**: scenario in which Belgium reduces its energy CO_2 emissions by 30% in 2030 compared to the 1990 level, lifetime extension of existing nuclear plants + possibility of having 1 new nuclear unit of 1700 MW after 2020 and CCS is available in the period 2020-2030
- **Bpk30s**: scenario in which Belgium reduces its energy CO_2 emissions by 30% in 2030 compared to the 1990 level, decommissioning of nuclear plants and CCS is not available in the period 2020-2030
- **Bpk30ns**: scenario in which Belgium reduces its energy CO_2 emissions by 30% in 2030 compared to the 1990 level, lifetime extension of existing nuclear plants + possibility of having 1 new nuclear unit of 1700 MW after 2020 and CCS is not available in the period 2020-2030

Sensitivity analysis:
- **Bpk30h**: scenario in which Belgium reduces its energy CO_2 emissions by 30% in 2030 compared to the 1990 level, coupled with soaring oil and gas prices, CCS is available in the period 2020-2030
- **Bpk30nh**: scenario in which Belgium reduces its energy CO_2 emissions by 30% in 2030 compared to the 1990 level, lifetime extension of existing nuclear plants + possibility of having 1 new nuclear unit of 1700 MW after 2020 coupled with soaring oil and gas prices, CCS is available in the period 2020-2030

B. Marginal abatement cost

Given the growth in energy related CO_2 emissions in the baseline (+32% in 2030 compared to 1990), the imposition of emission reduction constraints requires additional effort to be undertaken by economic agents over the projection period. In the PRIMES modelling approach, this is reflected by the marginal abatement cost (or carbon value) which is equal to the shadow variable of the emission constraint. Following the introduction of a carbon value (CV), the producers and consumers of energy adjust their behaviour to emit less CO_2 emissions. The resulting changes in the energy system represent the least-cost solution for achieving the constraint. By construction, the marginal abatement costs are equal among the sectors.

The carbon value reflects the degree of ease or difficulty in achieving the constraint on emissions; it depends not only on the constraint itself but also on the number, potential and costs of the reduction options accounted for in the analysis.

The above statement is illustrated in the following table which gives the marginal abatement costs associated with the two constraints on CO_2 emissions considered in the study (-15% and -30%), according to the presence or not of two particular CO_2 reduction options in the power sector, namely nuclear energy and carbon capture and storage (CCS). To make the figures more “telling” by themselves, the carbon values are also expressed in $ per barrel of oil equivalent.

Table 8: Carbon values associated to the different emission reduction scenarios, year 2030

	Bpk15	Bpk15n	Bpk15s	Bpk15ns	Bpk30	Bpk30n	Bpk30s	Bpk30ns
in €/t CO_2	123	60	524	105	320	186	2150	490
in $/bbl	47	23	202	40	123	71	827	188

Source: PRIMES

The carbon value required to reduce the energy related CO_2 emissions of Belgium by 15% in 2030 at 1990 level range from 60 to 524 € per ton of CO_2 reduced. The lowest value corresponds to the scenario where both nuclear energy and CCS are made available as energy technology options (Bpk15n). The corresponding figure of 60 €/tCO_2 is equivalent to one third of current oil price (i.e. around 70$ per barrel). On the other hand, if both options are not made available (BPk15s), the CV climbs dramatically to reach three times the current oil price. The other two reduction scenarios show similar carbon values, in the range of 100-120 €/tCO_2.

A doubling of the emission constraint, from -15% to -30% in 2030 compared to 1990 levels, leads to more than a doubling of the marginal abatement cost. With CCS, the CV is roughly multiplied by three; without CCS, it is multiplied by a factor of four or more. The ranking of CV’s according to the scenario is the same as for the -15% reduction cases. It is interesting to notice that the CV’s required to achieve a 30% reduction of energy related CO_2 emissions in 2030 with nuclear energy and/or CCS as possible options, are lower than the CV estimated for the 15% reduction case in the absence of the these two options. This result underlines the role of the power generation sector for responding to the introduction of CO_2 emission reduction constraints either through the use of CCS or through the abrogation of the law of 2003 on the use of nuclear power generation. However, it does not address a wider range of policy strategies that exist in the final demand sectors and in the power sector.

Table 8 also shows that the selected constraints on CO_2 emissions could entail relatively high costs to the society. Having noted that, it is important to stress that (1) the analysis only copes with energy related CO_2 emissions, (2) the abatement costs can be (partially) compensated by reductions in other costs through appropriate policy measures (e.g. labour charges), and (3) the benefits of taking appropriate actions to reduce the negative impacts of climate change are not taken into account. In other words, the estimated carbon values should not be interpreted as costs of policy implementation but rather as an indicator of the relative difficulty of achieving the constraints. As regards the focus on energy related CO_2 emissions, it is reasonable to think that at such high carbon values, options aimed at reducing non-CO_2 greenhouse gases and the resort to flexible mechanisms under the Kyoto Protocol or to the EU Emission Trading Scheme (ETS) will be less costly than certain domestic actions focusing on CO_2 emissions alone.

In what follows, the main results of the alternative scenarios will be discussed.

C. Analysis of the impact of the alternative scenarios and variants

The analysis of the impact of a change in policy is quantitatively calculated with the use of the PRIMES model and focalises on the consequences on the Belgian energy system. The analysis takes place along two lines: first, a more general overview of the evolution and structure of the major energy indicators for all scenarios will be provided through the use of comprehensive tables, second, a selection of energy indicators will be presented through the format of coupled analyses, meaning that two alternative scenarios or variants will be jointly analysed and their impact relative to the baseline will be unfold. The latter (the coupled analyses) all describe the changes with respect to the baseline and for the year 2030, unless stated otherwise. Where relevant, the cost implications for the different sectors are also examined.

In order to facilitate the comparison with other parts of the report, the same type of graphs and tables are constructed and presented in each section.

1. Belgian reduction of energy CO_2 emissions by -15%

This part details all scenarios in which the CO_2 emission reduction obligation boils down to a decrease on the Belgian territory of the energy CO_2 emissions with 15% in 2030 compared to the energy CO_2 emission level obtained in 1990.

a. Primary energy demand

i General

The table below shows the total evolution (expressed in average annual growth rate) for the period 2000-2030 and the structure of the primary energy demand or gross inland consumption (GIC) for the year 2030 of, on the one hand, the baseline, on the other hand, the four -15% reduction scenarios.

Table 9: Primary energy demand, comparison baseline vs. -15% reduction scenarios, year 2030 (%)

	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns
Average annual growth rate 2000-2030	-0.1	-0.3	0.2	-0.8	0.1
Structure of GIC (%)					
- Coal	20.8	13.9	3.0	1.7	2.5
- Oil	38.6	38.0	33.6	39.0	33.1
- Natural gas	35.3	39.9	29.5	48.3	29.5
- Nuclear	0.0	0.0	27.4	0.0	27.9
- RES	5.3	8.2	6.5	11.0	7.0

Source: PRIMES

Looking at this table, it immediately becomes clear that, in order to reach the -15% reduction in energy CO_2 emissions, not only a fuel switch is necessary, but also a reduction in primary energy demand is indispensable. The alternative scenario in which the CO_2 reduction technology CCS is not available and nuclear decommissioning is in place (Bpk15s) is the hardest hit with an average primary demand reduction rate of -0.8% per year. Nuclear power erases this demand reduction and even leads to small annual demand increases: this evolution, however, has to do with the statistical convention related to nuclear energy (cf. supra).

Within the composition of the GIC, coal suffers most from the reduction constraint: its representation within the GIC shrinks considerably in the Bpk15 cases; when nuclear is added and/or when CCS is not available; its percentage shrivels even further. Turning to natural gas, we see that in the case in which nuclear power and CCS are no parts of the reduction alternatives, its share jumps to almost half the GIC. This is due to the fact that one cannot turn to nuclear in this alternative and coal without the CCS option is not interesting to use due to its high carbon content. With nuclear, the share of gas remains around 30%. Last, the CO_2 reduction of -15% translates into a higher use of renewable energy sources: the RES's share floats between 7 and 11% of the GIC.

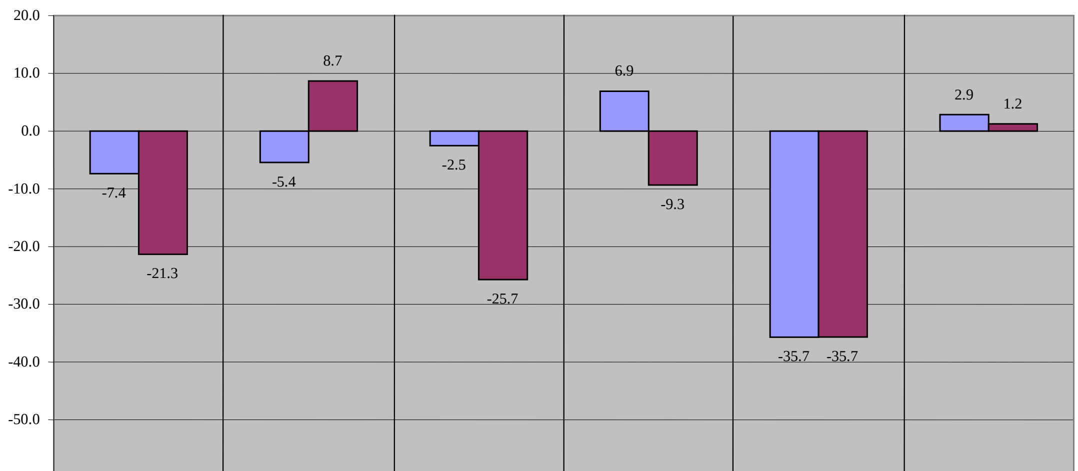
ii Coupled analysis

In this section, different scenarios are being pairwisely discussed, the first being the comparison between a scenario in which a -15% reduction will be reached by 2030 with nuclear phase-out and a scenario with the same reduction target but in which the lifetime of existing nuclear plants will be prolonged up to 60 years and new nuclear investment in one additional power plant is made possible.

Bpk15 vs. Bpk15n

This joint analysis between Bpk15 and Bpk15n can be seen as a study of the relative impact the nuclear option (decommissioning versus extension of plant operating lifetime to 60 years and possibility to invest in an additional unit of 1700 MW) has on primary energy related indicators for the year 2030, both subject to the CO_2 emission constraint of having to reduce the energy CO_2 emissions on Belgian soil by 15% in 2030 compared to 1990. The joint analysis also constitutes a deepening of the general analysis on the individual scenarios presented in table 9.

Figure 12: Primary energy related indicators for the Bpk15 and Bpk15n scenarios, year 2030, difference with the baseline (%)



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK15	-7.4	-5.4	-2.5	6.9	-35.7	2.9
BPK15n	-21.3	8.7	-25.7	-9.3	-35.7	1.2

Source: PRIMES

(*): expressed in percentage points

The net import of energy[18] for both scenarios will be lower than in the baseline, even much lower when nuclear energy is allowed back in the game. The fact that there is less import is due to the rather severe constraint that 15% of the energy CO_2 emissions has to be eliminated, what is translated into a serious dip in the energy consumption (hence, because of the lack of fossil fuel resources in Belgium, in import). Coal is victim number one of the -15% reduction constraint because it exhausts the most CO_2 per unit of output. In the case of 'nuclear allowed' (Bpk15n) even less coal is needed, especially

18 According to Eurostat convention, this excludes the import of uranium.

for the production of electricity. The latter will also employ less natural gas; nuclear after all seems to be more competitive than coal or gas when a constraint on CO_2 emissions is imposed. As a consequence, the indicator for import dependency will plunge in both cases, much lower though in the Bpk15n-case.

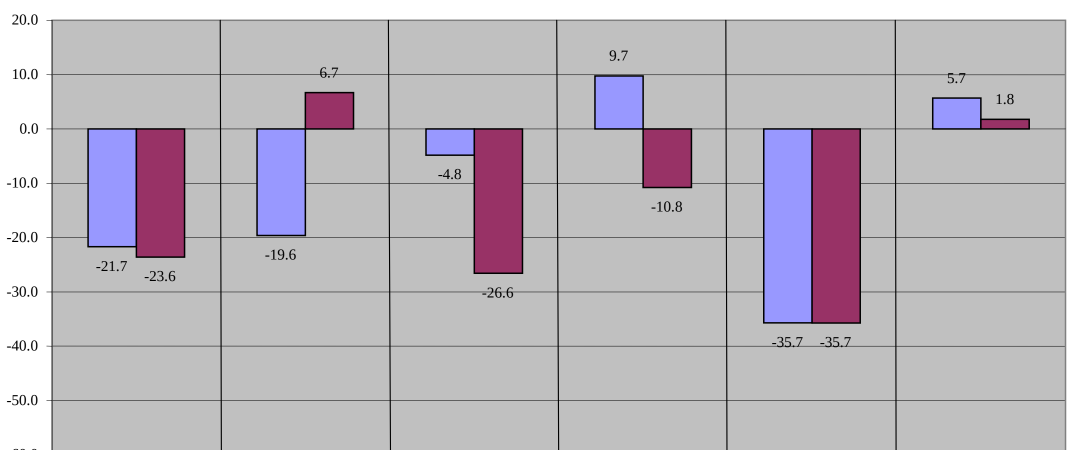
The gas needs are higher in the case of nuclear decommissioning. This is due to the fact that CO_2 emissions have to be reduced, nuclear is being phased out, coal emits more CO_2 per unit of output than gas and there is only a limited potential of some renewable energy sources available, so the only refuge is being provided by gas. 7% more gas will be consumed compared with the baseline, whilst gas needs are approximately 9% lower when nuclear is an option. CO_2 emissions will in both cases fall 36% under the baseline level: this is the translation of the 15% reduction compared with 1990, the starting point of both scenarios.

The share of renewable energy sources in the gross inland consumption is higher in both cases than the baseline level, although the non-nuclear scenario registers a higher renewables' share. In absolute terms, the share of RES reaches 8.1% of the GIC in 2030 in the Bpk15-scenario, whereas it only arrives at 6.5% in the Bpk15n-scenario (in the baseline, it is 5.2%).

Bpk15s vs. Bpk15ns

This coupled analysis investigates the two cases in which the novel emission reduction technology CCS is not used during the entire projection period (2000-2030) because this technology option is not assumed to be commercially viable at the stated carbon value and/or within the time frame studied. Overall, the changes in primary energy indicators compared to the baseline are more outspoken when CCS is not included in the analysis (cf. figure 12 vs. figure 13).

Figure 13: Primary energy related indicators for the Bpk15s and Bpk15ns scenarios, year 2030, difference with the baseline (%)



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK15s	-21.7	-19.6	-4.8	9.7	-35.7	5.7
BPK15ns	-23.6	6.7	-26.6	-10.8	-35.7	1.8

Source: PRIMES

(*): expressed in percentage points

Without CCS and with the nuclear phase-out in place, we see that renewable energy sources take off significantly. No less than 67% more renewable energy sources are deployed in the primary production of this variant. This adds up to a representation in the gross inland consumption of 10.9% (compared to 5.2% in the baseline). Because of the CO_2 emission constraint and the lack of CCS, the use of coal and, although to a lesser extent, oil is penalised: therefore, 93% less coal is being imported, 14% less oil, hence the strong dip in net imports. Gas on the other hand is consumed more than in the baseline and pulls the net import figure slightly up. The nuclear allowed scenario also shows a decline in both coal and oil import, but this time, even gas is less used (and imported). Nonetheless, the Bpk15ns scenario has a higher total GIC: this can be explained by the higher share of nuclear.

The lower net imports of energy entail a lower import dependency. Total gas needs are higher compared to the baseline in the nuclear decommissioning scenario without CCS, lower in the nuclear allowed scenario. This is because gas is the only refuge in the non-nuclear case (next to RES), whilst in the nuclear allowed scenario, nuclear is more competitive and outprices gas.

The share of renewables in the GIC is never higher than in the Bpk15s case: at a rate of almost 6 percentage points above the baseline, approximately 11% of the primary energy demand is being covered by renewable energy sources. Biomass and wind take up the lion's share, but also the appearance of solar PVs is worth noting and is much more significant than in the baseline (almost 6 times higher in 2030).

b. Electricity and steam generation

i General

Turning to electricity and steam generation, the following tables show some light on the discussion.

Table 10: Power generation, comparison, year 2030 (%)

	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns
Average annual growth rate 2000-2030	1.0	1.0	1.3	0.9	1.4
Structure of electricity generation					
- Nuclear	0.0	0.0	51.9	0.0	50.9
- RES	11.8	22.7	19.5	28.3	20.3
- Fossil fuels	88.2	77.3	28.6	71.7	28.8

Source: PRIMES

Power generation in the baseline grows by 1% on average each year, the alternative scenarios show higher growth rates provided nuclear is taken into account as an energy policy option. This is due to the privileged use of electricity in the CO_2 reduction scenarios, especially in industry where more electricity will be consumed to the detriment of fossil fuels (e.g. in the iron and steel sector). In the cases where nuclear is a part of the generation park, electricity consumption, hence production, growth rates are highest. In these scenarios, nuclear represents more than half of the power production by 2030, nibbling market share away from fossil fuel based plants. Renewable energy sources profit from the CO_2 reduction constraint: in the alternative scenarios, their share (almost) doubles compared to the baseline.

The reduction effort of the power and steam sector is assessed keeping the levels of net electricity imports equal to those calculated endogenously in the baseline. In other words, we do not consider the possibility to achieve reductions in CO_2 emissions through an increase in electricity imports and, hence, a decrease in electricity production on the national territory.

Table 11: Installed power capacity, comparison, year 2030 (MW)

	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns
Installed power capacity	22999	25524	27539	29998	27912
- Nuclear	0	0	7775	0	7775
- Wind onshore	1388	2045	1976	2058	2045
- Wind offshore	1019	3800	3791	3800	3800
- Solar PV	209	209	209	5903	209
- Biomass	1310	1568	1413	1631	1575
- Coal fired	7054	3940	0	0	0
- Gas fired	11240	12142	11704	12562	11834

Source: PRIMES

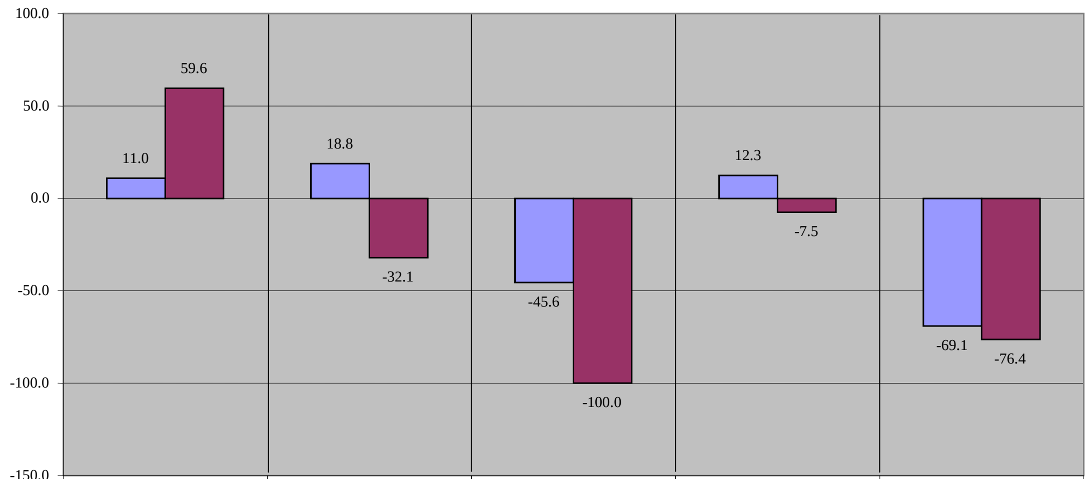
Digging somewhat deeper into power generation, we come up with the figures for the installed power capacity. It immediately becomes clear that the reduction scenarios go hand in hand with an expansion of the installed power capacity. When the nuclear option is included (Bpk15n and Bpk15ns), the increase in power capacity results mainly from the increase in the demand for electricity. When nuclear is phased out (Bpk15 and Bpk15s), the increment in capacity is due to higher shares of intermittent RES in the production park: additional capacity is needed to cope with relatively low availability factors of wind power and solar PV. Investments in wind turbines (on- and off-shore) become primordial: all alternative scenarios but the Bpk15n use the maximum potential of on- and off-shore wind by the end of the projection period. Also, more biomass is used than in the baseline. Coal, on the other hand, has completely vanished. Only exception is the Bpk15 scenario as coal, with the CCS option open, remains the only alternative next to gas as nuclear is being phased out. When CCS cannot be implemented, though, we see a spectacular surge in the use of solar PV. Although solar PV does not seem to be commercially viable in the other scenarios, the absence of other alternatives in the Bpk15s case obliges them to make their appearance in the future generation park.

The relative role of CO_2 reduction options in the power and steam sector is analysed further in section V.C.3.a.

ii Coupled analysis

Bpk15 vs. Bpk15n

Figure 14: Electricity production related indicators for the Bpk15 and Bpk15n scenarios, year 2030, difference with the baseline (%)



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK15	11.0	18.8	-45.6	12.3	-69.1
BPK15n	59.6	-32.1	-100.0	-7.5	-76.4

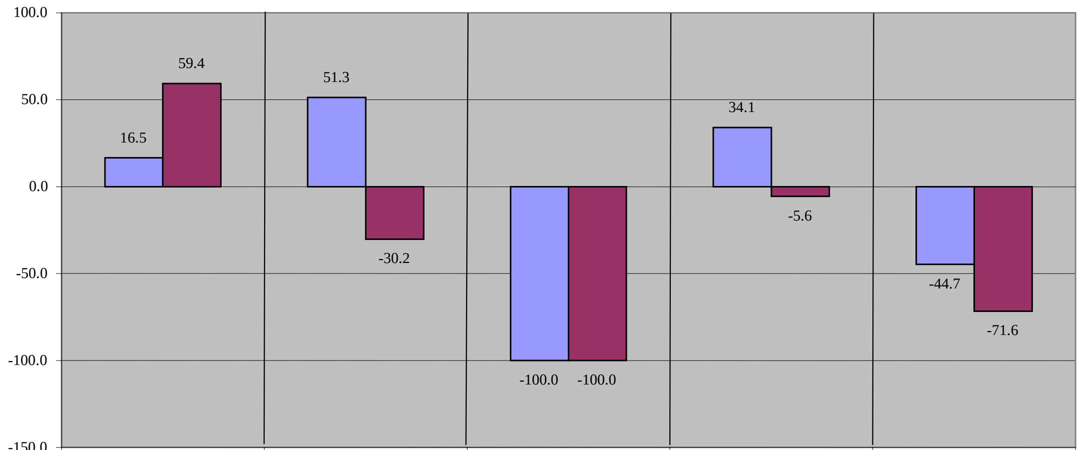
Source: PRIMES

The coupled analysis on electricity production with CCS possible shows a large impact of the nuclear come-back on the generation park. First of all, the carbon free share in power production is much higher when nuclear is allowed. For one, this is due to the fact that nuclear power is seen as a non-carbon emitting energy source (hence it is not penalized by placing a carbon tax on energy fuels). Second, the share of renewable energy sources in electricity generation in both scenarios is much higher compared to the baseline: in the Bpk15 scenario, it reaches almost 23%, in the Bpk15n case, it is 20%. This underwrites the thesis that nuclear and renewable energy sources are substitutes for fossil fuels, but that they do not form substitutes for one another. The appearance of nuclear does not, in other words, preclude the upsurge of RES.

Natural gas, on the other hand, is used more when Belgium has to answer to post-2012 CO_2 constraints without the use of nuclear. When new nuclear investments are allowed and the lifetime of existing plants can be extended, much less gas is needed to produce electricity. In this last scenario, coal even disappears completely from the power scene by the end of the projection period. These changed production patterns translate into a considerably cleaner power generation: without nuclear, almost 70% less CO_2 per MWh produced is being emitted, with nuclear a further reduction becomes possible (-76.4%).

Bpk15s vs. Bpk15ns

Figure 15: Electricity production related indicators for the Bpk15s and Bpk15ns scenarios, year 2030, difference with the baseline (%)



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK15s	16.5	51.3	-100.0	34.1	-44.7
BPK15ns	59.4	-30.2	-100.0	-5.6	-71.6

Source: PRIMES

Electricity production in these two non-CCS scenarios diverges strongly from the baseline. The carbon free share in power generation in both cases is (much) higher than in the baseline due to the preferred (read: less costly with the introduction of a carbon value) utilization of non carbon containing energy fuels like RES and nuclear power. The first scenario (Bpk15s) still uses a lot of gas in order to keep the lights on, the second (Bpk15ns) severely reduces its use of gas in favour of nuclear and renewables. Coal is completely abolished when CCS is not available, due to the high exhaustion rate and the carbon value that is subsequently raised on the use of this fuel. Power generation becomes cleaner compared to the baseline, especially in the second scenario. It is nevertheless noticeable that the Bpk15s case possesses, in the ranking order of all -15% reduction scenarios under discussion, the most polluting power generation sector: CCS, in other words, enables the electricity sector to produce in a much less polluting way.

iii Cost implications

The impact of a CO_2 emission reduction constraint on the costs of electricity and steam generation is estimated in this section through changes in average production costs. Average production cost is defined as the total cost of electricity and steam supply divided by total electricity and steam production. This cost indicator includes all (energy) costs related to electricity and steam generation in power plants (electricity only and CHP) as well as in industrial and refinery boilers; they also include costs for transmission, distribution and net electricity imports.

The average production costs are only illustrative of the impacts on the costs of the power and heat supply sector. They do not represent the full costs related to the implementation of CO_2 reduction policies. Indeed, the imposition of carbon values induces changes in behaviour, fuels and technologies (whose costs are reflected in the average production cost) but does not involve any policies needed to realise these changes.

Table 12 and figure 16 below compare the evolution of the average production costs in the baseline and in the different -15% reduction scenarios.

Table 12: Evolution of the average production costs of electricity and steam, -15% reduction scenarios (in €2000/(MWh_e+MWh_{th}))

	2000	2020	2030	% change between 2000 and 2030
Baseline	37.0	43.5	50.5	36.3
Bpk15	37.0	49.9	72.5	95.7
Bpk15n	37.0	43.0	43.2	16.6
Bpk15s	37.0	48.8	60.8	64.2
Bpk15ns	37.0	43.4	41.7	12.7

Source: PRIMES

In the Bpk15 scenario – the only scenario that assumes the same set of technology options as the baseline - the average production cost almost doubles compared to the cost in 2000. Compared to the baseline, this translates into a cost increase of 43.6% in 2030. The increase reflects the costs of CCS and of additional (and more expensive) renewable power capacities that prove to be cost-effective options to achieve the constraint on total energy related CO_2 emissions at least cost.

If one assumes that CCS is not a feasible option at the horizon of 2030 (scenario Bpk15s), the rise in cost is lower (+64.2% compared to 2000 and +20.4% compared to the baseline). Indeed, given the lack of CO_2 reduction options in the power sector besides very expensive investments in solar PV[19], CO_2 emission reductions in this sector are less significant than in Bpk15, leading to lower average production costs. The energy system adapts to the CO_2 constraint in reducing comparatively more in the demand sectors. Overall, the energy system costs are higher in Bpk15s than in Bpk15 (see infra).

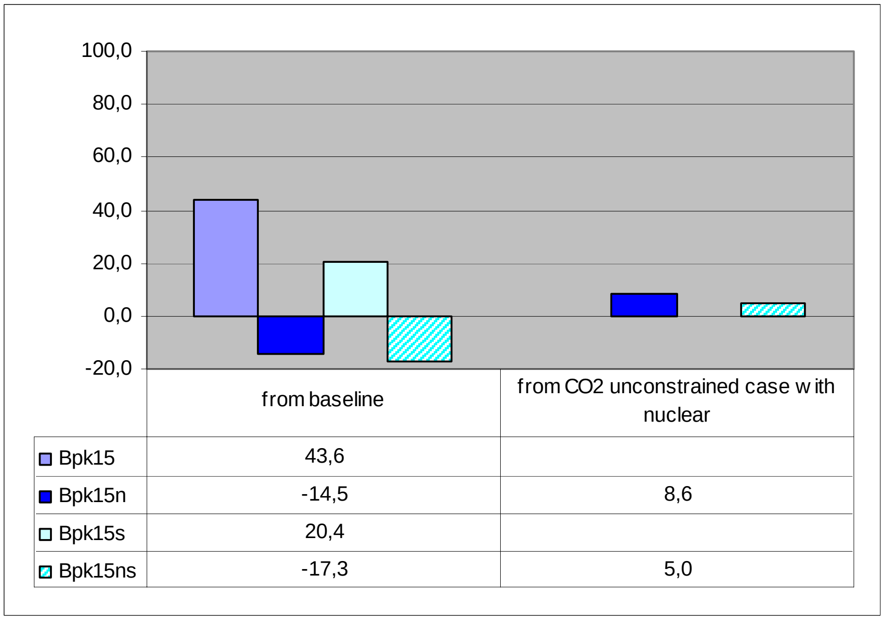
As regards the evolution of average production costs in the CO_2 constrained scenarios with the nuclear option allowed (Bpk15n and Bpk15ns), the comparison with the baseline must be interpreted with caution when assessing the costs of achieving CO_2 emission reductions. In the baseline, the average production costs include the sunk costs related to the nuclear decommissioning. Investments in new capacities are not only necessary to meet the increasing demand of electricity but also to replace nuclear capacities that must close after 40 years of operation. This is not the case in Bpk15n and Bpk15ns where the extension of the lifetime of existing nuclear power plants avoids part of the investments[20] in new power capacities and therefore leads to lower production costs. In other words, changes in average production cost with respect to the baseline as shown in figure 16 do not only reflect the abatement costs but also different investment frameworks.

Keeping this clarification in mind, the results are the following: (1) the average production costs increase by respectively 16.6% and 12.7% in the Bpk15n and Bpk15ns scenarios between 2000 and 2030, and (2) the average production costs are respectively 14.5% and 17.3% lower than the costs in the baseline in 2030. To isolate the impact of the constraint on CO_2 emissions on the average production costs when nuclear is allowed, one has to calculate the difference with respect to a CO_2 unconstrained case with similar assumptions as to the development of nuclear energy. Doing so (cf. right part of figure 16), one sees that the -15% constraint leads to average production costs that are respectively 8.6% and 5.0% higher in 2030 than the costs in the unconstrained cases.

19 The potential of wind power both on- and off-shore is fully implemented in the Bpk15s scenario as it was already the case in the Bpk15 scenario.

20 I.e. corresponding to the capacity of the existing nuclear power plants.

Figure 16: Average production costs of electricity and steam in the -15% reduction cases, difference from unconstrained cases in 2030 (%)



Source: PRIMES

c. Final energy demand

i General

In analogy with the baseline and the sensitivity analysis, the analysis of the GIC and the electricity production is followed by a study on the final energy demand.

Table 13: Final energy demand, comparison, year 2030 (%)

	Base	Bpk15	Bpk15n	Bpk15s	Bpk15ns
Average annual growth rate 2000-2030	0.3	0.1	0.2	-0.4	0.2
Structure of FED					
- Solids	5	2	3	1	2
- Oil	39	39	39	38	38
- Gas	28	28	27	26	27
- Electricity	22	24	25	27	26
- Heat	4	4	4	4	4
- Other	2	3	2	4	3

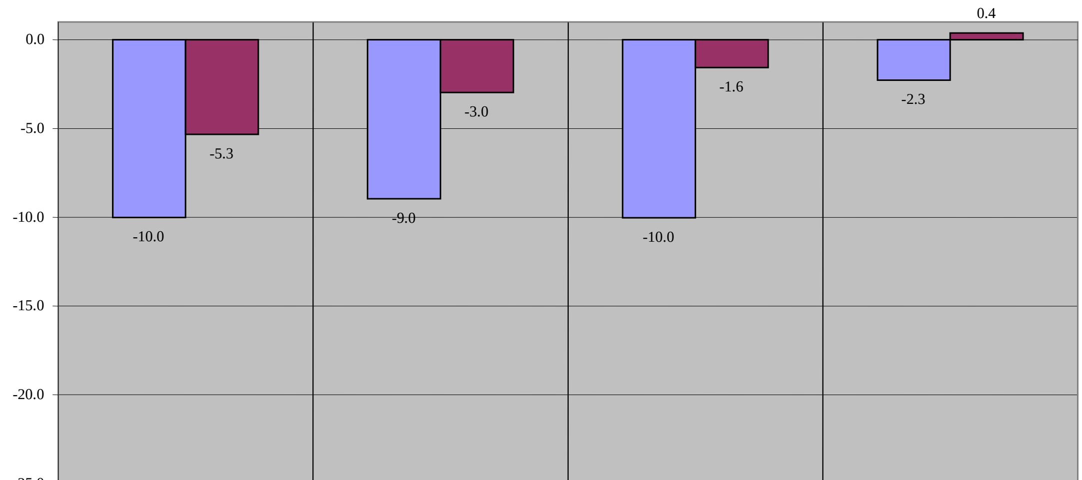
Source: PRIMES

First thing that pops out of this table is the fact that the average annual final energy demand growth rate in the -15% reduction scenarios is lower than in the baseline. In the Bpk15s scenario, it even becomes negative. Next to supply side contributions, significant final energy demand reductions are thus essential when a CO_2 constraint is installed, all the more so when supply side CO_2 reduction options are limited. When it comes to the fuel structure of the final energy demand, table 13 shows that fuel switching plays a smaller role for CO_2 reduction at the final energy level than in primary energy demand as strong shifts towards less carbon intensive energy forms already take place in the baseline. The most significant changes from the baseline are (1) the decline and demise of the solid fuels (2) the upsurge of electricity. The expiration of solid fuels is due to the penalisation of CO_2 exhaustion, and since coal is a large CO_2 emitter, its use consequently shrinks. The introduction of a carbon value hurts electricity relatively less (compared to fossil fuels), hence its larger share.

ii Coupled analysis

Bpk15 vs. Bpk15n

Figure 17: Changes in sectoral final energy demand for the Bpk15 and Bpk15n scenarios, year 2030, difference with the baseline (%)



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK15	-10.0	-9.0	-10.0	-2.3
BPK15n	-5.3	-3.0	-1.6	0.4

Source: PRIMES

This graph proves, next to the table above, that the installation of a -15% constraint leads to a dip in the final energy demand. The difference between the two alternative scenarios (Bpk15 and Bpk15n) is worth noting: without the nuclear option, efforts on the demand side are far more significant, especially in the industry and tertiary. These two sectors have to give in 10% of their final consumption relative to the baseline. As no change in value added is assumed in the CO_2 constraint scenarios (compared to baseline), this means that the energy intensity[21] of industry and the tertiary sector decreases by 10% in 2030 compared to the baseline. Two main factors contribute to the decrease in the final energy consumption of industry: (1) a partial switch from integrated steelworks to electric arc furnaces in the iron and steel sector (40%), and (2) a further increase in the energy efficiency (60%). The decline recorded in the tertiary and residential sectors is due, on the one hand, to a decrease in the demand for energy services and, on the other hand, to further improvements in the efficiency of heating devices and electric appliances.

Transport responds the least to the -15% reduction constraint. A high level of taxation on transport fuels combined with low price elasticities recorded in this sector cause the impact of the carbon values required in the -15% reduction cases to be rather small. The reduction by 2.3% in final energy demand of transport results mainly from a decrease in transport activity (both passengers and freight) and an increase of the energy efficiency of airplanes[22]. The energy efficiency of other vehicles remains almost unchanged as well as the fuel mix. It is worth underlining here that the share of biofuels in transport is an exogenous policy parameter in PRIMES. In all alternative scenarios, the share of biofuels is assumed to follow a similar trend than in the baseline, i.e. 2.1% in 2010, 6.4% in 2020 and 8% in 2030.

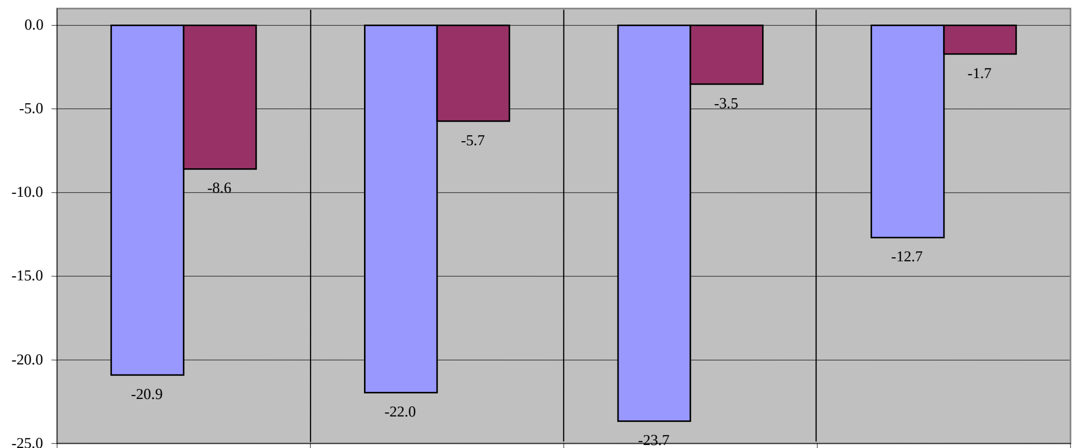
[21] Final energy consumption on value added.

[22] The responsiveness of the aviation sector to price increases is higher than that of the other transport modes.

With nuclear power in place, final demand decreases are more moderate as more significant CO_2 emission reductions take place in the power supply sector. However, the general pattern of changes is similar to that in Bpk15.

Bpk15s vs. Bpk15ns

Figure 18: Changes in sectoral final energy demand for the Bpk15s and Bpk15ns scenarios, year 2030, difference with the baseline (%)



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK15s	-20.9	-22.0	-23.7	-12.7
BPK15ns	-8.6	-5.7	-3.5	-1.7

Source: PRIMES

If CCS is not assumed to be a commercially or technically viable option by 2030, moderate final consumption changes in the scenario with nuclear can be noticed, but the Bpk15s scenario notes a sharp decline of the final energy demand in all the end sectors. Without both CCS and nuclear, the demand side has to carry a relatively big part of the CO_2 emission reduction burden, with reductions as high as almost a quarter of the final energy consumption (e.g. tertiary sector) compared to the baseline. The determinants of the changes in the level of final energy consumption are the same as the ones cited in Bpk15; they, however, intensify their role.

iii Cost implications

The imposition of a CO_2 emission reduction constraint has an impact on the energy related costs of the final demand sectors. The impact results from changes in consumer behaviour, production processes and technology choices triggered by the carbon values in order to adjust to the constraints. To assess the cost implications on the demand side, several cost indicators are considered.

For industry and the tertiary sector, the cost indicators are the energy related costs per toe consumed (in €2000/toe) and the energy related costs per unit of value added[23]. The energy costs include both the costs related to energy equipment (capital and O&M[24]) and those related to fuel purchases. In the residential sector, the assessment is made via the energy related costs per toe consumed (in €2000/toe) and the energy related expenditures per household (in €2000). The cost implications in the transport sector are provided by the total cost per passenger-kilometre (pkm) and per ton-kilometre (tkm) travelled (in €2000/pkm or tkm). The former indicator relates to passenger transport, the latter to

23 €2000 energy related costs per million €2000 value added.

24 I.e. operation and maintenance costs

freight transport. The total cost comprises the fuel costs, the energy equipment costs and the non-energy costs (e.g. infrastructure costs) that are important factors in transport.

By construction, all above cost indicators include the changes in costs in the power and steam sector. Indeed, changes in average production costs are transferred to electricity prices paid by the final consumers, affecting the total energy costs of the final demand sectors[25].

As already stressed in the section on the power and steam generation, the computed cost indicators do not represent the full costs related to the implementation of the reduction policies. They are only indicative of the relative difficulty of achieving the reduction constraints.

Before moving to the analysis of the cost implications of CO_2 emission constraints for the demand sectors, it is worth noting that, in the baseline, energy related costs per toe consumed increase in all sectors over the period 2000-2030. This trend is notably due to the rise in energy prices (oil, natural gas, electricity, etc.) making the fuel purchases more expensive for the final consumers. The costs related to energy equipments are also moving up over the projection period. Overall, the (energy) cost increase ranges from 24% in industry to 63% in the residential sector. The evolution of the energy related costs per unit of value added or per household shows different patterns. In industry, these costs represent a declining trend. In other words, the rate of increase in energy related costs is lower than the rate of increase in value added. In the tertiary sector, the energy related costs per unit of value added remain roughly constant between 2000 and 2030. Finally, in the residential sector, the energy related expenditures per household increase but at a lower pace than the energy related costs per unit of toe consumed.

When a constraint is imposed on the emissions of CO_2, energy related costs increase further compared to the baseline, reflecting the impact of the carbon value. The size of the impacts depends on the sector and on the reduction scenario.

Table 14 and figure 19 give the results for industry according to the different -15% reduction cases. The cost implications for the tertiary sector are provided in table 15 and figure 20. The results for the residential sector are reported in table 16 and figure 21. And finally, the impacts on the costs of transport are summarised in table 17 and figure 22.

[25] In PRIMES, the pricing of electricity follows the Ramsey-Boiteux principle, which is close to average cost pricing. The principle is interpreted as a regime of regulated monopoly for new technologies, but also as a result of long-run equilibrium of monopolistic competition in case of mature technologies. The selling price of electricity that each consumer faces is then derived by adding transport and distribution costs, mark-ups and taxes. This price setting mechanism may lead to electricity prices that are considerably different from current market prices.

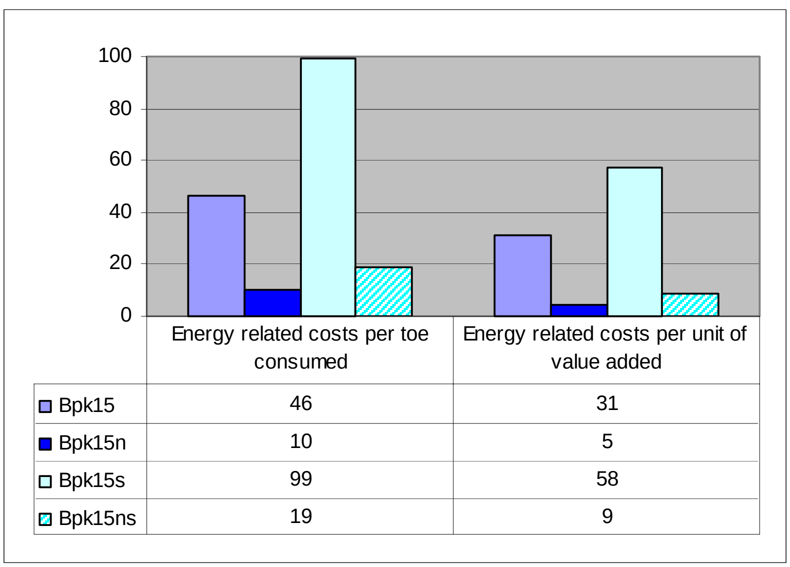
Table 14: Evolution of energy related costs in industry, -15% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Energy related costs per toe consumed (in €2000/toe)				
Baseline	537	581	664	24
Bpk15	537	767	970	81
Bpk15n	537	663	734	37
Bpk15s	537	1077	1324	146
Bpk15ns	537	727	789	47
Energy related costs per unit of value added (*)				
Baseline	159	131	129	-19
Bpk15	159	158	169	6
Bpk15n	159	143	135	-16
Bpk15s	159	192	203	27
Bpk15ns	159	150	140	-12

Source: PRIMES
(*) in €2000 energy related costs per thousand €2000 value added

Irrespective of the sector, the lowest cost impacts are recorded in the CO_2 reduction scenarios that include the nuclear option (Bpk15n and Bpk15ns). This is explained by two related factors. First, the reduction effort in the demand side is comparatively smaller in the scenarios with nuclear (but higher in the power and steam sector) than in the scenarios with nuclear decommissioning. Second, electricity prices[26] which constitute one element of the energy costs reach lower levels in the scenarios with nuclear than in the others (see supra). The latter factor is however less relevant for the transport sector whose consumption is dominated by oil products.

Figure 19: Energy related costs in industry in the -15% reduction cases, difference from baseline in 2030 (%)



Source: PRIMES

The cost increase is particularly dramatic in the Bpk15s scenario in all sectors but transport (between +146% and +169% in 2030 compared to 2000 and between +64% and +99% compared to the baseline). Due to limited and expensive reduction options on top of those already implemented in the Bpk15

[26] Which are related to the average costs of electricity production.

scenario, most of the reduction effort is transferred to the demand sectors with a non negligible impact on the energy related costs.

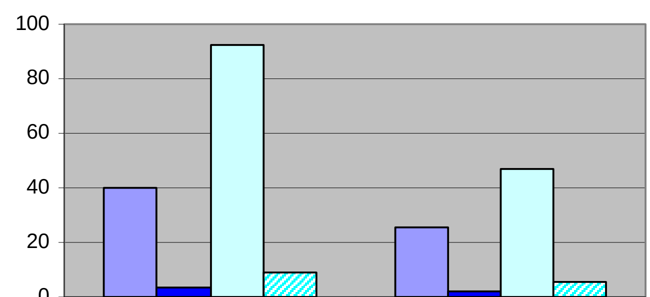
Table 15: Evolution of energy related costs in the tertiary sector, -15% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Energy related costs per toe consumed (in €2000/toe)				
Baseline	817	914	1071	31
Bpk15	817	1139	1496	83
Bpk15n	817	1006	1110	36
Bpk15s	817	1623	2061	152
Bpk15ns	817	1079	1170	43
Energy related costs per unit of value added (*)				
Baseline	21	20	21	1
Bpk15	21	23	27	27
Bpk15n	21	21	22	3
Bpk15s	21	28	31	48
Bpk15ns	21	22	22	6

Source: PRIMES
(*) in €2000 energy related costs per thousand €2000 value added

Looking at the energy related costs per unit of value added or per household, the differences with respect to the baseline reflect the impact on the energy related costs of the sectors as the evolution of value added and number of households is the same in all scenarios. The differences in energy related costs (from the baseline) are systematically lower than the differences in energy related costs per toe consumed. Indeed, the increase in costs per toe leads to lower consumption levels so that the rise in the former factor is partly counterbalanced by the decline in the latter[27].

Figure 20 : Energy related costs in the tertiary sector in the -15% reduction cases, difference from baseline in 2030 (%)



	Energy related costs per toe consumed	Energy related costs per unit of value added
Bpk15	40	26
Bpk15n	4	2
Bpk15s	92	47
Bpk15ns	9	5

Source: PRIMES

[27] Following the formula C = Q x C/Q.

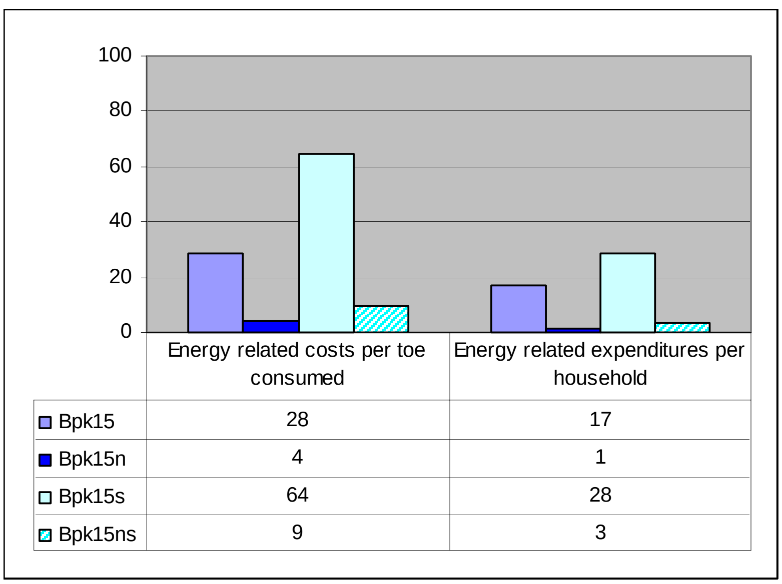
In relative terms, the cost implications of the -15% reduction constraint are comparable in industry and the tertiary sector. They are however comparatively less important in the residential sector. For instance, the difference from baseline in the residential sector of energy related costs per toe consumed is 64% in the Bpk15s scenario, compared to about 100% in industry and the tertiary sector.

Table 16 : Evolution of energy related costs in the residential sector, -15% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Energy related costs per toe consumed (in €2000/toe)				
Baseline	962	1305	1572	63
Bpk15	962	1551	2018	110
Bpk15n	962	1422	1640	71
Bpk15s	962	2083	2585	169
Bpk15ns	962	1509	1720	79
Energy related expenditures per household (in €2000)				
Baseline	2150	2695	2979	39
Bpk15	2150	2971	3483	62
Bpk15n	2150	2823	3018	40
Bpk15s	2150	3375	3825	78
Bpk15ns	2150	2917	3073	43

Source: PRIMES

Figure 21: Energy related costs in the residential sector in the -15% reduction cases, difference from baseline in 2030 (%)



Source: PRIMES

In general, the effects of the -15% emission constraint on the cost indicators for transport are less significant than the impact on the costs of the other final demand sectors. This result is explained by the low responsiveness of the sector[28] to price increases (i.e. low price elasticity and high share of taxes in the end-user prices) and by the relatively less important share of fuel costs in the total cost of transport. The imposition of carbon values changes first of all the priority among fuels and does not generate a significant impact on the allocation of transport activity among the different modes nor on

[28] With the exception of the aviation sector.

the demand for mobility. Doing so would require other policy strategies than those solely based on fuel prices.

Table 17: Cost evolution in transport, -15% reduction scenarios

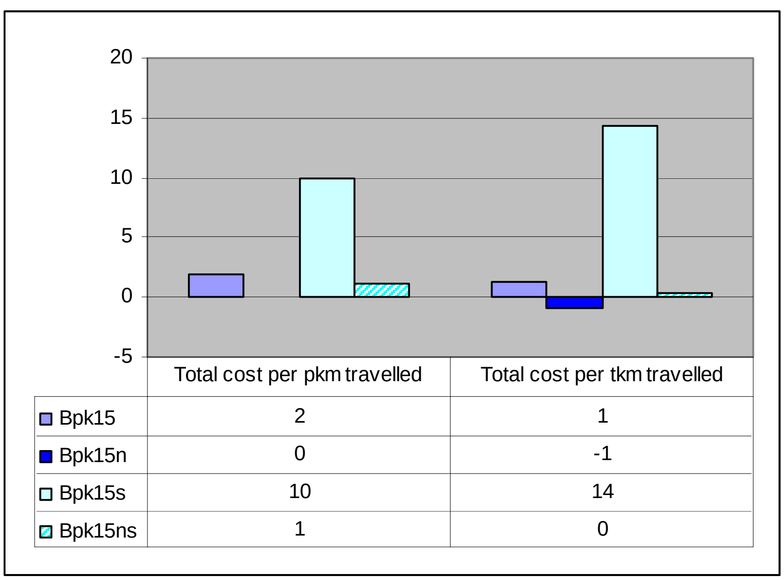
	2000	2020	2030	% change between 2000 and 2030
Total cost per pkm travelled (in €/pkm)				
Baseline	0.26	0.26	0.29	11
Bpk15	0.26	0.27	0.29	14
Bpk15n	0.26	0.27	0.29	11
Bpk15s	0.26	0.29	0.32	22
Bpk15ns	0.26	0.27	0.29	13
Total cost per tkm travelled (in €/tkm)				
Baseline	0.32	0.33	0.35	10
Bpk15	0.32	0.34	0.35	11
Bpk15n	0.32	0.33	0.34	9
Bpk15s	0.32	0.37	0.40	25
Bpk15ns	0.32	0.34	0.35	10

Source: PRIMES

The evolution of the total cost of transport is similar for passenger and freight transport, irrespective of the scenario. It is also comparable in the baseline and in the -15% reduction scenarios with the exception of the Bpk15s scenario. Again, the CO_2 reduction limitations in the power and steam sector in Bpk15s enhance the reduction effort in the demand sectors including transport with a direct impact on the costs of the sector.

Compared to the baseline, the total cost per pkm and tkm travelled in 2030 in the -15% reduction cases increases only slightly (less than 2%) except in the Bpk15s scenario where it increases by 10 to 14%, depending on the transport activity.

Figure 22: Costs in transport in the -15% reduction cases, difference from baseline in 2030 (%)



Source: PRIMES

d. CO_2 emissions by sector

Other indicators of interest are the sectoral CO_2 emissions indicators. Whereas the total CO_2 emissions are the same in 2030 in all -15% reduction scenarios, the allocation of emissions among sectors may vary from one scenario to another. The table below describes these CO_2 emissions in absolute values (Mt) for the year 2030 for the main sectors. The electricity and steam generation sector has two inputs, though, reflecting a subdivision between net emitted emissions and captured emissions (through the use of the CCS technology, denominated *CO_2 emissions captured*).

Table 18: CO_2 emissions by sector, comparison, year 2030 (Mt)

	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns
Electricity and steam generation					
- Net emissions	52.4	12.4	8.9	27.0	12.8
- CO_2 emissions captured	0.0	31.7	4.0	0.0	0.0
Industry	23.5	17.7	19.1	12.8	17.1
Residential	18.3	16.1	16.9	12.0	15.9
Tertiary	10.2	9.2	9.7	7.4	9.4
Transport	31.3	30.6	31.5	27.3	30.8

Source: PRIMES

The availability of nuclear power and/or CCS has a large impact on the power generation emissions. Compared to the baseline, the power generation emissions are at least 4 times smaller than the baseline emissions. When nuclear is being phased out, CCS takes care of three quarters of the power generation reduction; otherwise its contribution drops to one third. Table 18 also shows that the lower the reduction possibilities in the electricity and steam sector, the higher the reductions implemented in the final demand sectors.

e. Sensitivity analysis on prices

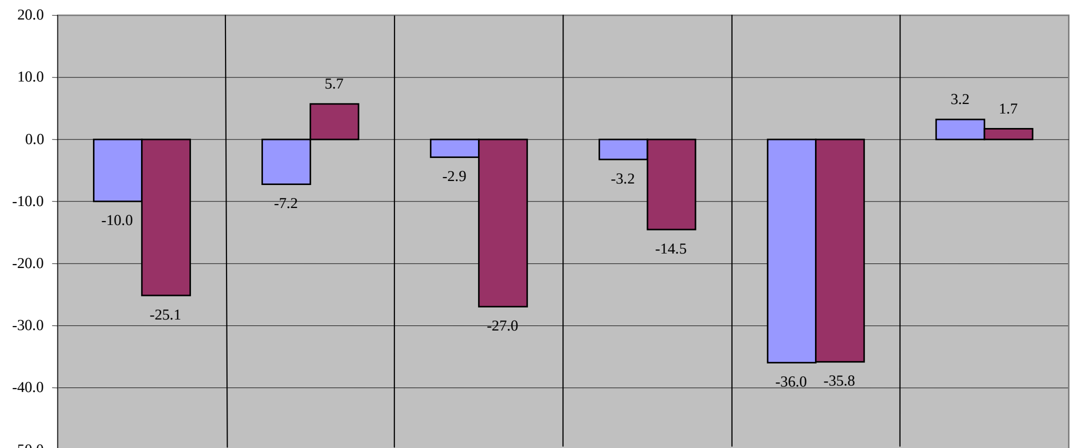
After the discussion on the alternative scenarios, this section deals with what happens if international energy prices are higher than expected in the baseline (see graph 8). This section only describes the coupled analyses (and not the general analysis) as to put the finger on the difference the changing of one parameter (here: the international energy prices) has on the scenario in which we are interested.

i Bpk15h vs. Bpk15nh

The graphs below show the same scenarios as the Bpk15 and Bpk15n alternative scenarios, but this time, adjusted for the higher oil and gas prices.

Primary energy demand

Figure 23: Primary energy related indicators for the Bpk15h and Bpk15nh scenarios, year 2030, difference with the baseline (%)

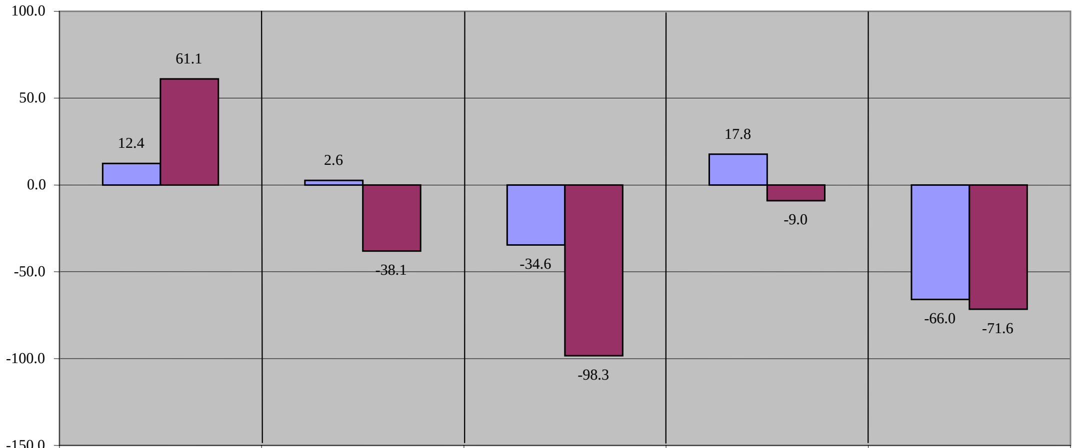


	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK15h	-10.0	-7.2	-2.9	-3.2	-36.0	3.2
BPK15nh	-25.1	5.7	-27.0	-14.5	-35.8	1.7

Source: PRIMES

This graph is quite similar to figure 12, the difference being the scale of changes and the total gas needs in the Bpk15h variant. Total gas needs in the sensitivity analysis on Bpk15 decrease by 3.2% (whereas they increased by 6.9% in the Bpk15 scenario), meaning that at these soaring prices, gas becomes too expensive and is replaced by other fuels where possible. For the rest, the effect on the import of fossil fuels, hence the import dependency indicator becomes somewhat more outspoken compared to the previous alternative scenarios. CO_2 emissions, on the other hand, remain constant due to the obligatory -15% reduction and plunge in both cases by 36% compared to the baseline. The share of renewable energy sources in the gross inland consumption will be slightly higher (0.3 and 0.5 percentage points respectively relative to Bpk15 and Bpk15n) to compensate for the loss in gas.

Figure 24: Electricity production related indicators for the Bpk15h and Bpk15nh scenarios, year 2030, difference with the baseline (%)



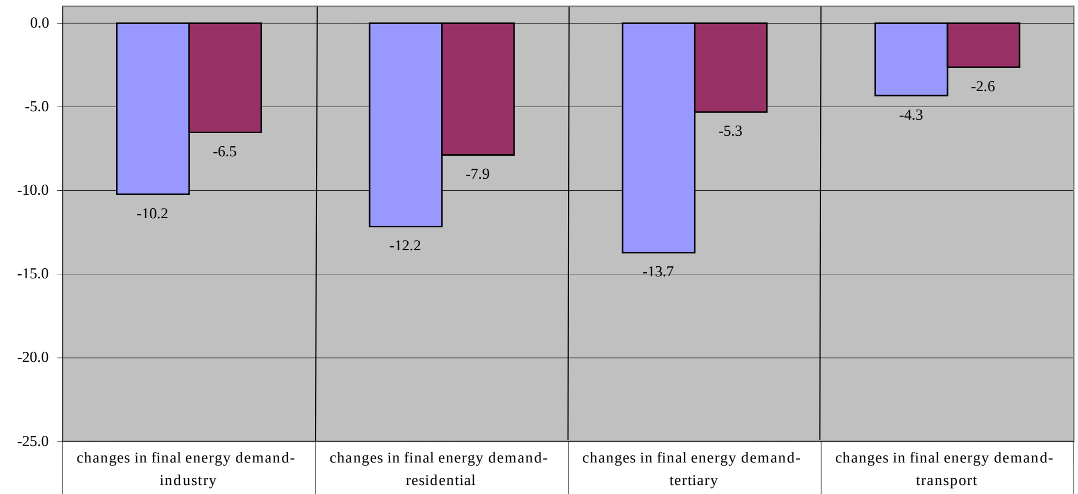
	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK15h	12.4	2.6	-34.6	17.8	-66.0
BPK15nh	61.1	-38.1	-98.3	-9.0	-71.6

Source: PRIMES

Electricity production at these high price conditions is depicted in figure 24. In both variants, compared with the Bpk15 and Bpk15n scenarios (see figure 14), the carbon free share climbs with almost 2 percentage points (1.4 and 1.5 respectively), much less gas is used in the generation of electricity, while coal is exploited somewhat more (but less than in the baseline): the absence of carbon in RES and the relatively more competitive coal prices take the credit for these changes. The production of electricity still happens in a cleaner way than in the baseline, although the higher use of coal will entail more CO_2 emissions compared to the Bpk15 and Bpk15n scenarios, hence the slightly less favourable percentages of CO_2 per MWh produced.

Final energy demand

Figure 25: Changes in sectoral final energy demand for the Bpk15h and Bpk15nh scenarios, year 2030, difference with the baseline (%)



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK15h	-10.2	-12.2	-13.7	-4.3
BPK15nh	-6.5	-7.9	-5.3	-2.6

Source: PRIMES

Soaring fuel prices coupled with the -15% restriction do make a difference in the final energy demand: energy is considerably less consumed in all end sectors, not only compared to the baseline but also compared to Bpk15 and Bpk15n. The transport sector again is the least affected by the price increases in both cases. This can be subscribed to the fact that the latter already has to support relatively high fuel levies; additional price rises caused by the soaring oil prices then do not have a proportionally equal impact on this sector. The other sectors do carry the weight of the higher prices. Nuclear production seems to lessen the impact on the final energy consumption, although even in this case, sacrifices on the demand side have to be made. Compared to the Bpk15 and Bpk15n scenarios, final demand reductions are more significant to compensate for the higher CO_2 emissions in the power sector.

2. Belgian reduction of energy CO_2 emissions by -30%

This part details all scenarios in which the CO_2 reduction constraint boils down to a reduction on the Belgian territory of the energy CO_2 emissions with 30% compared to the energy CO_2 emission level obtained in 1990. As in the previous part, the analysis consists of 2 components: first, a rather general overview of the energy indicator is given for the baseline and the alternative scenarios, second, different scenarios and variants are being pairwisely analysed and discussed.

a. Primary energy demand

i General

Table 19: Primary energy demand, comparison baseline vs. -30% reduction scenarios, year 2030 (%)

	Baseline	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Average annual growth rate 2000-2030	-0.1	-0.4	0.1	-1.2	-0.2
Structure of GIC (%)					
- Coal	20.8	12.5	3.1	0.8	1.3
- Oil	38.6	36.8	32.6	37.1	31.4
- Natural gas	35.3	41.5	29.0	48.8	28.2
- Nuclear	0.0	0.0	28.2	0.0	30.5
- RES	5.3	9.2	7.1	13.3	8.7

Source: PRIMES

With a more strict reduction constraint in place, an immediate impact on the average annual growth rate of the GIC can be noticed. This growth rate becomes negative in all scenarios, except when both nuclear and CCS are available (Bpk30n). In all other cases, primary energy consumption has to be reduced year after year in order to satisfy the -30% constraint. Turning to the structure of the primary demand, we see that coal almost disappears from the GIC landscape, while renewable energy sources take in a higher share than is the case in the baseline and in the -15% reduction scenarios.

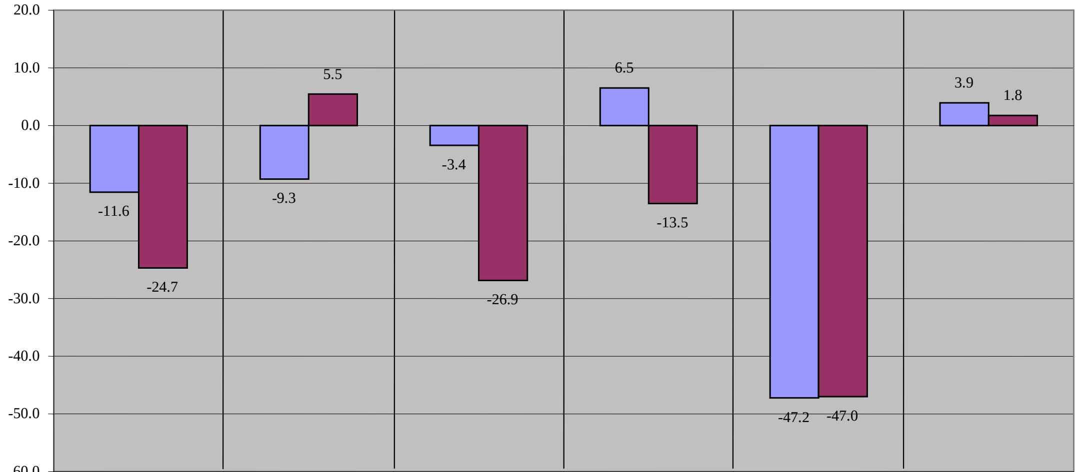
ii Coupled analysis

The coupled analyses presented below give the opportunity to detail the general analysis shown in table 19.

Bpk30 vs. Bpk30n

The first coupled analysis compares two scenarios in which the energy CO_2 emissions on Belgian soil decline by no less than 30%. The first scenario studies the impact such a reduction has in terms of the national energy system and its emissions, the second couples this same analysis with the fact that nuclear is allowed back in the energy playing field (prolongation of lifetime of existing plants and possibility of one new investment). Analysing these two scenarios together makes it possible to distinct the relative impact nuclear energy could have in pulling down the energy CO_2 emission level to such an ambitious level (-30% in 2030 compared to 1990).

Figure 26: Primary energy related indicators for the Bpk30 and Bpk30n scenarios, year 2030, difference with the baseline (%)



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK30	-11.6	-9.3	-3.4	6.5	-47.2	3.9
BPK30n	-24.7	5.5	-26.9	-13.5	-47.0	1.8

Source: PRIMES

This graph shows that at the ambitious reduction target of -30% for Belgium, CO_2 emissions have to decline by 47% compared to the baseline. In order to reach this goal, both variants carry on in a different way. In the Bpk30 scenario, net imports of energy are much lower than in the baseline, due in the first place to a fall in coal (-46%) and oil (-14%) consumption. Gas imports are approximately 6.5% higher, but are not able to make up for the difference. Total net imports then will be around 12% lower, which will have an effect on the import dependency indicator. The share of renewable energy sources in the primary consumption reaches 9.2%, almost 4 percentage points higher than the baseline (and 1.1 percentage point higher than the Bpk15 scenario).

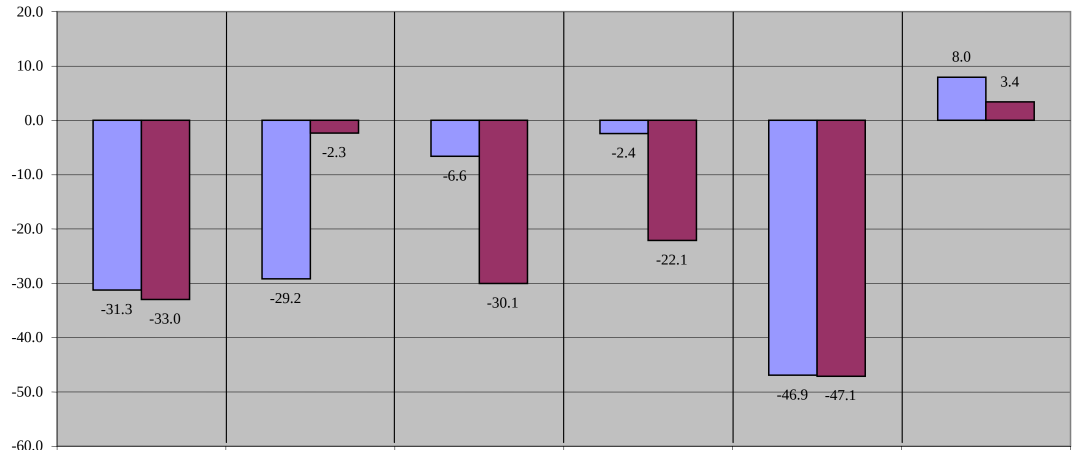
The (re)appearance of nuclear energy in the Bpk30n scenario shows a different picture. First, net imports drop with about one quarter compared to the baseline. This is basically due to a serious cutback in the consumption of polluting fossil fuels (coal, oil and gas). Even gas is not needed as much as in the baseline (almost 14% less overall consumption). This blank is filled in by a prolonged production and new investment in nuclear energy and more renewable energy sources that together make up for the difference[29]. The part of RES in the GIC climbs spectacularly: over the projection period, it goes from 1.5% in 2000 up to 7% by 2030, being 1.8 percentage points higher than the 2030 baseline figure.

Bpk30s vs. Bpk30ns

This analysis studies the impact on the primary energy needs when the CCS technology is no part of the emission reduction package for the -30% constraint.

[29] They even entail a bigger GIC which is 5.5% higher than the baseline GIC (for the major part due to the accounting convention on nuclear primary energy), while at the same time becoming less dependent of import.

Figure 27: Primary energy related indicators for the Bpk30s and Bpk30ns scenarios, year 2030, difference with the baseline (%)



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK30s	-31.3	-29.2	-6.6	-2.4	-46.9	8.0
BPK30ns	-33.0	-2.3	-30.1	-22.1	-47.1	3.4

Source: PRIMES

Without the CO_2 mitigating technology CCS and nuclear conform the law on the nuclear phase-out, the most striking effect of the -30% constraint is the free fall in the primary energy consumption: 29.2% fewer primary energy is consumed in 2030. This is in the first place caused by the dramatic drop in coal consumption: as coal emits the most CO_2 per unit of output and since CCS provides a technological solution to capture and store the CO_2 emitted by a.o. coal plants, the absence of the CCS technology will translate in a quasi vanishing of the solid energy fuels from the Belgian energy stage. Above that, fewer oil and gas makes it to Belgium. Consequently, this has an impact on the total net imports and the import dependency indicator. To fill up part of the void, more renewables are put into place (the share of RES climbs by 8 percentage points, reaching a high of 13.2% of the GIC). With nuclear (Bpk30ns), the same story goes, but even less gas is imported and consumed, while on the other hand the share of renewables stays 3.4 percentage points above the baseline level, representing 8.6% of the GIC.

b. Electricity and steam generation

i General

The impact of the ambitious -30% constraint on power generation is undeniable, proof delivered by the tables below.

Table 20: Power generation, comparison, year 2030 (%)

	Baseline	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Average annual growth rate 2000-2030	1.0	1.2	1.5	0.8	1.5
Structure of electricity generation (%)					
- Nuclear	0.0	0.0	49.4	0.0	49.5
- RES	11.8	22.7	17.9	32.8	22.3
- Fossil fuels	88.2	77.3	32.7	67.2	28.2

Source: PRIMES

Remarkable are the higher production growth rates relative to the baseline (the exception being the Bpk30s scenario). This can be explained by the partial substitution in the demand sectors of fossil fuels by electricity, the latter's price being less affected by the carbon value than the former. High shares of RES are reached in the -30% reduction scenarios which allow to replace a significant part of the fossil fuels.

Table 21: Installed power capacity, comparison, year 2030 (MW)

	Baseline	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Installed power capacity (MW)	22999	28592	29029	32367	31913
- Nuclear	0	0	7775	0	7775
- Wind onshore	1388	2049	2045	2049	2049
- Wind offshore	1019	3800	3800	3800	3800
- Solar PV	209	2477	209	9880	3792
- Biomass	1310	1587	1345	1570	1518
- Coal fired	7054	3706	837	0	0
- Gas fired	11240	12434	11823	11844	11992

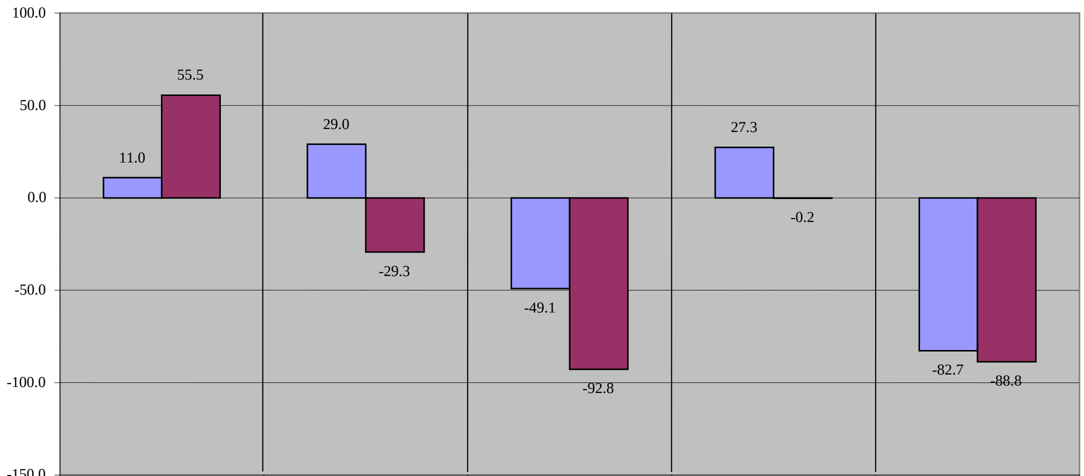
Source: PRIMES

An expansion of power capacity is expected in all -30% reduction cases, compared to the baseline. If nuclear can be exploited, the maximum potential assumed in the study is installed. As in the -15% reduction scenarios, the -30% restriction brings on a maximum of on- and off-shore wind parks all along with the use of solar PVs skyrocketing. The major difference between the -15% and -30% reduction scenarios exactly lies in the extended development of solar PV. In the Bpk30s scenario (i.e. neither nuclear nor CCS is available), the power capacity of solar PV is very close to the assumed maximum potential of 10 TW. Coal is being abandoned if CCS is no part of the emission reduction package as being too polluting.

ii Coupled analysis

Bpk30 vs. Bpk30n

Figure 28: Electricity production related indicators for the Bpk30 and Bpk30n scenarios, year 2030, difference with the baseline (%)



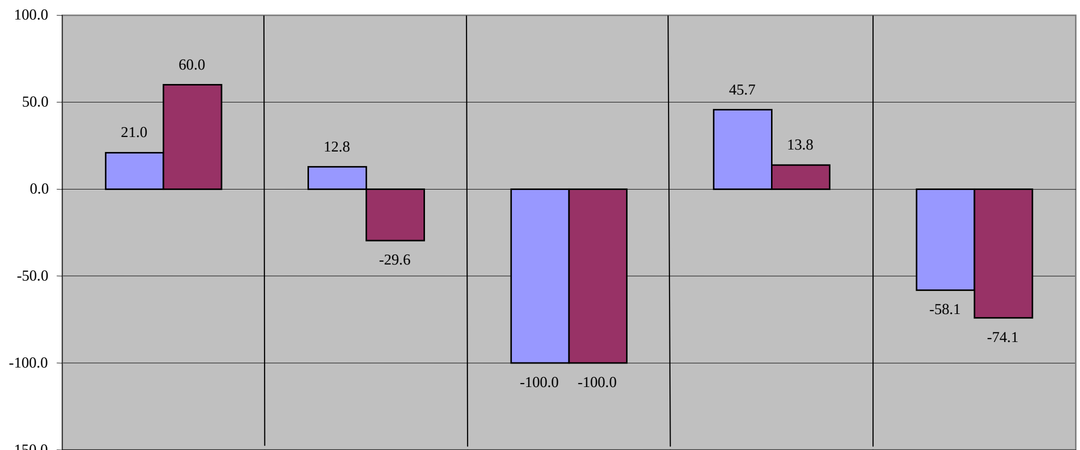
	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK30	11.0	29.0	-49.1	27.3	-82.7
BPK30n	55.5	-29.3	-92.8	-0.2	-88.8

Source: PRIMES

This graph further demonstrates the significant changes taking place in the generation landscape. For the Bpk30 scenario, an enlarged use of renewables and gas can be noted, while coal looses almost half of its volume. Things are different when nuclear is available: the carbon free share (for the major part driven by nuclear) surges and gas and coal are much less exploited in power generation (compared to both the baseline and the Bpk30 scenario). Both scenarios hold a remarkably cleaner power production, emitting over 80% less CO_2 per MWh produced.

Bpk30s vs. Bpk30ns

Figure 29: Electricity production related indicators for the Bpk30s and Bpk30ns scenarios, year 2030, difference with the baseline (%)



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK30s	21.0	12.8	-100.0	45.7	-58.1
BPK30ns	60.0	-29.6	-100.0	13.8	-74.1

Source: PRIMES

Without CCS, two things immediately become clear: the complete absence of coal in electricity generation and the less negative reduction figures for CO_2 emissions per MWh produced. As stated above, without CCS the use of coal is completely abolished as being too polluting. In the Bpk30s scenario, the share of renewables then goes up significantly, representing almost a third of power production by 2030. Next to renewable energy sources, hydrogen fuel cells come into play, standing for 13.1% of electricity production. The rest of the generation (around half) is being provided by natural gas. In the Bpk30ns scenario, fuel cells no longer appear, nuclear power provides almost half of the electricity, next to 28.2% supplied by fossil fuel plants (practically all natural gas plants) and 22.3% of renewable energy sources. Electricity production will, without the use of CCS, be more polluting than the other alternatives (Bpk30 and Bpk30n), but still be better off than in the baseline (without any CO_2 emission reduction constraint).

iii Cost implications

In the same way as for the -15% CO_2 constraint scenarios, the impact of the -30% reduction cases on the costs of electricity and steam generation is estimated through changes in average production costs.

Table 22 and figure 30 below compare the evolution of the average production costs in the baseline and in the different -30% reduction scenarios.

Table 22: Evolution of the average production costs of electricity and steam, -30% reduction scenarios (in €2000/(MWh_e+MWh_{th}))

	2000	2020	2030	% change between 2000 and 2030
Baseline	37.0	43.5	50.5	36.3
Bpk30	37.0	62.2	83.1	124.3
Bpk30n	37.0	49.2	51.0	37.7
Bpk30s	37.0	72.3	93.9	153.6
Bpk30ns	37.0	46.5	45.7	23.3

Source: PRIMES

In the Bpk30 scenario – the only scenario that assumes the same set of technology options as in the baseline - the average production cost more than doubles compared to the cost in 2000 (+124.3%). Compared to the baseline, this translates into a cost increase of 64.6% in 2030. The increase reflects the costs of CCS and of additional (and more expensive) renewable power capacities that prove to be cost-effective options to satisfy the constraint on total energy related CO_2 emissions at least cost. The average production costs are higher compared to the Bpk15 scenario because more power plants are equipped with CCS and more investments in solar PV are realised.

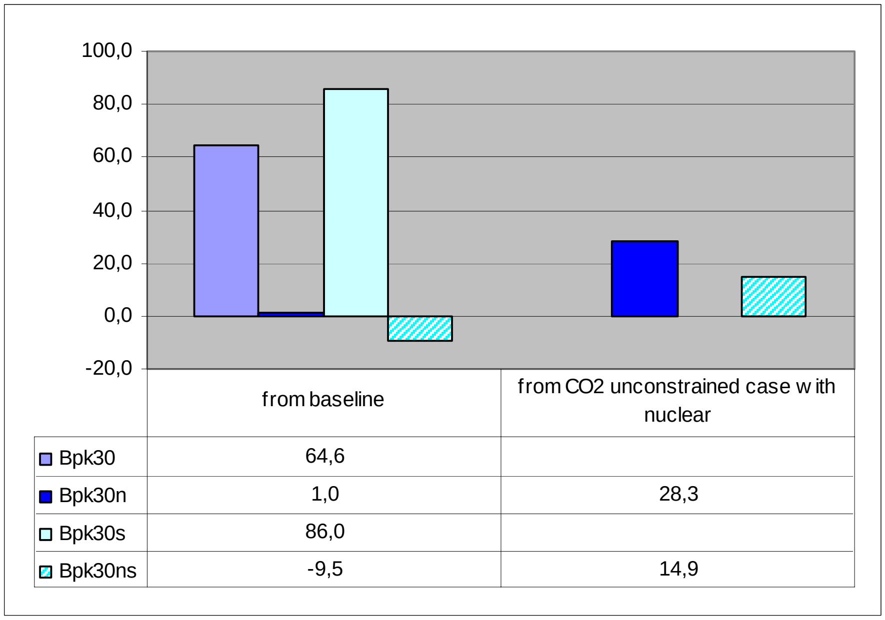
If one assumes that CCS is not a feasible option at the horizon of 2030 (scenario Bpk30s), the rise in cost is even higher (+153.6% compared to 2000 and +86.0% compared to the baseline). This trend is different from the one obtained in the Bpk15s scenario. Now, the strength of the constraint on energy related CO_2 emissions requires important investments in expensive solar PVs[30], investments that are close to the maximum potential, leading to higher average production costs in spite of the fact that CO_2 emission reductions in the power and steam sector are lower than in Bpk30. Here again, the energy system adapts to the CO_2 constraint in reducing comparatively more in the demand sectors.

As regards the evolution of average production costs in the CO_2 constrained scenarios with the nuclear option allowed (Bpk30n and Bpk30ns), the comparison with the baseline must be interpreted with caution when assessing the costs of achieving CO_2 emission reductions (see section V.C.1.b.iii). The changes in average production cost with respect to the baseline depicted in figure 30 do not only reflect the impact of the CO_2 constraint on the costs of the power and steam sector but also the different investment frameworks.

Keeping this clarification in mind, the results are the following: (1) the average production costs increase by respectively 37.7% and 23.3% in the Bpk30n and Bpk30ns scenarios between 2000 and 2030, and (2) the average production costs are respectively 1.0% higher and 9.5% lower than the costs in the baseline in 2030. To isolate the impact of the constraint on CO_2 emissions on the average production costs when nuclear is allowed, one has to calculate the difference with respect to a CO_2 unconstrained case with similar assumptions as to the development of nuclear energy. Doing so (cf. right part of figure 30), one sees that the -30% constraint leads to average production costs that are respectively 28.3% and 14.9% higher in 2030 than the costs in the unconstrained cases.

30 The potential of wind power both on- and off-shore is already fully implemented in the Bpk15 and Bpk15s scenarios.

Figure 30: Average production costs of electricity and steam in the -30% reduction cases, difference from unconstrained cases in 2030 (%)



Source: PRIMES

c. Final energy demand

i General

The final energy demand is also affected by the more strict CO_2 emission reduction constraint: it is considerably reduced compared to the baseline and even shows lower growth rates (and levels) than those reported in the -15% reduction cases.

Table 23: Final energy demand, comparison, year 2030 (%)

	Baseline	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Average annual growth rate 2000-2030	0.3	-0.2	0.0	-0.9	-0.3
Structure of FED					
- Solids	5	1	2	1	1
- Oil	39	38	38	36	37
- Gas	28	26	26	23	24
- Electricity	22	27	28	31	31
- Heat	4	4	4	4	4
- Other	2	4	4	5	4

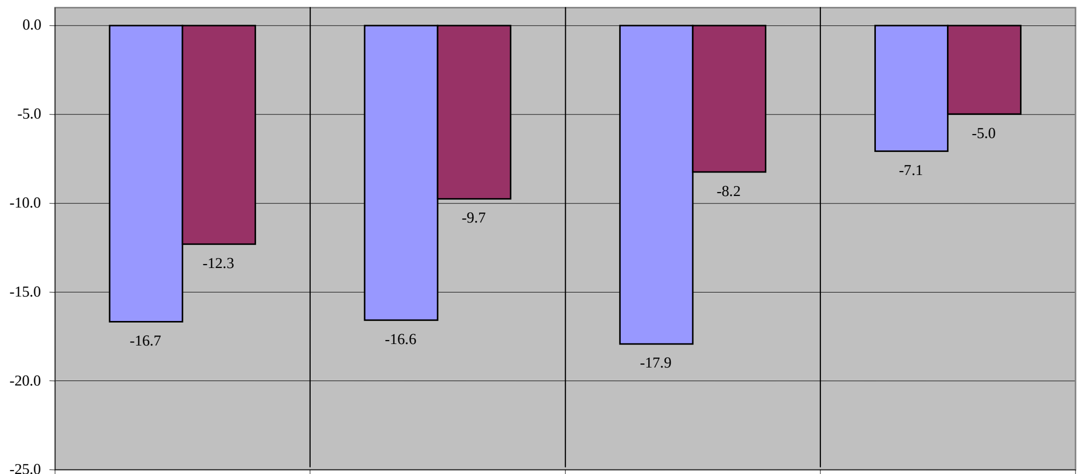
Source: PRIMES

All the -30% reduction scenarios have to hand in part of their final consumption, the Bpk30s scenario being hurt the most. The same conclusion as in the -15% cases can be drawn: solids have to give up most of their final demand share since coal is far less used, electricity takes on a major part and renewable energy sources (denominated as "*other*" in table 23) come into play (doubling their share in all the alternative scenarios).

Bpk30 vs. Bpk30n

Looking closer at the different scenarios through the coupled analysis, more specific conclusions can be drawn.

Figure 31: Changes in sectoral final energy demand for the Bpk30 and Bpk30n scenarios, year 2030, difference with the baseline (%)



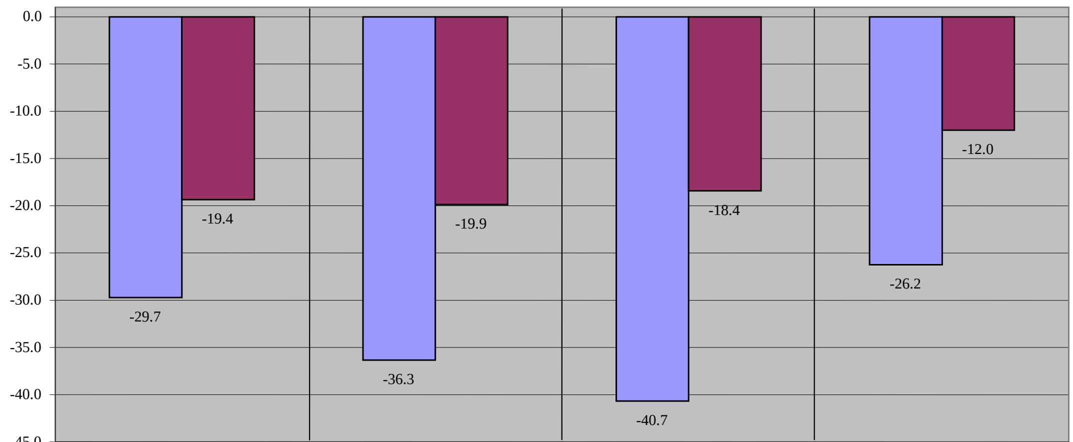
	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK30	-16.7	-16.6	-17.9	-7.1
BPK30n	-12.3	-9.7	-8.2	-5.0

Source: PRIMES

Relatively larger reductions in the final demand are attained compared to the -15% constraint scenarios. Because of the more severe restriction of energy CO_2 emissions in the Bpk30 and Bpk30n scenarios, the demand side has to lower its final energy consumption by considerably higher percentages. The drop is implemented through a reinforcement of the measures described in the section on the -15% reduction scenarios, namely a decrease in the demand for energy services and in transport activity, improvements in the energy efficiency of equipments and a shift away from the integrated steelworks in the iron and steel sector at the benefit of electric arc furnaces.

Bpk30s vs. Bpk30ns

Figure 32: Changes in sectoral final energy demand for the Bpk30s and Bpk30ns scenarios, year 2030, difference with the baseline (%)[31]



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK30s	-29.7	-36.3	-40.7	-26.2
BPK30ns	-19.4	-19.9	-18.4	-12.0

Source: PRIMES

Final energy demand really tumbles down in these 2 variants. Even when nuclear energy is used to produce electricity, final consumption is significantly lower than in the baseline. The scenario in which no nuclear and no CCS are taken up (Bpk30s) exhibits a major impact on the demand side. Even the traditionally least affected sector of transport has to give in more than a fourth of its final demand, the tertiary sector being the most hurt with a cutback in its final consumption of approximately 41%.

iii Cost implications

The imposition of a -30% reduction constraint on CO_2 emissions has significant impact on the energy related costs of the final demand sectors. The impact results from changes in consumer behaviour, production processes and technology choices triggered by the carbon values in order to adjust to the constraints. To assess the cost implications on the demand side, we have considered the same cost indicators as those defined in the section on the -15% reduction scenarios.

Again, the computed cost indicators do not represent the full costs related to the implementation of the reduction policies. They are only indicative of the relative difficulty to achieve the reduction constraints.

Table 24 and figure 33 give the results for industry according to the different -30% reduction cases. The cost implications for the tertiary sector are provided in table 25 and figure 34. The results for the residential sector are reported in table 26 and figure 35. Finally, the impacts on the costs of transport are summarised in table 27 and figure 36.

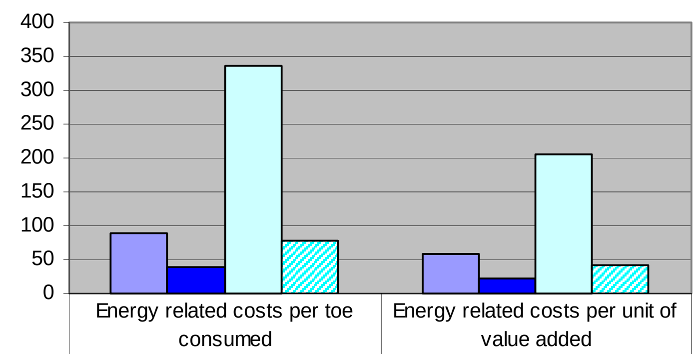
[31] Attention has to be paid to the fact that the scale is different than the one used for the previous final energy demand exercises.

Table 24: Evolution of energy related costs in industry, -30% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Energy related costs per toe consumed (in €2000/toe)				
Baseline	537	581	664	24
Bpk30	537	1002	1257	134
Bpk30n	537	814	930	73
Bpk30s	537	2197	2888	438
Bpk30ns	537	1029	1174	119
Energy related costs per unit of value added (*)				
Baseline	159	131	129	-19
Bpk30	159	190	203	27
Bpk30n	159	164	158	-1
Bpk30s	159	335	393	147
Bpk30ns	159	187	184	15

Source: PRIMES
(*) in €2000 energy related costs per thousand €2000 value added

Figure 33: Energy related costs in industry in the -30% reduction cases, difference from baseline in 2030 (%)



	Energy related costs per toe consumed	Energy related costs per unit of value added
Bpk30	89	58
Bpk30n	40	23
Bpk30s	335	206
Bpk30ns	77	43

Source: PRIMES

Overall, the evolution pattern of cost indicators in the different scenarios and changes with respect to the baseline are similar to those underlined in the cost analysis of the -15% reduction cases. There are two main differences, however. First, the scale of the changes is much more significant. For instance, the energy related costs per toe consumed can be multiplied by up to six between 2000 and 2030 (tertiary sector and Bpk30s scenario) whereas the increase is at most 170% in the -15% reduction cases (domestic sector and Bpk15s scenario). As regards the increase from the baseline in 2030, it ranges from 24% to 365% for the energy costs per toe consumed, depending on the scenario and the sector, from 21% and 206% for the energy costs per unit of value added in the tertiary sector and industry and from 12% to 104% for the energy costs per household. The highest figures correspond to the Bpk30s scenario that is characterised by an important emission reduction effort in the demand sectors.

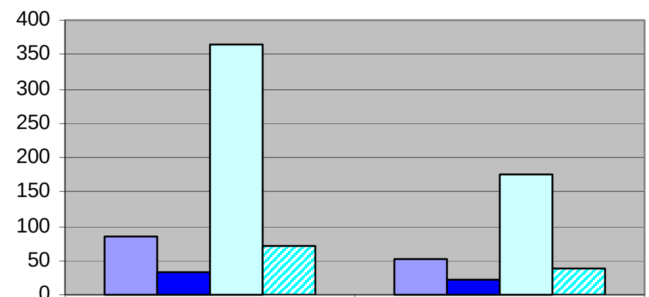
Table 25: Evolution of energy related costs in the tertiary sector, -30% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Energy related costs per toe consumed (in €2000/toe)				
Baseline	817	914	1071	31
Bpk30	817	1513	1983	143
Bpk30n	817	1214	1412	73
Bpk30s	817	3727	4979	509
Bpk30ns	817	1561	1823	123
Energy related costs per unit of value added (*)				
Baseline	21	20	21	1
Bpk30	21	28	32	53
Bpk30n	21	24	26	22
Bpk30s	21	51	58	178
Bpk30ns	21	28	29	40

Source: PRIMES
(*) in €2000 energy related costs per thousand €2000 value added

The second major difference between the -15% and -30% reduction cases is the weakening of the role of nuclear energy in moderating the cost increases in the demand sectors provided the CCS option is made available in the power and steam sector.

Figure 34: Energy related costs in the tertiary sector in the -30% reduction cases, difference from baseline in 2030 (%)



	Energy related costs per toe consumed	Energy related costs per unit of value added
Bpk30	85	52
Bpk30n	32	21
Bpk30s	365	176
Bpk30ns	70	39

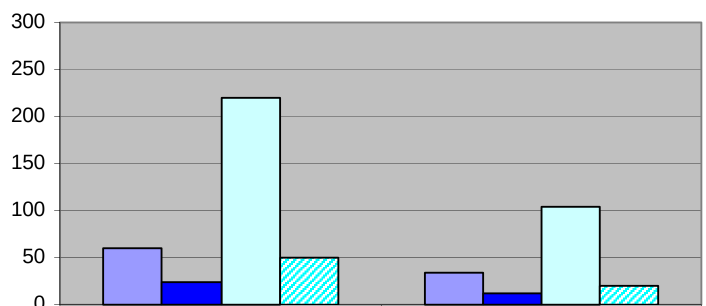
Source: PRIMES

Table 26: Evolution of energy related costs in the residential sector, -30% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Energy related costs per toe consumed (in €2000/toe)				
Baseline	962	1305	1572	63
Bpk30	962	1957	2527	163
Bpk30n	962	1647	1954	103
Bpk30s	962	3834	5026	423
Bpk30ns	962	2016	2354	145
Energy related expenditures per household (in €2000)				
Baseline	2150	2695	2979	39
Bpk30	2150	3384	3997	86
Bpk30n	2150	3051	3344	56
Bpk30s	2150	5102	6066	182
Bpk30ns	2150	3331	3577	66

Source: PRIMES

Figure 35: Energy related costs in the residential sector in the -30% reduction cases, difference from baseline in 2030 (%)



	Energy related costs per toe consumed	Energy related expenditures per household
Bpk30	61	34
Bpk30n	24	12
Bpk30s	220	104
Bpk30ns	50	20

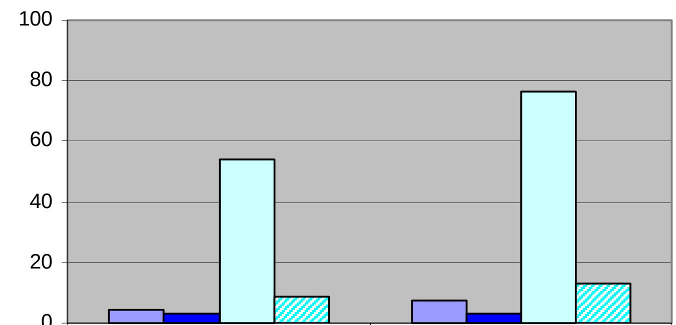
Source: PRIMES

Table 27: Cost evolution in transport, -30% reduction scenarios

	2000	2020	2030	% change between 2000 and 2030
Total cost per pkm travelled (in €/pkm)				
Baseline	0.26	0.26	0.29	11
Bpk30	0.26	0.28	0.30	16
Bpk30n	0.26	0.27	0.30	15
Bpk30s	0.26	0.39	0.44	71
Bpk30ns	0.26	0.29	0.31	21
Total cost per tkm travelled (in €/tkm)				
Baseline	0.32	0.33	0.35	10
Bpk30	0.32	0.36	0.37	18
Bpk30n	0.32	0.34	0.36	13
Bpk30s	0.32	0.54	0.61	94
Bpk30ns	0.32	0.37	0.39	24

Source: PRIMES

Figure 36: Costs in transport in the -30% reduction cases, difference from baseline in 2030 (%)



	Total cost per pkm travelled	Total cost per tkm travelled
Bpk30	5	8
Bpk30n	3	3
Bpk30s	54	76
Bpk30ns	9	13

Source: PRIMES

d. CO_2 emissions by sector

Finally, sectoral CO_2 emissions are scrutinised.

Table 28: CO_2 emissions by sector, comparison, year 2030 (Mt)

	Baseline	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Electricity and steam generation					
- Net emissions	52.4	6.5	3.2	18.6	12.7
- CO_2 emissions captured	0.0	39.7	14.6	0.0	0.0
Industry	23.5	12.8	14.0	9.7	11.5
Residential	18.3	13.7	14.8	8.3	11.5
Tertiary	10.2	8.2	8.8	5.5	7.4
Transport	31.3	29.0	29.8	23.0	27.5

Source: PRIMES

The large impact CCS has on the power generation emissions is telling. When CCS is available, it is used to capture a major part of the emissions. For the rest, industry and the residential sector deliver most of the work: they substantially reduce their emission level.

e. Sensitivity analysis on prices

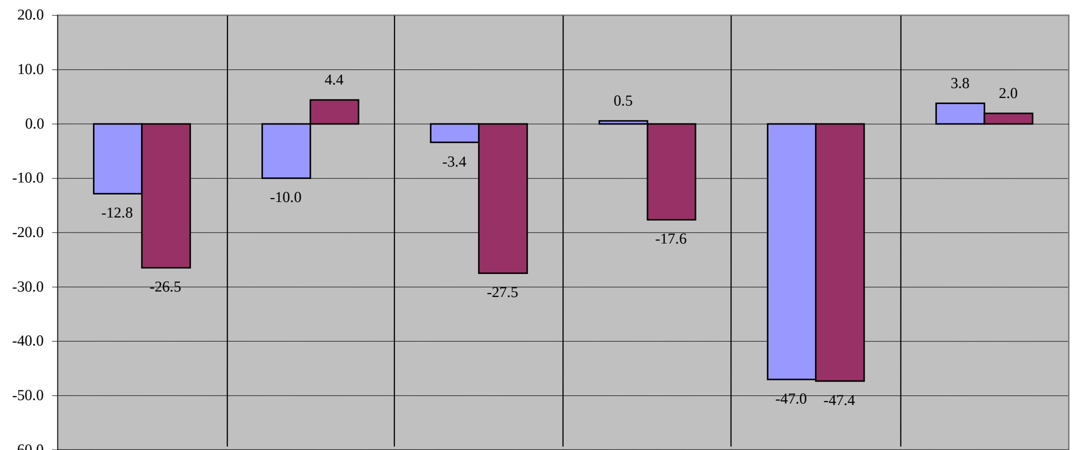
After the discussion on the -30% reduction scenarios, this section deals with what happens if international energy prices are higher than expected in the baseline (see graph 8). This section only describes the coupled analyses (and not the general analysis) as to put the finger on the difference the changing of one parameter (here: the international energy prices) has on the scenarios in which we are interested.

i Bpk30h vs. Bpk30nh

When we take the exact same conditions as in the Bpk30 and Bpk30n scenarios and add higher energy prices, the following graphs result.

Primary energy demand

Figure 37: Primary energy related indicators for the Bpk30h and Bpk30nh scenarios, year 2030, difference with the baseline (%)

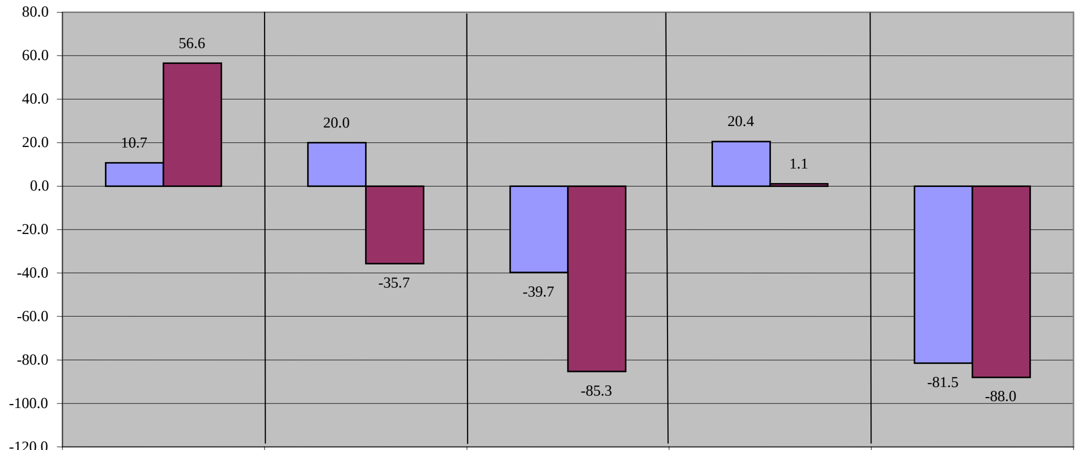


	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK30h	-12.8	-10.0	-3.4	0.5	-47.0	3.8
BPK30nh	-26.5	4.4	-27.5	-17.6	-47.4	2.0

Source: PRIMES

The same trends as in the Bpk30 and Bpk30n coupled analysis on primary consumption (figure 26) can be observed, although more explicit. The impact of the higher prices is particularly noticeable in the net imports indicator and in the total gas needs, which are (significantly) lower than in the baseline, even lower than in the Bpk30 and Bpk30n scenarios. The 2 phenomena can be jointly explained as, due to the higher fuel prices, the nation adapts to a smaller and/or less costly gross inland consumption. In the first case (Bpk30h), more expensive fuels will be substituted (although substitution options are scarce) and/or eliminated. Substitution takes place between fossil fuels and RES: solids and oil will be imported less; the amount of imported natural gas will stay approximately equal (but is significantly lower than in the Bpk30 and Bpk30n scenarios). The share of renewables in the gross inland consumption then will be higher (this is for the most part due to wind and biomass, but solar energy is also consumed more). Elimination takes place through a dip in the GIC: the primary consumption of energy will decline by 10% when the post-2012 constraint of -30% is installed simultaneously with skyrocketing energy prices. In the second variant (Bpk30nh), the declining imports caused by the soaring prices are for the major part replaced by nuclear energy. Even gas is less needed because of the competitive nuclear power. Next to nuclear, wind and biomass are being called upon. These renewable sources are consumed more (2 percentage points higher than in the baseline), even marginally more than in the Bpk30n scenario.

Figure 38: Electricity production related indicators for the Bpk30h and Bpk30nh scenarios, year 2030, difference with the baseline (%)



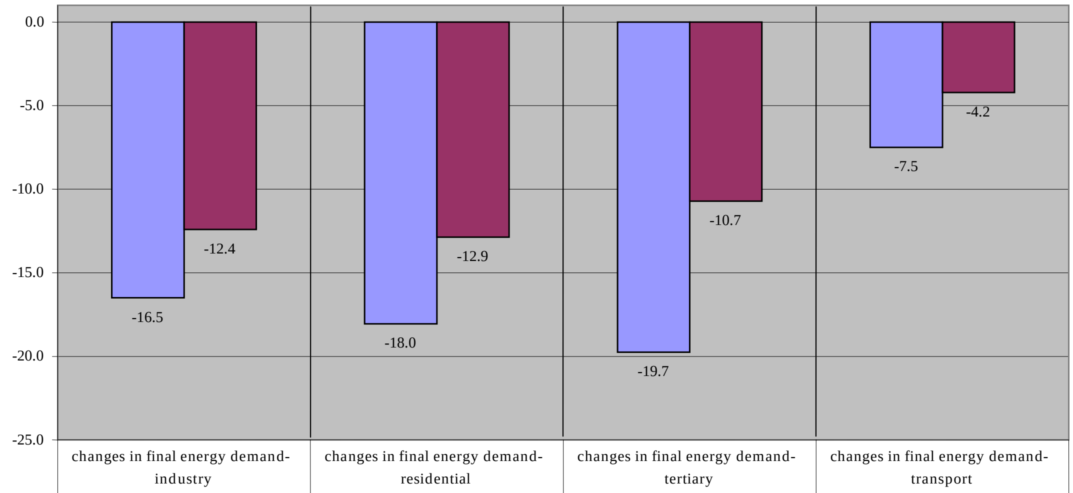
	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK30h	10.7	20.0	-39.7	20.4	-81.5
BPK30nh	56.6	-35.7	-85.3	1.1	-88.0

Source: PRIMES

The same pattern as in the Bpk30 and Bpk30n alternative scenarios repeats itself. When nuclear is being phased out, gas is used more in the production of electricity; coal is exploited less, although its share in electricity production still reaches almost 25%. With nuclear part of the generation park, the share of coal plunges to 5.5%, a quarter of the production will be filled in by gas, 50.1% will be nuclear and around 18% will be generated by renewable sources. The changed fuel mix will lead to a power production that emits not nearly as much CO_2 per MWh produced as the baseline.

Final energy demand

Figure 39: Changes in sectoral final energy demand for the Bpk30h and Bpk30nh scenarios, year 2030, difference with the baseline (%)



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK30h	-16.5	-18.0	-19.7	-7.5
BPK30nh	-12.4	-12.9	-10.7	-4.2

Source: PRIMES

Relative to the Bpk30 and Bpk30n scenarios as well as the baseline, final demand differences are most outspoken for the residential and tertiary sector. These two sectors will have to undergo the largest adaptations in their final consumption patterns because of the new high prices. Transport and industry linger: transport because of the existence of high fuel taxes, industry because of the already important energy efficiencies obtained in the baseline and the rather small medium term flexibility for structural changes.

3. Comparison of CO_2 reduction scenarios: key findings

The previous analyses have described the impact the two CO_2 emission reduction constraints (respectively -15% and -30%) implied in terms of some major energy indicators. In general, we could say that a more severe reduction constraint (-30% versus -15%) translates into more pronounced values on these indicators, hence has a larger impact on the national energy system. In order to follow this road further and to carefully pinpoint the differences in effect caused by the different constraints, this section extends the analysis and puts the two constraints (meaning: the alternative scenarios linked to each constraint) next to one another.

a. CO_2 reduction options

In the following table, the relative contribution of CO_2 reduction options (or measures) in the different scenarios is being summarised through the use of a selection of indicators. CO_2 reduction options are grouped into four broad categories: energy savings, carbon free production technologies or energy forms, cogeneration of heat and electricity (CHP) and carbon capture and storage (CCS).

Table 29: Contribution of CO_2 reduction options in the -15% and -30% constraint, year 2030, difference from baseline (except for CHP and CCS where absolute figures are shown)

		Bpk15	Bpk15n	Bpk15s	Bpk15ns	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Energy savings	Final energy demand	3117	1081	7893	2161	5802	3717	13068	7086
(ktoe)	*of which*								
	industry	1387	738	2896	1189	2309	1704	4117	2680
	residential	896	297	2198	574	1660	975	3637	1988
	tertiary	578	90	1364	203	1033	474	2345	1062
	transport	256	-43	1435	195	801	563	2968	1356
	Fuel input elec/steam	1101	10685	4579	10525	279	9494	5653	10588
Nuclear (MW)		0	7775	0	7775	0	7775	0	7775
RES for electricity	wind on	657	588	670	657	661	657	661	661
(MW)	wind off	2781	2772	2781	2781	2781	2781	2781	2781
	solar PV	0	0	5694	0	2268	0	9671	3583
	biomass	258	103	321	265	277	35	259	207
CHP[1]		14.3%	16.3%	14.5%	15.0%	12.8%	9.6%	14.1%	12.4%
RES in FED (ktep)		118	14	277	13	460	368	428	295
CCS[2]		72%	31%	0%	0%	86%	82%	0%	0%
CV (€/t CO_2)		123	60	524	105	320	186	2150	490

Source: PRIMES
[1] share of electricity produced in CHP units
[2] share of (gross) CO_2 emissions from electricity and steam production that is captured with the CCS technology

The comparison of the -15% with the -30% scenarios unravels some major differences, more specifically in the energy savings made in the final energy demand, in the installation of solar PVs, in the CHP used for electricity production, in the use of renewable energy sources in the final demand sectors and finally, in the amount of CO_2 emissions captured and stored.

Final energy savings are much larger in the -30% scenarios. This is due to the fact that, given the stricter reduction target and higher carbon values needed to meet it, it becomes cost-effective for the demand side to put in more effort. These enlarged efforts are translated into larger energy savings. Compared to the final energy consumption recorded in the baseline, energy savings represent 3 to 19% in 2030 in the -15% reduction scenarios and 9 to 32% in the -30% reduction cases.

Converted to the sector level, we see that industry and the residential sector are the largest contributors to energy savings in absolute terms. In relative terms[32], however, the contribution of industry, the tertiary and the residential sectors are comparable for a given scenario whereas transport contributes far less in all -15% reduction cases. To illustrate this statement, we calculate that energy savings in the Bpk15 scenario represent about 10% of the final energy consumption in all sectors but transport where they are estimated at 2%. Moving from 15% to 30% for the emission reductions, energy savings increase proportionally more in transport than in the other sectors. In other words, when the CO_2 emission reduction constraint becomes more stringent, transport has to come up with a larger relative effort whereas proportionally less stress is put on the other sectors, especially in the scenarios where CCS is not included. A deeper insight into the kind of energy savings is provided in section V.C.3.d below.

Fuel savings in the power and steam generation sector relate to the consumption of fossil fuels and biomass in thermal power plants. The imposition of carbon values has effects on fuel choices in the

[32] I.e. taking into account the shares of the sector in the total final energy demand (cf. III.B.3).

power and steam sector. These effects are however highly sensitive to the availability of nuclear and/or CCS. As expected, fuel savings are the highest in the scenarios including the nuclear option and the lowest in the scenarios where CCS is assumed to be available but where nuclear power plants are decommissioned.

Turning to carbon free power production technologies, we see that when nuclear is an option (extended lifetime and/or new investment), either in the -15% or in the -30% case, the maximum assumed capacity is used for production. Also, both CO_2 reduction constraints lead to the maximum (assumed) potentials of wind power, be it on- or off-shore and irrespective of the scenario[33].

The use of solar PVs, on the other hand, is much larger in the -30% scenarios. This can be subscribed to the fact that the -30% reduction entails a larger carbon value, and that at this new carbon value, solar PVs become commercially attractive. More remarkable is the result of the Bpk30s scenario where the maximum (assumed) capacity is almost reached. The constraints on CO_2 emissions lead also to additional investments in biomass-fired power plants, that are comparable in all scenarios except the ones where nuclear and CCS are accounted for.

Surprisingly, the share of combined heat and power in electricity production[34] is lower in all CO_2 reduction scenarios than the share projected in the baseline in 2030 (i.e. 18%). Moreover, CHP seems to reach smaller shares in electricity production in the -30% reduction scenarios than in the -15% reduction cases. It should be recalled that fossil fuel inputs (CHP uses mainly natural gas in the baseline) become more expensive in the alternative scenarios due to the carbon values imposed on fossil fuel consumption in relation to the carbon content of fuels and the global level of CO_2 reduction aimed at. Furthermore, the electric capacity of CHP units is usually below 300 MW so that CCS is not applicable to them. The combination of the above two factors explains the decrease in the share of CHP especially when the CVs are the highest: the role of CHP in limiting CO_2 emissions (through better conversion efficiencies) is partly overruled by unfavourable gas prices and CO_2 emissions that cannot be reduced at the source in the present state and expected development of the CCS technology.

In this connection, the table above underlines the significant role CCS could play in achieving the CO_2 reduction constraints if it becomes available and reliable by 2020. Furthermore, the CCS technology is far more exploited in the -30% cases due to the stricter constraint and the subsequent higher carbon value which has an effect on its relative price.

Finally, the use of renewable energy sources (mainly biomass and solar thermal) in the final energy demand is higher than in the baseline and significantly higher in the -30% scenarios than in the -15% reduction cases. Nevertheless, their share in final energy demand remains small: it is estimated to be at most 4%.

b. Total and sectoral CO_2 emissions

This section aims at further illustrating the differences between scenarios in the development of energy related CO_2 emissions (see also previous sections on this issue).

The different outset of the alternative scenarios leads to different paths to arrive at the -15%/-30% reductions. This is what is depicted in the following graph: Figure 40 shows how each alternative scenario arrives at its final reduction target (-15% or -30%).

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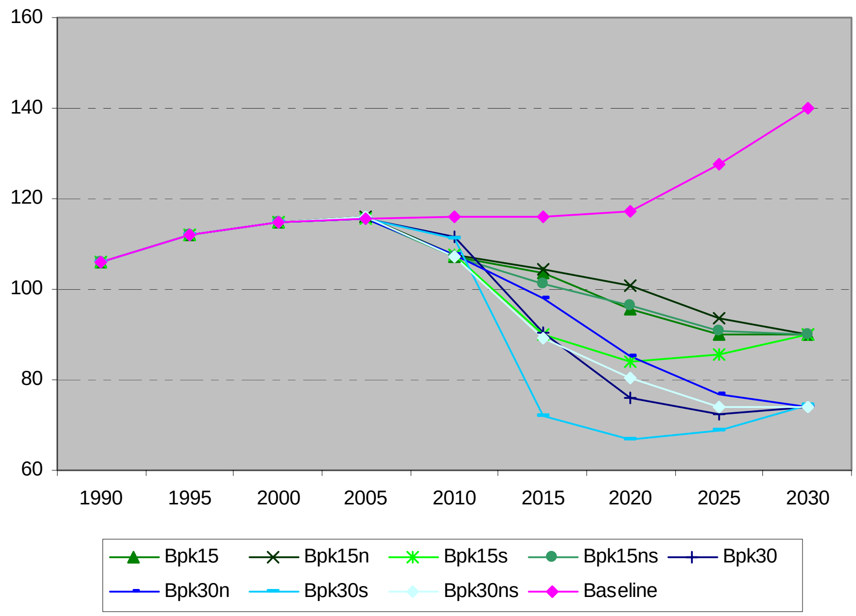
33 To be more precise, the maximum potential is reached in all scenarios but the Bpk15n scenario where there is a small gap of about 50 MW of onshore wind between the capacity installed and the maximum potential.

34 CHP relates here mainly to industrial CHP, the possible development of micro cogeneration in the residential sector is beyond the scope of the present analysis.

Figure 40: Total energy related CO_2 emissions, comparison, period 1990-2030 (Mt)

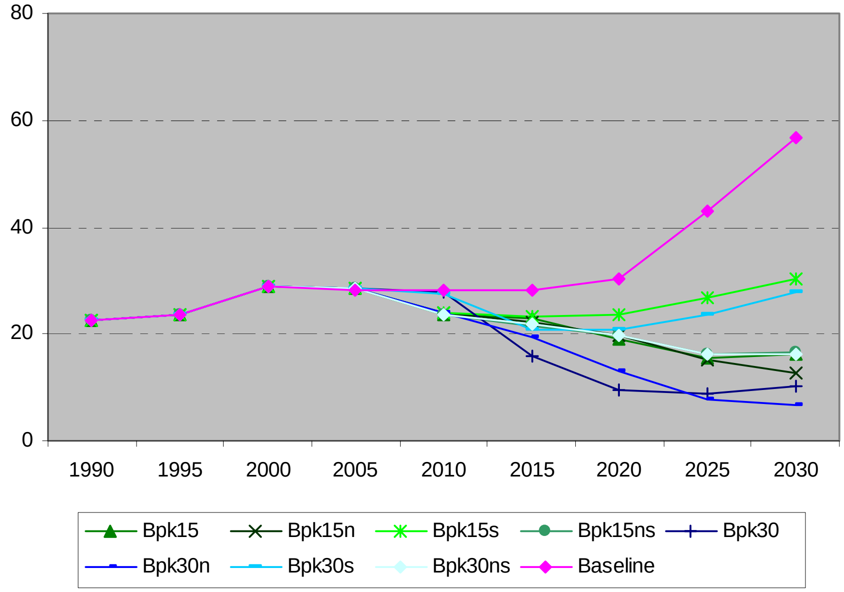


Source: PRIMES

This graph demonstrates that the respective reduction targets are being reached in a smoother way when nuclear and/or CCS are part of the electricity generation options than when they are not. The most drastic road to reduction seems to be to exclude both options from the CO_2 emissions reduction package: a large dive in the period 2010-2020 can then be noted, followed by a small increase in emissions during the next decennium.

The evolution of energy related CO_2 emissions in the different sectors may also differ strongly according to the scenario. This is illustrated in the following graphs, each representing a specific sector.

Figure 41: Energy related CO_2 emissions in the power and steam sector and energy branch (Mt)



Source: PRIMES

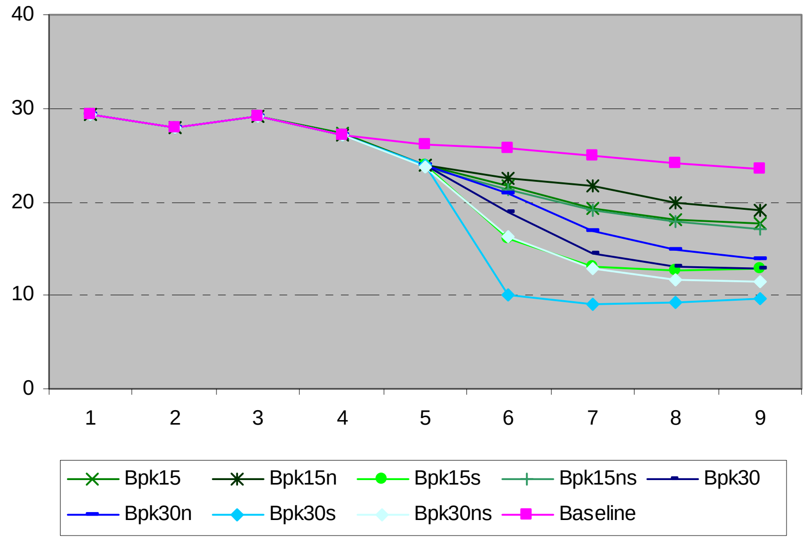
The graph on the power and steam sector underlines the role played by this sector in the reduction effort required to achieve the CO_2 constraints imposed on the Belgian energy system. It illustrates the impact CO_2 free production technologies (nuclear and RES) and CO_2 abatement devices may have on the emissions of the sector.

First, when looking at the evolution in the Bpk15s and Bpk30s scenarios (i.e. without nuclear and CCS), one can see the significant contribution of renewable energy sources: CO_2 emissions in the Bpk15s and Bpk30s scenarios are significantly lower than in the baseline. More precisely, emissions follow a U-curve: they first decrease over 2005 and 2020 and then increase over 2020-2030. In 2030, the emissions of the power and steam sector are above the level of 1990 (respectively +24% and +36%) but close to the level recorded in 2000. The difference between these two scenarios is however significant in terms of marginal abatement costs. The additional reduction achieved in the Bpk30s scenario compared to Bpk15s comes from expensive solar photovoltaics as all the assumed potential of wind power is already realised in the -15% reduction case.

Second, the graph shows that nuclear power and/or CCS allow for additional reductions. In these cases, CO_2 emissions in the power and steam sector decrease steadily to reach emission levels below the 1990 level. Up to 2025, nuclear power and CCS act more or less as substitutes in the reduction effort whereas nuclear allows for some additional reductions in the period 2025-2030.

Finally, when neither nuclear nor CCS are considered as possible options, emission reductions achieved in 2030 compared to the baseline are roughly half the reductions achieved otherwise.

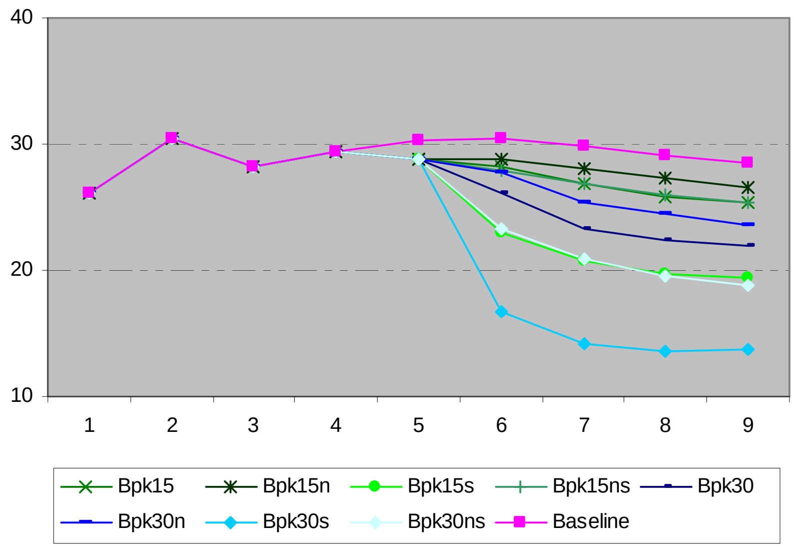
Figure 42: Energy related CO_2 emissions in industry (Mt)



Source: PRIMES

The response of industry to the introduction of emission reduction constraints is a further reduction of its CO_2 emissions compared to the baseline. Indeed, already in the baseline, the emissions of industry are lower than the level of 1990 (-20% in 2030). The largest emission reductions occur in the Bpk30s scenario which records the highest carbon value. In this particular case, CO_2 emissions are 67% below the 1990 level. By contrast to the other final demand sectors (see infra), emission reductions in industry do not come primarily from cuts in energy requirements but also from changes in the fuel mix towards the use of less carbon intensive fuels (e.g. electricity) as a result of changes in production processes. The principal example of such changes is the iron and steel sector where the share of electric arc furnaces increases at the expense of integrated steelworks using coal as a fuel.

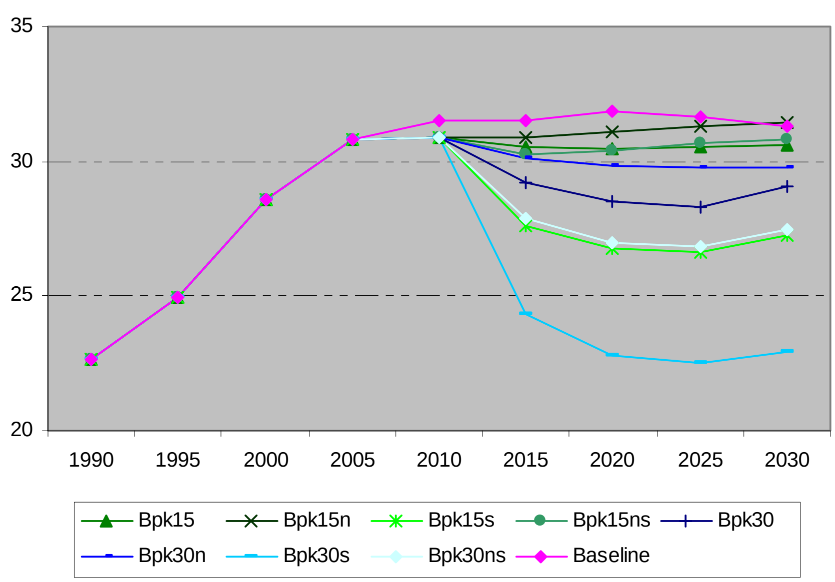
Figure 43: Energy related CO_2 emissions in the tertiary and residential sectors (Mt)



Source: PRIMES

The responsiveness of the tertiary and residential sectors to CO_2 emission constraints is comparable to that of industry. More precisely, the percentages of decline in emissions from baseline levels recorded in each scenario are similar in either sectors (or group of sectors). However, the bulk of reduction in the residential and tertiary sectors occurs mainly from changes in consumer's behaviour (leading to a lower demand for energy services) and from the adoption of more efficient technologies. Shifts in the fuel mix do not contribute much to emission reductions as the share of less carbon intensive energy forms (electricity and natural gas) is already high in the baseline.

Figure 44: Energy related CO_2 emissions in the transport sector (Mt)



Source: PRIMES

The development of CO_2 emissions in the transport sector shows very contrasting trends according to the scenario. Up to a carbon value of around 200 € per ton CO_2, carbon dioxide emissions from transport are not significantly reduced compared to baseline. Due to the existence of high consumption taxes on transport fuels, the additional energy cost faced by consumers brought along by the implementation of a carbon value does not alter much the overall energy use costs in this sector and, hence, the consumption and emission patterns. Consequently, CO_2 emissions in 2030 remain within a range of 32 to 39% above the 1990 emission level in scenarios Bpk15, Bpk15n, Bpk15ns, Bpk30n (the increase is 39% in the baseline).

When the emission constraint becomes more strict (-30%) and/or reduction possibilities are limited or rather expensive in the power supply sector (e.g. Bpk15s), CO_2 emission savings become larger. The largest savings occur in scenario Bpk30s and correspond to a CV of 2 150 €/t CO_2 which is equivalent to more than ten times the current price of a barrel of crude oil. In this case, CO_2 emissions return to the level of 1990 in 2030.

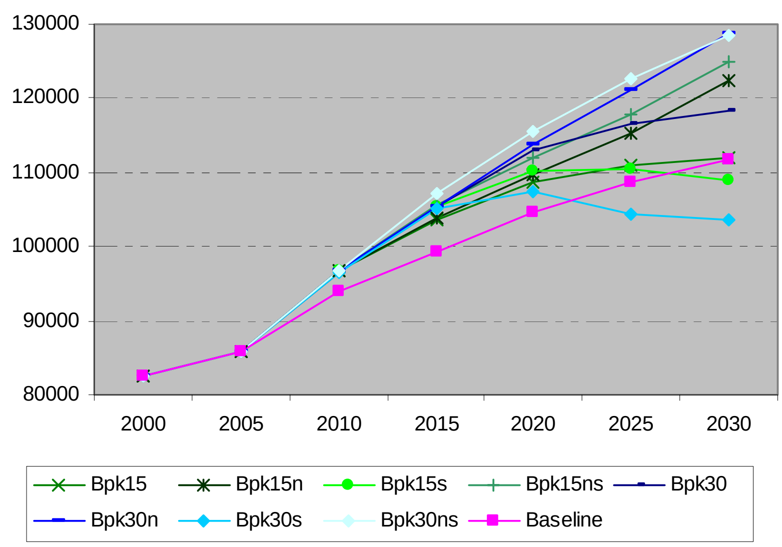
Consumers react to the introduction of the emission constraints by reducing overall transport activity (passengers and freight), shifting towards less energy intensive transport modes and adopting more efficient vehicle technologies. Changes in the fuel mix are, however, very limited. Thus, emission reductions in transport go hand in hand with a decline in energy requirements.

The implementation of strong specific policies aimed at promoting (further) the use of low or zero carbon fuel emissions in transport (hydrogen, biofuels, etc.) or at changing the mobility patterns, should have an impact on the cost-effectiveness of CO_2 reductions in transport, they are, nevertheless, out of the scope of the present analysis.

c. Electricity generation

As already stressed in previous sections, constraints on CO_2 emissions have an impact on the level of electricity production. Furthermore, the impact depends on the limit imposed on the emissions, on the availability of carbon free or carbon abatement technologies and on the relative costs between these technologies and electricity saving measures on the demand side.

Figure 45: Electricity generation (GWh)



Source: PRIMES

The first message the graph provides is that CO_2 emission constraints lead in general to an increase in the production of electricity compared to baseline. It is only when both nuclear and CCS are not part of the power generation park that electricity generation declines with respect to the baseline. The highest increase is 15% above the baseline (Bpk30n and Bpk30ns). The highest decrease is 7.4% below the baseline (Bpk30s). The two figures hold for the year 2030.

As regards the strength of the constraint, one sees that in general the higher the constraint the higher the electricity generation. The only exception occurs in the scenarios without nuclear and CCS where electricity production is lower in the Bpk30s case than in Bpk15s.

The availability (and costs) of carbon free or carbon abatement technologies in the power sector plays also a significant role in the development of electricity production. Provided they are passed on to the final consumers, lower average production costs recorded in the reduction scenarios with nuclear (compared to the scenarios without nuclear) lead to an increase in the demand for electricity which replaces fossil fuels and therefore contributes to emission reductions on the demand side. The increase is moderate in the residential and tertiary sectors (approximately one fourth of the total increase in demand) but significant in industry where shifts towards electricity offer the largest possibilities especially in the iron and steel and chemical sector: around 90% of the additional electricity demand comes from these two sectors.

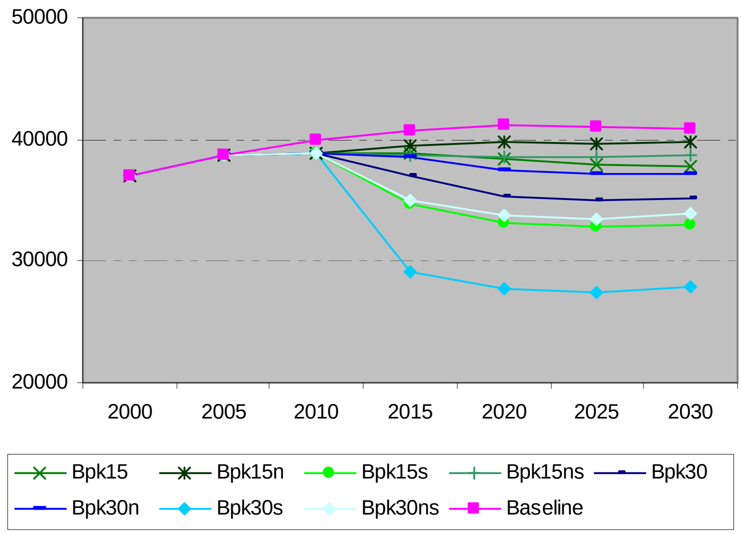
Although increases in electricity production are also observed in some reduction cases without nuclear, the picture is slightly different. The jump in electricity demand is then only driven by industry (mainly the iron and steel and chemical industry) whereas the demand for electricity declines in the tertiary and residential sectors compared to baseline. For the latter sectors, electricity savings prove to be more cost-effective than fuel switching in favour of electricity. The net effect on electricity demand (and production) is an increase when CCS is available in the power sector; it is a decrease, on the other hand, when this technology does not belong to the reduction package (Bpk15s and Bpk30s).

d. Final energy consumption

The evolution of final energy demand in the CO_2 constraint cases is roughly similar to the evolution of CO_2 emissions in the demand sectors[35] described in section V.C.3.b. This feature illustrates the statement according to which the response of the demand side to the introduction of emission reduction constraints is above all a reduction in energy consumption. Changes in the fuel mix generally play a less significant role.

[35] More accurately, the development of CO_2 emissions is driven by the evolution of final energy consumption.

Figure 46: Final energy demand (ktoe)



Source: PRIMES

In what follows, the final energy demand discrepancies between the different scenarios are further analysed in order to display the sectoral impacts. First, the residential and tertiary sectors are examined. The adoption of more efficient technologies and a reduced demand for energy services are the key drivers in the residential and tertiary sectors. The evolution of these two indicators compared to the baseline is given in the following table for the year 2030. Useful energy demand reflects the demand for energy services and includes the demand for heating, cooling, electric appliances and lighting. A reduction in useful energy demand takes place through changes in consumers' behaviour (e.g. reduction of inside temperature or stand-by electricity consumption) and better insulation. Energy efficiency is an index that measures the improvement in energy efficiency of equipments and appliances compared to the baseline (=100).

Table 30: Useful energy demand and energy efficiency, year 2030, difference from baseline

	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Residential									
Useful energy demand (ktoe)	9909	-6,8%	-1,5%	-16,3%	-3,0%	-12,2%	-6,0%	-26,8%	-13,1%
Energy efficiency (baseline=100)	100	3,0%	1,7%	8,7%	3,3%	6,5%	4,9%	13,7%	10,2%
Tertiary									
Useful energy demand (ktoe)	4615	-8,8%	-1,0%	-19,4%	-2,7%	-14,8%	-6,4%	-30,7%	-14,8%
Energy efficiency (baseline=100)	100	1,4%	0,6%	5,6%	0,9%	3,8%	2,0%	16,8%	4,5%

Source: PRIMES

In the transport sector, energy savings originate primarily from reductions in transport activity focusing on the most energy intensive modes of transport (e.g. aviation). The table bellow illustrates the changes in total passenger and freight transport activities compared to the baseline for the year 2030.

Table 31: Total passenger and freight transport activities, year 2030, difference from baseline

	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Passenger transport activity (Gpkm)	189	-3,7%	-1,8%	-12,3%	-3,1%	-8,4%	-5,2%	-23,5%	-11,6%
Freight transport activity (Gtkm)	104	-5,0%	-2,6%	-14,5%	-4,2%	-10,4%	-6,8%	-22,9%	-13,8%

Source: PRIMES
Gpkm: billion of passenger-kilometres
Gtkm: billion of ton-kilometres

Finally, the decline in total energy demand of industry is largely due to the significant restructuring in the iron and steel sector (see the table below) but also to additional energy intensity gains in other industrial sectors.

Table 32: Structure of the production of iron & steel, year 2030

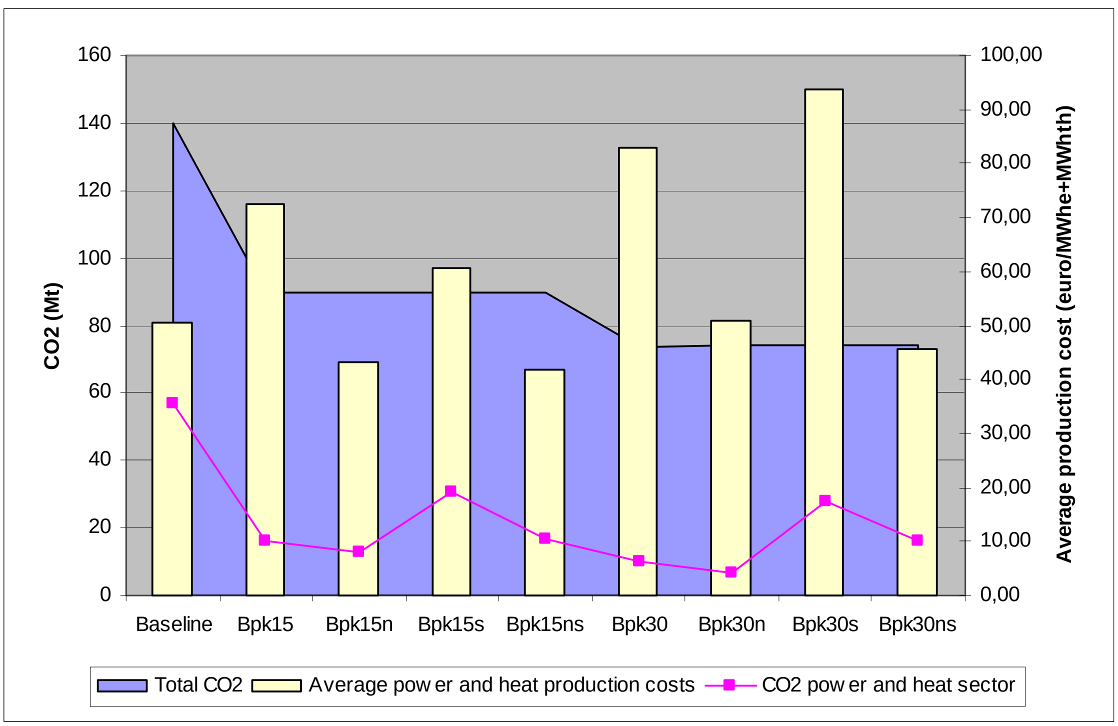
	Baseline	Bpk15	Bpk15n	Bpk15s	Bpk15ns	Bpk30	Bpk30n	Bpk30s	Bpk30ns
Integrated steelworks	65%	43%	49%	14%	40%	17%	26%	2%	9%
Electric processing	35%	57%	51%	86%	60%	83%	74%	98%	91%

Source: PRIMES

e. Average power and heat production costs

The graph below provides a comprehensive picture of the changes in average power and heat production costs according to the constraints on CO_2 emissions and the policy options in the power and heat sector.

Figure 47: Average power and heat production costs vs. CO_2 emissions in the year 2030



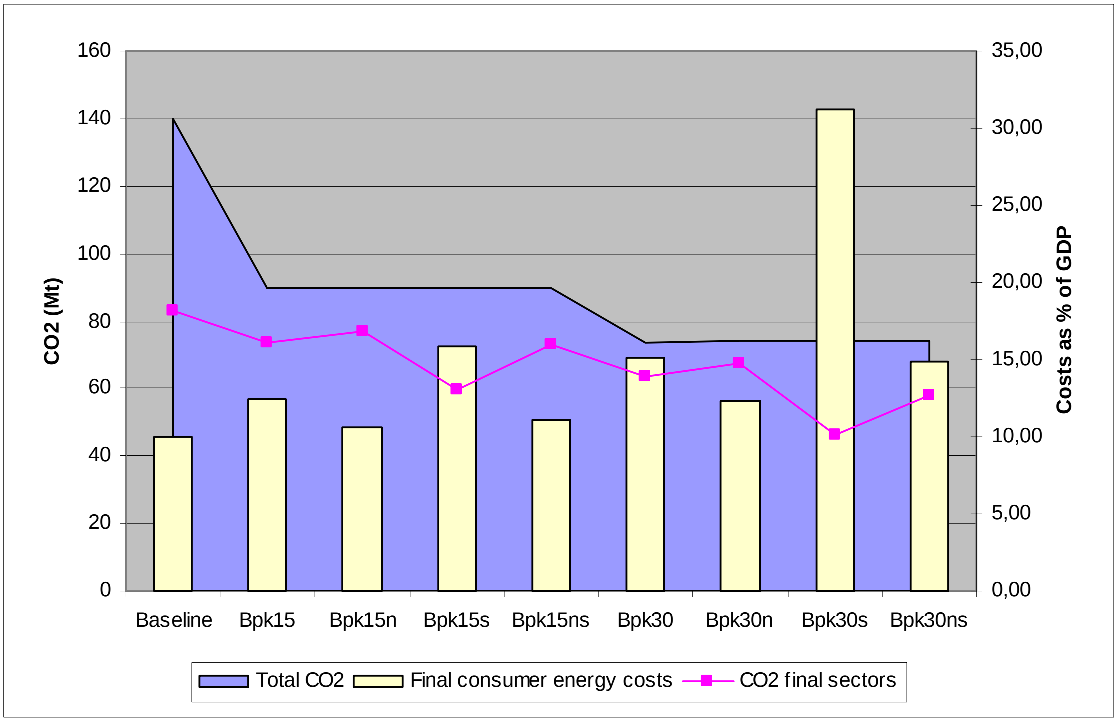
Source: PRIMES

Keeping in mind the remarks made in sections V.C.1.b.iii and V.C.2.b.iii concerning the lower average production costs recorded in most scenarios with nuclear compared to baseline[36], constraints on CO_2 emissions may lead to significant cost increases in the power and heat sector. The average production costs increase with the level of the constraint (they are higher in the -15% reduction cases than in the -30% reduction scenarios). They are above all very sensitive to the policy options taken into account. They are the lowest when both nuclear and CCS are made available to the sector, and the highest otherwise. Furthermore, in these latter cases (Bpk15s and Bpk30s), CO_2 emission reductions are comparatively lower than in the other reduction scenarios.

f. Energy costs for the final consumers

To compare the impact of the CO_2 constraints on the energy costs born by the demand side, an overall cost indicator is constructed. This indicator gives the total energy related costs of final consumers per unit of GDP (%). It gives a global picture of the cost implications of CO_2 reduction constraints on the demand side. It includes the changes in electricity prices which, in the PRIMES model, are related to changes in average production costs.

Figure 48: Total energy related costs of final consumers per unit of GDP vs. CO_2 emissions in the year 2030



Source: PRIMES

The energy related costs of final consumers increase with the constraint on total CO_2 emissions. Furthermore, the additional costs depend directly on the reductions achieved on the demand side, but are significantly higher in the Bpk30s scenario: this scenario experiences the highest reduction effort, both in physical and financial terms.

[36] The savings in sunk costs the power sector takes advantage of when the operating lifetime of existing power plants could be extended to 60 years (as assumed in the scenarios with nuclear) more than counterbalance the CO_2 abatement costs.

VI. Conclusion

At the end of this report, it is time to draw some conclusions based on the analyses undertaken in this study.

In the **baseline** which reflects the evolution of the Belgian energy system under current policies and trends, energy demand decreases slightly (-0.1% per year in 2000-2030) whereas GDP grows at a pace of 1.9% per year, leading to significant improvements in energy intensity. However, at the same time, the structure of energy demand changes markedly: in 2030, fossil fuels represent about 95% of the country energy requirements (respectively 21%, 38% and 35% for coal, oil and natural gas), the remaining 5% being provided by renewable energy sources. Given the limited domestic energy resources (mainly wind, solar and biomass) compared to total energy requirements, Belgium relies more and more on imports with the associated concern on the security of energy supply. Furthermore and despite the trends of energy demand, the predominant role of fossil fuels makes the CO_2 emissions increase significantly over 2000-2030. In 2030, energy related CO_2 emissions are 32% above the 1990 level.

A different evolution of world energy prices generates some changes in the future evolution of the Belgian energy system. In the **higher-oil-higher-gas variant**, world oil, gas and coal prices are 71%, 64% and 32% higher respectively, in constant terms, than in the baseline in 2030. These higher prices result, on the one hand, in further improvements in energy intensity but, on the other hand, in a deterioration of the carbon intensity of the system. Indeed, this variant leads to higher coal consumption at the detriment of natural gas, essentially in the power and steam generation sector. This evolution puts less stress on the security of energy supply (coal supplies are better allocated among world regions than are gas supplies). Finally, the shift towards a more carbon intensive energy form (coal) cancels the effect of energy savings so that the development of CO_2 emissions in this price variant is similar to that of the baseline.

In this study, the FPB was asked to examine different scenarios from various energy policy angles. More precisely, the repercussions of constraints on energy related CO_2 emissions on the development of the Belgian energy system were analysed in different (policy) contexts, reflecting different levels of reductions and different policies or technological developments in the power generation sector. The policy scenarios were defined by the Commission Energy 2030 in collaboration and after discussion with the DG Energy from the Ministry of Economy and with the FPB. Two emission constraints were analysed: reductions of energy CO_2 emissions by -15% and -30% in 2030 compared to 1990. For each emission constraint, four policy scenarios were defined according to whether or not CO_2 reduction options in power generation include nuclear power and carbon capture and storage.

The key findings for the **policy scenarios** examined are the following:

First, some policy scenarios include the possibility of turning back the clock on the *nuclear* decommissioning decision, hence, leaving the nuclear option open[37]. Although the results of these scenarios seem promising as a tool to reach CO_2 emission reductions at low energy related system costs, promoting the use of nuclear has to be carefully considered and nuanced with reflections on the functioning of the electricity market, safety, nuclear waste, decommissioning and public acceptance.

As regards the first element, namely the functioning of the internal electricity market, it is worth coming back to the methodology underlying the assessment of the energy related costs of final

[37] Nevertheless, the baseline and a number of policy scenarios depart from the hypothesis that a nuclear phase-out will take place, all along the lines of the Law on the progressive phase-out of nuclear energy as published in the Belgian Official Journal (February 28, 2003).

consumers. In the PRIMES model, the pricing of electricity is close to average cost pricing (i.e. follows the Ramsey-Boiteux principle), whereas in a fully competitive electricity market, electricity prices are equal to the marginal production costs. In both cases, the nuclear option as described in the study will lead to lower (marginal and average) production costs and, provided these cost reductions are passed on to the final consumers, to lower overall energy related costs. However, the current situation as regards electricity prices seems to be far from these theoretical considerations and to depend more on balances of power between market operators. For instance, a recent study of the French Ministry of Industry has shown that electricity prices in France are determined by the (high) German electricity prices rather than by the (low) production costs due to nuclear. Therefore, the conclusions concerning the relatively lower total energy related costs of final consumers when nuclear power is an option must be interpreted with caution as they are not likely to hold in the situation prevailing on the today electricity markets. Appropriate policies towards a better functioning of the electricity markets are necessary to “realise” the benefits assessed for the demand side.

The analysis of the other factors related to nuclear power is beyond the scope of this study. Nevertheless, it is clear that public acceptance of nuclear energy will be influenced by the implementation of legal provisions on waste management, the actual cost of decommissioning[38] as well as by the development of new reactor designs incorporating improved levels of safety.

Second, the study of the alternative scenarios has enlightened the merits of the *carbon capture and storage* technology. Although in an explorative study phase and still extremely costly, this technology proofs to have a potentially big impact on the reduction of energy CO_2 emissions and related costs. Especially in the most stringent CO_2 emission constraint scenarios, the CCS technology can bring breathing space and is able to lower power generation emissions by more than 80%. It is therefore of utmost importance that the research on and the commercialisation of this technology is being continued and speeded up and that all issues related to this technology will be coped with. The horizon of 2020 can become within reach only with the aid of a sustained R&D investment programme.

Third, throughout the analyses, it became crystal clear that a *trade-off* in reduction efforts takes place between the electricity and steam generation sector and the demand sectors. More specifically, we see that if electricity generation is less flexible in terms of CO_2 reduction options (e.g. in the absence of specific policies directed towards nuclear power, CCS or more RES), the demand side has to carry a far larger reduction burden. The final demand sectors, in other words, have to undertake much larger consumption reductions in the case of a power generation sector that is not able to exploit the full range of reduction options.

Among the final demand sectors, the transport sector seems to be the last sector that has to come up with profound reduction efforts (only in the Bpk30s case, transport is hit hard). This is because of the sector’s low sensitivity to price increases and the relatively small share of fuel costs in the total cost of transport. This result is in line with the view of a number of experts according to which the costs to reduce CO_2 emissions are highest in this particular sector. Nevertheless, when all other reduction options are exhausted (more particularly, in the power generation sector and the other final demand sectors), transport has to take a share in the reduction effort, at a very high price.

The scenario analysis has pointed out the comparatively higher marginal abatement costs required in order to achieve larger reduction levels in the demand sectors. Given the inertia of the systems that give rise to energy consumption (e.g. consumption patterns or lifetime of the buildings stock in the residential and tertiary sectors, land use policies or mobility behaviours in transport, structure of industrial production in industry), the costs involved are high in the absence of specific policies some of which were analysed in the study for Minister Tobback. In other words, an appropriate institutional and policy framework might reduce the costs of implementing the energy savings identified in the

38 The cost of decommissioning is included in the cost data of nuclear power plants, but is subject to large uncertainties.

demand sectors or facilitate a number of changes that goes beyond those already realised[39]. For instance, the implementation of a policy specifically aimed at promoting renewable energy sources could result in higher potentials than defined in these scenarios (e.g. wind, biofuels).

Coming to the power generation sector, we see that, the moment a reduction constraint comes into play, this sector will deploy the maximum (assumed) potential of wind energy. Already in the -15% reduction scenarios, the entire capacity of wind energy (both on- and off-shore) is exploited. Other renewable energy sources are also called upon: we see that solar PVs, although they are branded as being a very expensive technology at the moment, will be exploited if all other CO_2 reduction options are constrained or depleted. To be noted, however, is that a power sector resulting from this generation structure (being a structure based on many renewable energy sources) entails additional investments in generation capacities and a non negligible impact on the transport and/or distribution network. The first effect is quantified in the study whereas the technical and economic challenges related to large amounts of intermittent wind and solar put on the network are beyond the scope of our analysis.

Fourth, there is the issue of security of energy supply[40]. This general term in fact encompasses three concepts[41]: there is (1) the short term security of supply (or *system reliability*), covering everything that has to do with the capability of the energy industry to satisfy the demand at any time and to get electricity to the final consumers in a proper way (no black-outs, no net interruptions), (2) the long-term security of supply which is measured through sufficient investments in the system and (3) the security of energy inputs.

The study with the PRIMES model inherently takes care of a number of aspects related to the security of energy supply, whereas other issues are not covered. First, the permanent physical disruption that can occur when an energy source is exhausted is coped with in the analysis. Oil and gas supplies on the Belgian territory are compatible with available oil and gas reserves worldwide and with the demands in other world regions or countries; the relationship between these two indicators determines the world or regional energy prices (POLES model) which are an input for PRIMES. Second, the provision of sufficient investments in the electricity sector is being covered through the model. These investments are simulated as to follow electricity demand up close which leads to the fact that sufficient generation capacities will be available at all times. On the other hand, temporary physical disruptions or erratic fluctuations in the price of energy products, the consequences of which can be significant both for consumers and the economy in general are beyond the scope of the analysis. These can result from a geopolitical crisis or from structural supply difficulties (i.e. related to transport networks or power generation capacities).

Although the security of energy inputs has a broader scope, it can be examined through the indicator *import dependency*. This indicator measures the share of energy imports in the total energy supplies of a country[42]. Turning to the results, we see that the dependency on imports becomes sky high in the baseline by the year 2030 (95.3% compared to 77.7% in 2000) because of the large use of fossil fuels, the decommissioning of nuclear power and the moderate penetration of renewable energy sources. Imposing a carbon constraint then effects the consumption, hence the supply and import, of the different fuels. We see that the -15% and -30% reduction scenarios are able to lower this import dependency somewhat and that the higher the constraint on CO_2 emissions, the higher the decline in import dependency. This is explained through a more significant penetration of renewable energy sources. Another important factor is nuclear power: import dependency turns out to be the lowest in the scenarios in which the nuclear option is available (around 67%).

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39 Cf. annex G on Energy savings in the PRIMES model.

40 European Commission, Green Paper: Towards a European strategy for the security of energy supply, 2001.

41 For more information, see Devogelaer D. and D. Gusbin, Een kink in de kabel: de kosten van een storing in de stroomvoorziening, FPB, WP 18-04, September 2004.

42 It is important to underline that, according to Eurostat statistical convention, the import of uranium for nuclear power production is not included in the energy imports.

Nevertheless, the reader should beware of drawing conclusions too soon based on the import dependency indicator. First, when looking at drastic reductions in dependency when nuclear energy is part of the game, one has to bear in mind that nuclear energy can only bring (part of) a solution for security of energy supply in one particular sector: power generation. Supply problems in the transport sector for instance cannot be solved through an extended use of nuclear power; for this sector, access to oil is the major challenge. We then plead for a broad and open approach of the security of supply issue, as to avoid that the discussion strands on only one aspect of the problem, be it one interpretation, one sector or one energy source.

This statement is further reinforced by the fact that Belgium cannot rely on domestic fossil fuel resources and that the resources in the EU are steadily declining. In other words, energy self-sufficiency is an utopia; the actual challenge is rather to secure our energy supplies and to manage properly our supply dependence. The realisation of these objectives has to go through a number of policy actions (in Belgium and in the EU) including limiting the growth of energy consumption, the development of renewable energy sources, the availability of sufficient stocks, the completion of the internal energy markets, the extension of the number of transport routes for natural gas (i.e. diversification of supply routes from producing to consuming regions) and a permanent dialogue with the energy producing countries.

Although the impact of the constraints on the national energy system does require major changes in consumer behaviour, production processes and technology choices, and lead, in some scenarios, to significant cost increases, it can nevertheless be mitigated through the use of some other instruments, not taken up in this study though. Some of them are listed below:

- Reduction in other greenhouse gases emissions: in this study, only the energy CO_2 emissions are being modelled, and the constraint was put on this specific source of pollution. Most (inter)national conventions, however (e.g. Kyoto), do specify their reduction objectives in terms of total greenhouse gases. If it is less costly to reduce the other GHG, it is recommended to first cut down these other GHG before turning to the energy CO_2 emissions. Also, flexible mechanisms and the European Emission Trading System can bring some additional room to reduce the costs of achieving the emission reduction constraints.
- Compensation policies (cf. the analysis with HERMES in the study for Minister Tobback): the costly impact on society of installing a carbon value can be mitigated through the recurring effect of investing the higher state revenues in societal benefits like employment (e.g. through the lowering of labour taxes). In this way, society pays for a better environment (through the carbon value) and gains a healthier nation (through an increase in employment triggered by lower labour taxes). The enjoying of these two benefits is called a “double dividend”.
- Long-term environmental gains: although the constraints seem stringent, installing them in a timely fashion benefits the climate (climate mitigation) before large climate changes have taken place and had the chance to destroy or pollute large parts of our environmental heritage. Taking action now lowers the future negative effects which one way or another have to be paid at some time in the future. Avoiding them brings along a cost or change in society as we know it, but keeps us from incurring even higher costs and detrimental effects linked to non-action.

Finally, this study does not pretend to be exhaustive in any way. The FPB is fully aware that the scenario choices do not cover all possible emission reduction options, let alone all climate mitigating opportunities and that the broad range of impacts is only partially assessed. Despite these shortcomings, the study provides a sound and coherent quantitative basis and therefore a valuable input to the Commission Energy 2030 when it comes to developing thoughts as to the Belgian energy future.

Annexes

A. International price forecasts for fuels used in the scenarios for the Commission 2030: clarification

Modelling of oil and gas supply and prices in the POLES model: key elements of the underlying methodology

(Source: LEPII-EPE December 2005)

A key feature of the POLES model is its detailed simulation module for the oil and gas discovery and development process, which is in particular essential to the endogenous process of international oil and gas prices determination. In broad terms, the logic used in order to model oil and gas supply and price is based on the following sequence:

- The Ultimate Recoverable Resources (URR) is derived from the USGS estimates, but are modified over the projection period in order to account for the impact of increasing recovery rates (which are assumed to be dependent on the oil and gas prices).
- Discoveries depend on the drilling effort (also oil and gas price dependent) and the reserves are equal to the total discoveries minus the past cumulative production.
- For all regions except the Gulf, the production depends on a price dependent “reserve on production” or R/P ratio.
- The international prices depends, in the case of oil on the world R/P ratio (including non conventional oil), and for gas on regional R/P ratios as well as of an indexation term to the oil price.

In this process, the driving exogenous hypothesis is related to the URR estimate at the beginning of the simulation. The uncertainty concerning this set of hypotheses is quite high as testifies the long-lasting controversy between ‘optimists’ and ‘pessimists’ concerning oil and gas resources. In order to produce the Baseline projection, a relatively optimistic view on oil and gas resource availability has been adopted. It is based on a set hypothesis which corresponds to an increase of 30% of the US Geological Survey's median view (50%probability): this results in oil recoverable resources of around 3 300 billion barrels at the beginning of the simulation.

A principal feature of the POLES model is that it estimates international prices for oil, gas and coal, based on an explicit description of the fundamentals of each international market and a detailed representation of the reserve and resource constraints.

The model calculates a single world price; the oil market is described as “one great pool”. It depends in the short-term on variations in the rate of utilisation of capacity in the Gulf countries and, more importantly, in the medium and long-term on the average Reserve-to-Production ratio across the world.

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.

The price of coal is also estimated for each regional market as the average price of the key suppliers on each market, weighted by their market shares. The average price of the key suppliers is derived from variations in mining and operating costs (that are a function of the increase in per capita GDP and of a productivity trend) and from the capital and transport costs (both depending on the simulated production increases, as compared to a "normal" expansion rate of production capacity).

The energy price outlook in the baseline scenario

(Source: LEPII-EPE & NTUA)

The energy prices calculated in the Baseline reflect a situation in which no strong supply constraints are supposed to be felt at least in the period to 2020. At the beginning of the simulation period, the decline in the oil price to 45 $05/bl until 2015 reflects a situation of relatively abundant supply due to competition among key producers. After that date, when the production of the Gulf and OPEC regions has to expand more rapidly to keep pace with world demand, the oil price increases steadily and attains 58 $05/bl in 2030, a level that is higher than the one reached in 2005, under particularly tense supply conditions.

These changes reflect the built-in dynamic processes in the model: in the short run, oil prices depend on changes in global oil demand and on the productive capacities of the Gulf countries, considered as the "swing producers" in the oil market. In the longer run, oil prices are likely to be influenced to a greater extent by the "fundamentals", i. e. the relative dynamics of oil demand and of available reserves, which is measured by the variations in the R/P ratio.

While the oil market is fairly integrated at a global level (“one great pool”), this is not the case for gas and coal, the markets of which still show a strong regional basis. The main reason for these regional differentiations is the high transport cost of gas and coal, relative to their production cost. Although the development of LNG transport facilities will introduce some degree of trade-off between the regional gas markets, the price differentials are not expected to fully disappear over the next 30 years under the baseline assumptions for energy prices.

For gas, the R/P ratio in 2000 is significantly different from one region to the other, from about 18 years in the American market to more than 100 years for the European market. While the decline in R/P ratio explains the rise in gas prices in the projection, it has to be noted that the hierarchy in R/P by region doesn’t explain the hierarchy in price levels as the latter indeed depends of the structure of supply of each market: the Asian market with the highest proportion of LNG supply has the highest price level and the American market which is mostly continental the lowest, while Europe is in an intermediate position for both features.

The European gas price dynamics remains quite parallel to that of oil price until 2025, while later the gap widens with a lower increase for the gas price. During all the period it stays in the middle of the range between American and Asian markets prices.

In a very different profile, coal prices on the three markets converge at the end of the period at a level of 15 €05/boe, about one fourth of the oil price.

This trend in the prices of oil and gas create a structural cost advantage for coal. Resources of coal are much larger than of oil and gas; they are dispersed and often located in large consuming countries. Consequently, the absolute increase in coal price, expressed in terms of oil equivalent, is expected to be less than for hydrocarbons. In the baseline, coal prices roughly double from the current level, which is similar to the relative change expected for oil.

B. Definition of the indicators used in the PRIMES analyses

Table 33: List of the indicators and their definition used in the analysis of the PRIMES results

Lexicon of indicators

	Indicator	*Description*	*Unit*
Primary energy needs	Net imports of energy	Sum of the imports of solids, oil (consisting of crude oil and feedstocks and oil products), natural gas and electricity minus the sum of their exports	ktoe
	Energy intensity of GDP	Gross Inland Consumption divided by GDP	toe/MEUR'00
	Import dependency	Share of Net Imports of energy in the Gross Inland Consumption (defined as the sum of Primary Production and Net Imports)	%
	Total gas needs	Total national gas requirements or gross inland consumption of natural gas	ktoe
	CO2 emissions	Energy related CO2 emissions	Mt of CO2
	Renewables share in GIC	Share of renewable energy forms in the Gross Inland Consumption	%
Power generation	Carbon free share in power	Share in power generation of energy forms which do not emit CO2 while producing power	%
	Gas for power	Electricity generated on the basis of gas	GWh
	Coal for power	Electricity generated on the basis of coal	GWh
	Power capacity extension	Expansion of national power capacity from 2005 on (cumulative)	MWe
	CO2 per MWh	CO2 emitted per MWh produced	tCO2/MWh
Sectors			
Industry	Changes in final energy demand	Change in the industrial energy demand compared to the baseline	ktoe
Residential	Changes in final energy demand	Change in the final energy demand of households compared to the baseline	ktoe
Tertiary	Changes in final energy demand	Change in the final energy demand of the tertiary sector compared to the baseline	ktoe
Transport	Changes in final energy demand	Change in the energy demand of the transport activity compared to the baseline	ktoe

C. Details on the design of the alternative scenarios

The design of the different scenarios was defined by the Commission Energy 2030 further to discussions with the FPB, the CES (KULeuven) and the Energy Directorate of the Ministry of Economy.

- *Constraints on energy related CO_2 emissions*

According to the Kyoto Protocol of December 1997, the European Community should reduce its greenhouse gas (GHG) emissions by 8% in the period 2008-2012 relative to 1990. This target was translated into Member States' commitments; for Belgium the commitment is a reduction of 7,5% below the level of 1990. The GHG covered by the Kyoto Protocol are CO2 (energy and non-energy related emissions), methane, nitrous oxyde and fluorinated gases.

Given the long term effects of climate change, climate policy will not stop in 2012. Discussions are now underway at international, European, national and regional level in order to assess and subsequently define post-2012 commitments.

The analysis performed with the use of the PRIMES model places itself in this larger context and focuses on the repercussions that the introduction of emission constraints in the long term (2030) would generate on the Belgian energy system. Given that the analysis of GHG emissions other than energy related CO_2 emissions is outside the scope of the PRIMES model, the emission constraints for Belgium are treated as if they apply only to energy related CO_2 emissions. Consequently, they are only indicative of the required changes in the energy system and as such, cannot be interpreted as possible post-2012 targets.

Two emissions constraints are considered in the analysis, reflecting two degrees of reinforcement of the Kyoto commitment in 2008-2012. The first constraint is a reduction by 15% of the energy related CO_2 emissions in 2030 relative to the level of the year 1990; the second one is a reduction by 30% of energy related CO_2 emissions in 2030 relative to the level of the year 1990. Furthermore, the constraints are to be met on the Belgian territory as the use of flexible mechanisms falls outside the scope of the analysis.

- *Come-back of nuclear energy for electricity production*

The come-back of nuclear power is defined along the following assumptions as regards costs, timing and production capacities:

1. The lifetime of the existing nuclear plants can be extended up to 60 years. For the newest units (Tihange 2 and 3, Doel 3 and 4), it is assumed that such an extension does not entail any additional investments. The older units, on the other hand, do need extra investments when their operational time is to be prolonged: the lifetime of the Tihange 1 nuclear power unit can be extended up to a maximum of 60 years provided an investment cost that equals 25% of the cost of a newly built plant, while the Doel 1&2 units can be upgraded to 60 years at an investment cost of 30% of a newly built unit (due to the older technology).

2. On top of that, the model can decide to invest in one additional nuclear unit after 2020 with a capacity of 1700 MW. The overnight cost for this newly built unit is set at 1800 €/kW installed.

The come-back of nuclear power is however not only a question of economics and the economics of downstream nuclear activities still entail uncertainties. The nuclear option is promising if a satisfactory and transparent solution can be found to the question of safety and nuclear waste management, and this at a reasonable cost. Opinion surveys recently undertaken by the European Commission confirm this statement. They show a.o. that a clear policy for the management of nuclear waste would significantly enhance public attitudes towards the use of nuclear power. It is therefore important for the EU to ensure that Member States take decisions as regards safe disposal within a reasonable time and with future generations in mind. According to most experts, permanent deep disposal is the best-known solution for the long-term management of radioactive waste. Research into the technology of radioactive waste management has not yet resulted in a practicable alternative to geological disposal. However, research should be continued to give future generations access to new technologies for the treatment of radioactive waste - such as transmutation - in the hope that in due course waste can be significantly reduced. Concerning safety, technology is constantly on the cutting edge and new types of reactors putting safety as one of the top priorities are in the phase of implementation. On top of that, the European Commission has proposed a package of three measures covering nuclear safety and the decommissioning of obsolete installations, the management of radioactive waste and trade in nuclear materials with Russia.

- *Carbon Capture and Storage (CCS)*

CCS is a novel and promising technological option used to reduce carbon dioxide emissions. More specifically, CCS is a procedure in which CO_2 is captured while it is being produced, e.g. when coal or natural gas are being burnt. Afterwards, the CO_2 is transported and stored in a permanent way in e.g. old coal mines or deep rock formations.

This technology is essentially aimed at large (above 300 MW) electricity production plants[1]. The deployment of CCS poses technological, scientific as well as financial challenges for producers and consumers. Leaving aside the economics of CCS which are crucial but coped with in the quantitative analysis with PRIMES [2] (although large uncertainties on costs are to be borne in mind), there are major R&D and demonstration gaps to be bridged over the next few years if CCS technologies are to be developed in time for their potential to be realised. These gaps relate to the three components of CCS, namely CO_2 capture technologies, CO_2 transport over long distances and CO_2 storage facilities. The public acceptance and environmental acceptability of CCS remains an issue as well. An overview of carbon capture and storage and more detailed information about the challenges associated with this technology can be found in the following reports:

- IEA, *Energy Technology Perspectives: Scenarios & Strategies to 2050*, 2006
- Devogelaer D., D. Gusbin, D. Bassilière, F. Bossier, I. Bracke, F. Thiery, A. Henry and N. Gouzée, *Het klimaatbeleid na 2012: Analyse van scenario's voor emissiereductie tegen 2020 en 2050*, Federaal Planbureau, Rapport in opdracht van de federale Minister van Leefmilieu, 2006

Given this overall context, it has been decided to consider two sets of scenarios: one set in which it is assumed that CCS would become technically and commercially available in the period 2020-2030, another set in which this CO_2 abatement technology is not taken up as part of the CO_2 reduction options.

1 CCS is also envisaged in hydrogen production plants.

2 The technico-economic data of CCS used in the PRIMES analysis are principally based on Tzimas E. et all (2005). The economic assessment of CCS presented in this paper leads to the conclusion that the introduction of CCS technologies in Europe in 2020 will result in an increase in the production cost of electricity of 30-55% depending on the electricity generation technology used. The cost of capture is the highest among the three cost components (capture, transport and storage), it lies in the range of 20-40 € per ton CO_2 avoided; the cost of CO_2 transport is estimated at 1 to 4 € per ton CO_2 and the cost of storage is within the range of 1-3 € per ton CO_2 stored.

D. Detailed scenario results

BELGIUM: Baseline **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14450**	**11344**	**2908**	**0,7**	**0,7**	**-2,4**	**-12,7**
Fossil fuels	1094	193	0	0	0	-15,9			
Nuclear	10707	12422	12926	9004	0	1,5	0,4	-3,6	
Renewable energy sources	727	856	1524	2340	2908	1,6	5,9	4,4	2,2
Hydro	23	39	39	39	39	5,6	0,0	0,0	0,0
Biomass & Waste	701	810	1241	1932	2292	1,4	4,4	4,5	1,7
Wind	1	1	221	312	483	7,9	67,3	3,5	4,5
Solar and others	2	5	22	57	83	10,0	16,5	9,9	3,9
Net Imports (ktoe)	**38857**	**48547**	**51783**	**53238**	**59052**	**2,3**	**0,6**	**0,3**	**1,0**
Solids	9492	7566	6388	5171	11485	-2,2	-1,7	-2,1	8,3
Oil	21468	27331	29160	28688	27780	2,4	0,6	-0,2	-0,3
Natural gas	8217	13278	15617	18932	19463	4,9	1,6	1,9	0,3
Electricity	-320	372	618	448	325		5,2	-3,2	-3,2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**60354**	**58280**	**55429**	**1,9**	**0,5**	**-0,3**	**-0,5**
Solids	10244	8200	6388	5171	11485	-2,2	-2,5	-2,1	8,3
Oil	17730	21949	23281	22386	21249	2,2	0,6	-0,4	-0,5
Natural gas	8169	13369	15617	18932	19463	5,0	1,6	1,9	0,3
Nuclear	10707	12422	12926	9004	0	1,5	0,4	-3,6	
Electricity	-320	372	618	448	325		5,2	-3,2	-3,2
Renewable energy forms	727	856	1524	2340	2908	1,6	5,9	4,4	2,2
as % in Gross Inland Consumption									
Solids	21,7	14,3	10,6	8,9	20,7				
Oil	37,5	38,4	38,6	38,4	38,3				
Natural gas	17,3	23,4	25,9	32,5	35,1				
Nuclear	22,7	21,7	21,4	15,4	0,0				
Renewable energy forms	1,5	1,5	2,5	4,0	5,2				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**8343**	**10215**	**17282**	**1,4**	**0,6**	**2,0**	**5,4**
Solids	3879	3030	2781	2126	8906	-2,4	-0,9	-2,6	15,4
Oil	318	172	141	134	123	-6,0	-2,0	-0,5	-0,8
Gas	2239	4186	4732	7001	7012	6,5	1,2	4,0	0,0
Biomass & Waste	403	488	689	954	1241	1,9	3,5	3,3	2,7
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**37200**	**36665**	**35307**	**1,5**	**-0,9**	**-0,1**	**-0,4**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2334**	**2216**	**2161**	**0,3**	**-0,2**	**-0,5**	**-0,3**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5337**	**5097**	**5043**	**7,8**	**-0,9**	**-0,5**	**-0,1**
Final Energy Demand (ktoe)	**31355**	**37055**	**39968**	**41197**	**40930**	**1,7**	**0,8**	**0,3**	**-0,1**
by sector									
Industry	11944	13769	13993	14102	13851	1,4	0,2	0,1	-0,2
Residential	8337	9465	10311	10314	10008	1,3	0,9	0,0	-0,3
Tertiary	3370	4158	4848	5446	5763	2,1	1,5	1,2	0,6
Transport	7704	9662	10816	11336	11308	2,3	1,1	0,5	0,0
by fuel									
Solids	3783	3373	2453	2143	1907	-1,1	-3,1	-1,3	-1,2
Oil	14734	16038	17497	17003	16091	0,9	0,9	-0,3	-0,5
Gas	6993	9615	10312	11052	11300	3,2	0,7	0,7	0,2
Electricity	4986	6667	7822	8597	9052	2,9	1,6	0,9	0,5
Heat (from CHP and District Heating)	566	1046	1369	1529	1605	6,3	2,7	1,1	0,5
Other	293	316	514	873	975	0,8	5,0	5,4	1,1
CO2 Emissions (Mt of CO2)	**105,9**	**114,7**	**115,9**	**117,0**	**139,9**	**0,8**	**0,1**	**0,1**	**1,8**
Power generation/District heating	22,4	23,5	23,4	25,9	52,4	0,5	-0,1	1,0	7,3
Energy Branch	5,3	5,3	4,7	4,5	4,2	0,0	-1,2	-0,5	-0,7
Industry	29,3	29,1	26,1	24,9	23,5	-0,1	-1,1	-0,4	-0,6
Residential	18,7	20,0	20,8	19,8	18,3	0,7	0,4	-0,5	-0,8
Tertiary	7,5	8,2	9,4	10,1	10,2	0,9	1,5	0,7	0,2
Transport	22,6	28,6	31,5	31,9	31,3	2,4	1,0	0,1	-0,2
CO2 Emissions Index (1990=100)	**100,0**	**108,3**	**109,5**	**110,5**	**132,2**				

Source: PRIMES

BELGIUM: Baseline **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9,968	10,246	10,554	10,790	10,984	0,3	0,3	0,2	0,2
GDP (in 000 MEUR'00)	200,1	247,9	302,9	370,1	431,7	2,2	2,0	2,0	1,5
Gross Inl. Cons./GDP (toe/MEUR'00)	236,2	230,6	199,3	157,5	128,4	-0,2	-1,4	-2,3	-2,0
Gross Inl. Cons./Capita (toe/inhabitant)	4,74	5,58	5,72	5,40	5,05	1,6	0,2	-0,6	-0,7
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	8900	9685	10174	1,4	1,0	0,8	0,5
Carbon intensity (t of CO_2/toe of GIC)	2,24	2,01	1,92	2,01	2,52	-1,1	-0,4	0,4	2,3
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10,62	11,19	10,98	10,84	12,74	0,5	-0,2	-0,1	1,6
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529,0	462,6	382,6	316,1	324,1	-1,3	-1,9	-1,9	0,3
Import Dependency %	75,7	77,7	78,2	82,4	95,3				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100,0	97,5	86,0	73,9	63,4	-0,2	-1,3	-1,5	-1,5
Residential (Energy on Private Income)	100,0	92,7	85,0	71,9	60,9	-0,8	-0,9	-1,7	-1,7
Tertiary (Energy on Value added)	100,0	99,5	92,7	84,7	76,7	0,0	-0,7	-0,9	-1,0
Transport (Energy on GDP)	100,0	101,2	92,8	79,5	68,0	0,1	-0,9	-1,5	-1,6
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0,29	0,25	0,21	0,21	0,40	-1,7	-1,5	-0,1	6,6
Final energy demand (t of CO_2/toe)	2,49	2,32	2,20	2,10	2,04	-0,7	-0,5	-0,4	-0,3
Industry	2,46	2,12	1,86	1,77	1,70	-1,5	-1,3	-0,5	-0,4
Residential	2,24	2,11	2,02	1,92	1,82	-0,6	-0,4	-0,5	-0,5
Tertiary	2,22	1,96	1,94	1,85	1,78	-1,2	-0,1	-0,5	-0,4
Transport	2,94	2,96	2,91	2,81	2,77	0,1	-0,2	-0,4	-0,1

Source: PRIMES

BELGIUM: Baseline **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**101117**	**109703**	**115530**	**1,5**	**0,8**	**0,5**
Final energy consumption	77525	90957	99969	105258	1,6	0,9	0,5
Industry	39861	47105	49472	50059	1,7	0,5	0,1
Households	23734	27717	30883	33553	1,6	1,1	0,8
Tertiary	12491	14606	18133	20248	1,6	2,2	1,1
Transport	1440	1529	1481	1398	0,6	-0,3	-0,6
Energy branch	5757	6334	5966	6523	1,0	-0,6	0,9
Transmission and distribution losses	3682	3826	3769	3749	0,4	-0,2	-0,1
Electricity supply (GWh)	**86964**	**101117**	**109703**	**115530**	**1,5**	**0,8**	**0,5**
Net imports	4325	7182	5204	3774	5,2	-3,2	-3,2
Domestic production	82639	93935	104499	111756	1,3	1,1	0,7
Electricity generation by fuel type (GWh)	**82639**	**93935**	**104499**	**111756**	**1,3**	**1,1**	**0,7**
Nuclear energy	48148	50103	34898	0	0,4	-3,6	
Renewables	1693	4816	9273	13177	11,0	6,8	3,6
Hydro	459	458	458	458	0,0	0,0	0,0
Wind	15	2570	3631	5616	67,3	3,5	4,5
Solar	0	7	25	54		13,8	8,2
Biomass & waste	1219	1780	5159	7048	3,9	11,2	3,2
Fossil fuels	32798	39017	60328	98579	1,8	4,5	5,0
Coal	12903	11854	10757	47227	-0,8	-1,0	15,9
Petroleum products	738	648	592	544	-1,3	-0,9	-0,8
Natural gas	16086	24058	46848	49229	4,1	6,9	0,5
Coke & blast-furnace gasses	3071	2458	2131	1579	-2,2	-1,4	-3,0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37,1	42,1	55,1	52,6			
Load factor for gross electric capacities (%)	63,0	63,6	61,1	55,5			
CHP indicator (% of electricity from CHP)	7,9	14,3	18,5	18,2			
Non fossil fuels in electricity generation (%)	60,3	58,5	42,3	11,8			
- nuclear	58,3	53,3	33,4	0,0			
- renewable energy forms	2,0	5,1	8,9	11,8			

Source: PRIMES

BELGIUM: Higher-oil-higher-gas price variant **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14497**	**11693**	**3336**	**0.7**	**0.7**	**-2.1**	**-11.8**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Renewable energy sources	727	856	1570	2689	3336	1.6	6.3	5.5	2.2
Hydro	23	39	39	39	39	5.6	0.0	0.0	0.0
Biomass & Waste	701	810	1261	2211	2614	1.4	4.5	5.8	1.7
Wind	1	1	246	368	545	7.9	69.1	4.1	4.0
Solar and others	2	5	24	71	138	10.0	17.3	11.5	6.9
Net Imports (ktoe)	**38857**	**48547**	**50921**	**51872**	**57523**	**2.3**	**0.5**	**0.2**	**1.0**
Solids	9492	7566	6399	7732	13945	-2.2	-1.7	1.9	6.1
Oil	21468	27331	27463	26622	25815	2.4	0.0	-0.3	-0.3
Natural gas	8217	13278	16441	17071	17438	4.9	2.2	0.4	0.2
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**59793**	**57650**	**54758**	**1.9**	**0.4**	**-0.4**	**-0.5**
Solids	10244	8200	6399	7732	13945	-2.2	-2.4	1.9	6.1
Oil	17730	21949	21838	20706	19715	2.2	-0.1	-0.5	-0.5
Natural gas	8169	13369	16441	17071	17438	5.0	2.1	0.4	0.2
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Renewable energy forms	727	856	1570	2689	3336	1.6	6.3	5.5	2.2
as % in Gross Inland Consumption									
Solids	21.7	14.3	10.7	13.4	25.5				
Oil	37.5	38.4	36.5	35.9	36.0				
Natural gas	17.3	23.4	27.5	29.6	31.8				
Nuclear	22.7	21.7	21.6	15.6	0.0				
Renewable energy forms	1.5	1.5	2.6	4.7	6.1				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**8416**	**10865**	**17925**	**1.4**	**0.7**	**2.6**	**5.1**
Solids	3879	3030	2781	4673	11418	-2.4	-0.9	5.3	9.3
Oil	318	172	144	114	100	-6.0	-1.7	-2.3	-1.3
Gas	2239	4186	4801	4996	5132	6.5	1.4	0.4	0.3
Biomass & Waste	403	488	689	1082	1275	1.9	3.5	4.6	1.7
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**35198**	**34303**	**33149**	**1.5**	**-1.5**	**-0.3**	**-0.3**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2243**	**2143**	**2106**	**0.3**	**-0.5**	**-0.5**	**-0.2**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5288**	**5007**	**4937**	**7.8**	**-0.9**	**-0.5**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**39482**	**40043**	**39706**	**1.7**	**0.6**	**0.1**	**-0.1**
by sector									
Industry	11944	13769	13928	13947	13554	1.4	0.1	0.0	-0.3
Residential	8337	9465	10132	9810	9436	1.3	0.7	-0.3	-0.4
Tertiary	3370	4158	4772	5241	5466	2.1	1.4	0.9	0.4
Transport	7704	9662	10650	11045	11250	2.3	1.0	0.4	0.2
by fuel									
Solids	3783	3373	2473	2207	1911	-1.1	-3.1	-1.1	-1.4
Oil	14734	16038	16482	15741	14962	0.9	0.3	-0.5	-0.5
Gas	6993	9615	10763	10948	10930	3.2	1.1	0.2	0.0
Electricity	4986	6667	7867	8606	9045	2.9	1.7	0.9	0.5
Heat (from CHP and District Heating)	566	1046	1363	1529	1612	6.3	2.7	1.2	0.5
Other	293	316	534	1011	1247	0.8	5.4	6.6	2.1
CO2 Emissions (Mt of CO2)	**105.9**	**114.7**	**113.6**	**117.9**	**140.6**	**0.8**	**-0.1**	**0.4**	**1.8**
Power generation/District heating	22.4	23.5	23.5	31.2	57.8	0.5	0.0	2.8	6.4
Energy Branch	5.3	5.3	4.3	4.0	3.8	0.0	-2.1	-0.5	-0.6
Industry	29.3	29.1	25.6	24.2	22.3	-0.1	-1.3	-0.6	-0.8
Residential	18.7	20.0	20.1	18.3	16.6	0.7	0.0	-0.9	-1.0
Tertiary	7.5	8.2	9.2	9.5	9.5	0.9	1.2	0.4	-0.1
Transport	22.6	28.6	31.0	30.7	30.5	2.4	0.8	-0.1	0.0
CO2 Emissions Index (1990=100)	**100.0**	**108.3**	**107.3**	**111.4**	**132.8**				

Source: PRIMES

BELGIUM: Higher-oil-higher-gas price variant **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	197.4	155.7	126.9	-0.2	-1.5	-2.3	-2.0
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.67	5.34	4.99	1.6	0.2	-0.6	-0.7
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	8944	9723	10193	1.4	1.0	0.8	0.5
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.90	2.05	2.57	-1.1	-0.5	0.7	2.3
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.76	10.93	12.80	0.5	-0.4	0.2	1.6
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	375.0	318.5	325.6	-1.3	-2.1	-1.6	0.2
Import Dependency %	75.7	77.7	77.8	81.6	94.5				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	85.6	73.1	62.1	-0.2	-1.3	-1.6	-1.6
Residential (Energy on Private Income)	100.0	92.7	83.5	68.4	57.4	-0.8	-1.0	-2.0	-1.7
Tertiary (Energy on Value added)	100.0	99.5	91.2	81.5	72.7	0.0	-0.9	-1.1	-1.1
Transport (Energy on GDP)	100.0	101.2	91.3	77.5	67.7	0.1	-1.0	-1.6	-1.3
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.21	0.25	0.44	-1.7	-1.5	1.7	5.7
Final energy demand (t of CO_2/toe)	2.49	2.32	2.17	2.07	1.99	-0.7	-0.6	-0.5	-0.4
Industry	2.46	2.12	1.84	1.73	1.64	-1.5	-1.4	-0.6	-0.5
Residential	2.24	2.11	1.98	1.87	1.76	-0.6	-0.6	-0.6	-0.6
Tertiary	2.22	1.96	1.92	1.82	1.73	-1.2	-0.2	-0.5	-0.5
Transport	2.94	2.96	2.91	2.78	2.72	0.1	-0.2	-0.5	-0.2

Source: PRIMES

BELGIUM: Higher-oil-higher-gas price variant **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**101578**	**110109**	**115730**	**1.6**	**0.8**	**0.5**
Final energy consumption	77525	91478	100067	105170	1.7	0.9	0.5
Industry	39861	47253	50114	50773	1.7	0.6	0.1
Households	23734	28075	30714	33479	1.7	0.9	0.9
Tertiary	12491	14604	17750	19569	1.6	2.0	1.0
Transport	1440	1546	1490	1349	0.7	-0.4	-1.0
Energy branch	5757	6256	6273	6817	0.8	0.0	0.8
Transmission and distribution losses	3682	3844	3769	3743	0.4	-0.2	-0.1
Electricity supply (GWh)	**86964**	**101578**	**110109**	**115730**	**1.6**	**0.8**	**0.5**
Net imports	4325	7181	5203	3773	5.2	-3.2	-3.2
Domestic production	82639	94397	104907	111957	1.3	1.1	0.7
Electricity generation by fuel type (GWh)	**82639**	**94397**	**104907**	**111957**	**1.3**	**1.1**	**0.7**
Nuclear energy	48148	50103	34898	0	0.4	-3.6	
Renewables	1693	5110	10681	14095	11.7	7.7	2.8
Hydro	459	458	458	458	0.0	0.0	0.0
Wind	15	2864	4283	6332	69.1	4.1	4.0
Solar	0	7	25	54		13.8	8.2
Biomass & waste	1219	1780	5915	7251	3.9	12.8	2.1
Fossil fuels	32798	39184	59327	97862	1.8	4.2	5.1
Coal	12903	11854	23969	60245	-0.8	7.3	9.7
Petroleum products	738	651	594	545	-1.2	-0.9	-0.9
Natural gas	16086	24220	32630	35493	4.2	3.0	0.8
Coke & blast-furnace gasses	3071	2460	2134	1579	-2.2	-1.4	-3.0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	41.9	51.6	50.4			
Load factor for gross electric capacities (%)	63.0	63.9	60.3	54.9			
CHP indicator (% of electricity from CHP)	7.9	13.2	19.3	18.6			
Non fossil fuels in electricity generation (%)	60.3	58.5	43.4	12.6			
- nuclear	58.3	53.1	33.3	0.0			
- renewable energy forms	2.0	5.4	10.2	12.6			

Source: PRIMES

BELGIUM: Bpk15 **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
							Annual % Change		
Primary Production (ktoe)	**12528**	**13471**	**14529**	**12150**	**4256**	**0.7**	**0.8**	**-1.8**	**-10.0**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Renewable energy sources	727	856	1603	3146	4256	1.6	6.5	7.0	3.1
Hydro	23	39	39	39	39	5.6	0.0	0.0	0.0
Biomass & Waste	701	810	1308	2262	2678	1.4	4.9	5.6	1.7
Wind	1	1	233	784	1442	7.9	68.1	12.9	6.3
Solar and others	2	5	23	61	97	10.0	16.7	10.3	4.8
Net Imports (ktoe)	**38857**	**48547**	**49960**	**49723**	**54693**	**2.3**	**0.3**	**0.0**	**1.0**
Solids	9492	7566	3963	1973	7250	-2.2	-6.3	-6.7	13.9
Oil	21468	27331	28503	27318	26316	2.4	0.4	-0.4	-0.4
Natural gas	8217	13278	16876	19985	20804	4.9	2.4	1.7	0.4
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**58610**	**55571**	**52419**	**1.9**	**0.2**	**-0.5**	**-0.6**
Solids	10244	8200	3963	1973	7250	-2.2	-7.0	-6.7	13.9
Oil	17730	21949	22624	21016	19785	2.2	0.3	-0.7	-0.6
Natural gas	8169	13369	16876	19985	20804	5.0	2.4	1.7	0.4
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Renewable energy forms	727	856	1603	3146	4256	1.6	6.5	7.0	3.1
as % in Gross Inland Consumption									
Solids	21.7	14.3	6.8	3.6	13.8				
Oil	37.5	38.4	38.6	37.8	37.7				
Natural gas	17.3	23.4	28.8	36.0	39.7				
Nuclear	22.7	21.7	22.1	16.2	0.0				
Renewable energy forms	1.5	1.5	2.7	5.7	8.1				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**7839**	**10020**	**16181**	**1.4**	**0.0**	**2.5**	**4.9**
Solids	3879	3030	778	1	5762	-2.4	-12.7	-48.0	134.9
Oil	318	172	72	566	155	-6.0	-8.4	23.0	-12.1
Gas	2239	4186	6250	8260	8756	6.5	4.1	2.8	0.6
Biomass & Waste	403	488	740	1193	1508	1.9	4.3	4.9	2.4
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**36251**	**34413**	**32945**	**1.5**	**-1.2**	**-0.5**	**-0.4**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2273**	**2162**	**2171**	**0.3**	**-0.4**	**-0.5**	**0.0**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5365**	**5126**	**5072**	**7.8**	**-0.8**	**-0.5**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38872**	**38404**	**37813**	**1.7**	**0.5**	**-0.1**	**-0.2**
by sector									
Industry	11944	13769	13568	12893	12464	1.4	-0.1	-0.5	-0.3
Residential	8337	9465	9999	9569	9112	1.3	0.5	-0.4	-0.5
Tertiary	3370	4158	4689	5082	5186	2.1	1.2	0.8	0.2
Transport	7704	9662	10616	10860	11051	2.3	0.9	0.2	0.2
by fuel									
Solids	3783	3373	2010	1177	926	-1.1	-5.0	-5.2	-2.4
Oil	14734	16038	16833	15504	14847	0.9	0.5	-0.8	-0.4
Gas	6993	9615	10148	10503	10600	3.2	0.5	0.3	0.1
Electricity	4986	6667	8098	8923	9008	2.9	2.0	1.0	0.1
Heat (from CHP and District Heating)	566	1046	1251	1322	1339	6.3	1.8	0.6	0.1
Other	293	316	532	975	1093	0.8	5.4	6.2	1.2
CO2 Emissions (Mt of CO2)	**105.9**	**114.7**	**107.1**	**95.8**	**90.0**	**0.8**	**-0.7**	**-1.1**	**-0.6**
Power generation/District heating	22.4	23.5	18.8	15.1	12.4	0.5	-2.2	-2.2	-1.9
Energy Branch	5.3	5.3	4.7	4.1	3.9	0.0	-1.2	-1.4	-0.6
Industry	29.3	29.1	23.9	19.2	17.7	-0.1	-2.0	-2.1	-0.8
Residential	18.7	20.0	19.8	17.7	16.1	0.7	-0.1	-1.1	-0.9
Tertiary	7.5	8.2	9.0	9.2	9.2	0.9	1.0	0.3	0.0
Transport	22.6	28.6	30.9	30.5	30.6	2.4	0.8	-0.1	0.1
CO2 Emissions Index (1990=100)	**100.0**	**108.3**	**101.1**	**90.5**	**85.0**				

Source: PRIMES

BELGIUM: Bpk15 **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
							Annual % Change		
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	193.5	150.1	121.4	-0.2	-1.7	-2.5	-2.1
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.55	5.15	4.77	1.6	0.0	-0.8	-0.8
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9172	10068	10198	1.4	1.3	0.9	0.1
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.83	1.72	1.72	-1.1	-0.9	-0.6	0.0
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.14	8.88	8.19	0.5	-1.0	-1.3	-0.8
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	353.5	258.7	208.4	-1.3	-2.7	-3.1	-2.1
Import Dependency %	75.7	77.7	77.5	80.4	92.8				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.4	67.6	57.1	-0.2	-1.6	-2.1	-1.7
Residential (Energy on Private Income)	100.0	92.7	82.4	66.7	55.4	-0.8	-1.2	-2.1	-1.8
Tertiary (Energy on Value added)	100.0	99.5	89.6	79.0	69.0	0.0	-1.0	-1.3	-1.3
Transport (Energy on GDP)	100.0	101.2	91.0	76.2	66.5	0.1	-1.1	-1.8	-1.4
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.17	0.12	0.10	-1.7	-3.7	-3.2	-2.2
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.99	1.95	-0.7	-0.8	-0.7	-0.2
Industry	2.46	2.12	1.76	1.49	1.42	-1.5	-1.8	-1.6	-0.5
Residential	2.24	2.11	1.98	1.85	1.76	-0.6	-0.7	-0.7	-0.5
Tertiary	2.22	1.96	1.92	1.81	1.78	-1.2	-0.2	-0.6	-0.2
Transport	2.94	2.96	2.91	2.81	2.77	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk15 **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**103983**	**113832**	**115787**	**1.8**	**0.9**	**0.2**
Final energy consumption	77525	94159	103760	104747	2.0	1.0	0.1
Industry	39861	50003	54113	53550	2.3	0.8	-0.1
Households	23734	28094	30708	31894	1.7	0.9	0.4
Tertiary	12491	14523	17462	18003	1.5	1.9	0.3
Transport	1440	1539	1477	1301	0.7	-0.4	-1.3
Energy branch	5757	5868	6166	7311	0.2	0.5	1.7
Transmission and distribution losses	3682	3956	3906	3729	0.7	-0.1	-0.5
Electricity supply (GWh)	**86964**	**103983**	**113832**	**115787**	**1.8**	**0.9**	**0.2**
Net imports	4325	7182	5203	3771	5.2	-3.2	-3.2
Domestic production	82639	96801	108629	112016	1.6	1.2	0.3
Electricity generation by fuel type (GWh)	**82639**	**96801**	**108629**	**112016**	**1.6**	**1.2**	**0.3**
Nuclear energy	48148	50103	34898	0	0.4	-3.6	
Renewables	1693	5142	15917	25479	11.7	12.0	4.8
Hydro	459	458	458	458	0.0	0.0	0.0
Wind	15	2705	9119	16763	68.1	12.9	6.3
Solar	0	7	25	54		13.8	8.2
Biomass & waste	1219	1971	6315	8204	4.9	12.3	2.7
Fossil fuels	32798	41557	57814	86537	2.4	3.4	4.1
Coal	12903	3300	4	25707	-12.7	-49.2	141.5
Petroleum products	738	378	2664	751	-6.5	21.6	-11.9
Natural gas	16086	35420	53013	58500	8.2	4.1	1.0
Coke & blast-furnace gasses	3071	2459	2132	1579	-2.2	-1.4	-3.0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	47.8	55.0	50.4			
Load factor for gross electric capacities (%)	63.0	60.4	58.1	50.1			
CHP indicator (% of electricity from CHP)	7.9	12.4	14.3	14.3			
Non fossil fuels in electricity generation (%)	60.3	57.1	46.8	22.7			
- nuclear	58.3	51.8	32.1	0.0			
- renewable energy forms	2.0	5.3	14.7	22.7			

Source: PRIMES

BELGIUM: Bpk15n **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14529**	**16362**	**20311**	**0.7**	**0.8**	**1.2**	**2.2**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	13476	16399	1.5	0.4	0.4	2.0
Renewable energy sources	727	856	1603	2886	3913	1.6	6.5	6.1	3.1
Hydro	23	39	39	39	39	5.6	0.0	0.0	0.0
Biomass & Waste	701	810	1308	2094	2346	1.4	4.9	4.8	1.1
Wind	1	1	233	694	1431	7.9	68.1	11.5	7.5
Solar and others	2	5	23	59	96	10.0	16.7	10.0	5.1
Net Imports (ktoe)	**38857**	**48547**	**50032**	**48614**	**46456**	**2.3**	**0.3**	**-0.3**	**-0.5**
Solids	9492	7566	4165	2448	1821	-2.2	-5.8	-5.2	-2.9
Oil	21468	27331	28373	27308	26666	2.4	0.4	-0.4	-0.2
Natural gas	8217	13278	16876	18411	17644	4.9	2.4	0.9	-0.4
Electricity	-320	372	618	448	325		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**58682**	**58674**	**60236**	**1.9**	**0.3**	**0.0**	**0.3**
Solids	10244	8200	4165	2448	1821	-2.2	-6.6	-5.2	-2.9
Oil	17730	21949	22494	21006	20135	2.2	0.2	-0.7	-0.4
Natural gas	8169	13369	16876	18411	17644	5.0	2.4	0.9	-0.4
Nuclear	10707	12422	12926	13476	16399	1.5	0.4	0.4	2.0
Electricity	-320	372	618	448	325		5.2	-3.2	-3.2
Renewable energy forms	727	856	1603	2886	3913	1.6	6.5	6.1	3.1
as % in Gross Inland Consumption									
Solids	21.7	14.3	7.1	4.2	3.0				
Oil	37.5	38.4	38.3	35.8	33.4				
Natural gas	17.3	23.4	28.8	31.4	29.3				
Nuclear	22.7	21.7	22.0	23.0	27.2				
Renewable energy forms	1.5	1.5	2.7	4.9	6.5				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**7914**	**7533**	**6597**	**1.4**	**0.0**	**-0.5**	**-1.3**
Solids	3879	3030	979	0	0	-2.4	-10.7		
Oil	318	172	16	11	10	-6.0	-21.3	-3.1	-1.8
Gas	2239	4186	6179	6414	5313	6.5	4.0	0.4	-1.9
Biomass & Waste	403	488	740	1108	1275	1.9	4.3	4.1	1.4
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**36099**	**34723**	**33566**	**1.5**	**-1.2**	**-0.4**	**-0.3**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2275**	**2157**	**2121**	**0.3**	**-0.4**	**-0.5**	**-0.2**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5364**	**5120**	**5072**	**7.8**	**-0.8**	**-0.5**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38874**	**39761**	**39850**	**1.7**	**0.5**	**0.2**	**0.0**
by sector									
Industry	11944	13769	13568	13497	13113	1.4	-0.1	-0.1	-0.3
Residential	8337	9465	10000	9914	9712	1.3	0.6	-0.1	-0.2
Tertiary	3370	4158	4690	5267	5674	2.1	1.2	1.2	0.7
Transport	7704	9662	10616	11082	11351	2.3	0.9	0.4	0.2
by fuel									
Solids	3783	3373	2010	1571	1218	-1.1	-5.0	-2.4	-2.5
Oil	14734	16038	16803	16023	15395	0.9	0.5	-0.5	-0.4
Gas	6993	9615	10177	10854	10840	3.2	0.6	0.6	0.0
Electricity	4986	6667	8099	9034	9951	2.9	2.0	1.1	1.0
Heat (from CHP and District Heating)	566	1046	1252	1392	1456	6.3	1.8	1.1	0.4
Other	293	316	532	887	989	0.8	5.4	5.2	1.1
CO_2 Emissions (Mt of CO_2)	**105.9**	**114.7**	**107.4**	**100.6**	**90.0**	**0.8**	**-0.7**	**-0.7**	**-1.1**
Power generation/District heating	22.4	23.5	19.3	15.7	8.9	0.5	-2.0	-2.0	-5.5
Energy Branch	5.3	5.3	4.7	4.2	3.9	0.0	-1.3	-1.1	-0.6
Industry	29.3	29.1	23.9	21.6	19.1	-0.1	-2.0	-1.0	-1.3
Residential	18.7	20.0	19.8	18.4	16.9	0.7	-0.1	-0.7	-0.9
Tertiary	7.5	8.2	9.0	9.6	9.7	0.9	1.0	0.6	0.2
Transport	22.6	28.6	30.9	31.1	31.5	2.4	0.8	0.1	0.1
CO_2 Emissions Index (1990=100)	**100.0**	**108.3**	**101.5**	**95.1**	**85.0**				

Source: PRIMES

BELGIUM: Bpk15n — Indicators

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	193.8	158.5	139.5	-0.2	-1.7	-2.0	-1.3
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.56	5.44	5.48	1.6	0.0	-0.2	0.1
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9178	10162	11153	1.4	1.3	1.0	0.9
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.83	1.71	1.49	-1.1	-0.9	-0.7	-1.4
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.18	9.33	8.19	0.5	-0.9	-0.9	-1.3
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	354.7	271.8	208.5	-1.3	-2.6	-2.6	-2.6
Import Dependency %	75.7	77.7	77.5	74.8	69.6				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.4	70.8	60.1	-0.2	-1.6	-1.6	-1.6
Residential (Energy on Private Income)	100.0	92.7	82.5	69.1	59.1	-0.8	-1.2	-1.8	-1.6
Tertiary (Energy on Value added)	100.0	99.5	89.7	81.9	75.5	0.0	-1.0	-0.9	-0.8
Transport (Energy on GDP)	100.0	101.2	91.0	77.8	68.3	0.1	-1.1	-1.6	-1.3
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.17	0.12	0.06	-1.7	-3.5	-3.2	-6.5
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	2.03	1.94	-0.7	-0.8	-0.6	-0.5
Industry	2.46	2.12	1.76	1.60	1.45	-1.5	-1.8	-0.9	-1.0
Residential	2.24	2.11	1.98	1.86	1.74	-0.6	-0.7	-0.6	-0.7
Tertiary	2.22	1.96	1.92	1.81	1.72	-1.2	-0.2	-0.6	-0.5
Transport	2.94	2.96	2.91	2.81	2.77	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk15n — Electricity and steam generation sector

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**104051**	**114848**	**126280**	**1.8**	**1.0**	**1.0**
Final energy consumption	77525	94175	105045	115710	2.0	1.1	1.0
Industry	39861	49987	53673	57175	2.3	0.7	0.6
Households	23734	28116	31690	35832	1.7	1.2	1.2
Tertiary	12491	14532	18187	21313	1.5	2.3	1.6
Transport	1440	1540	1494	1390	0.7	-0.3	-0.7
Energy branch	5757	5919	5848	6456	0.3	-0.1	1.0
Transmission and distribution losses	3682	3957	3955	4114	0.7	0.0	0.4
Electricity supply (GWh)	**86964**	**104051**	**114848**	**126280**	**1.8**	**1.0**	**1.0**
Net imports	4325	7182	5204	3775	5.2	-3.2	-3.2
Domestic production	82639	96869	109644	122505	1.6	1.2	1.1
Electricity generation by fuel type (GWh)	**82639**	**96869**	**109644**	**122505**	**1.6**	**1.2**	**1.1**
Nuclear energy	48148	50103	52234	63561	0.4	0.4	2.0
Renewables	1693	5142	14371	23880	11.7	10.8	5.2
Hydro	459	458	458	458	0.0	0.0	0.0
Wind	15	2705	8070	16638	68.1	11.5	7.5
Solar	0	7	25	54		13.8	8.2
Biomass & waste	1219	1972	5817	6730	4.9	11.4	1.5
Fossil fuels	32798	41625	43040	35064	2.4	0.3	-2.0
Coal	12903	4160	0	0	-10.7		
Petroleum products	738	80	59	50	-20.0	-2.9	-1.7
Natural gas	16086	34925	40848	33435	8.1	1.6	-2.0
Coke & blast-furnace gasses	3071	2459	2132	1579	-2.2	-1.4	-3.0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	47.4	55.8	54.5			
Load factor for gross electric capacities (%)	63.0	60.7	59.6	50.8			
CHP indicator (% of electricity from CHP)	7.9	12.8	17.2	16.3			
Non fossil fuels in electricity generation (%)	60.3	57.0	60.7	71.4			
- nuclear	58.3	51.7	47.6	51.9			
- renewable energy forms	2.0	5.3	13.1	19.5			

Source: PRIMES

BELGIUM: Bpk15s **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
							Annual % Change		
Primary Production (ktoe)	**12528**	**13471**	**14544**	**12520**	**4864**	**0.7**	**0.8**	**-1.5**	**-9.0**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Renewable energy sources	727	856	1617	3516	4864	1.6	6.6	8.1	3.3
Hydro	23	39	39	42	39	5.6	0.0	0.6	-0.6
Biomass & Waste	701	810	1308	2422	2805	1.4	4.9	6.4	1.5
Wind	1	1	247	784	1442	7.9	69.1	12.3	6.3
Solar and others	2	5	23	269	578	10.0	16.7	28.1	8.0
Net Imports (ktoe)	**38857**	**48547**	**50030**	**43492**	**46222**	**2.3**	**0.3**	**-1.4**	**0.6**
Solids	9492	7566	4203	1036	756	-2.2	-5.7	-13.1	-3.1
Oil	21468	27331	28332	23824	23783	2.4	0.4	-1.7	0.0
Natural gas	8217	13278	16878	18185	21359	4.9	2.4	0.7	1.6
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**58695**	**49710**	**44555**	**1.9**	**0.3**	**-1.6**	**-1.1**
Solids	10244	8200	4203	1036	756	-2.2	-6.5	-13.1	-3.1
Oil	17730	21949	22453	17521	17252	2.2	0.2	-2.4	-0.2
Natural gas	8169	13369	16878	18185	21359	5.0	2.4	0.7	1.6
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Renewable energy forms	727	856	1617	3516	4864	1.6	6.6	8.1	3.3
as % in Gross Inland Consumption									
Solids	21.7	14.3	7.2	2.1	1.7				
Oil	37.5	38.4	38.3	35.2	38.7				
Natural gas	17.3	23.4	28.8	36.6	47.9				
Nuclear	22.7	21.7	22.0	18.1	0.0				
Renewable energy forms	1.5	1.5	2.8	7.1	10.9				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**7914**	**9456**	**12703**	**1.4**	**0.0**	**1.8**	**3.0**
Solids	3879	3030	1017	0	0	-2.4	-10.3		
Oil	318	172	75	225	382	-6.0	-8.0	11.6	5.4
Gas	2239	4186	6081	8057	10827	6.5	3.8	2.9	3.0
Biomass & Waste	403	488	740	1173	1494	1.9	4.3	4.7	2.4
Other (hydrogen,…)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**36050**	**29555**	**29405**	**1.5**	**-1.2**	**-2.0**	**-0.1**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2273**	**1909**	**1790**	**0.3**	**-0.4**	**-1.7**	**-0.6**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5364**	**5131**	**5065**	**7.8**	**-0.8**	**-0.4**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38870**	**33195**	**33038**	**1.7**	**0.5**	**-1.6**	**0.0**
by sector									
Industry	11944	13769	13567	11168	10955	1.4	-0.1	-1.9	-0.2
Residential	8337	9465	9999	8095	7810	1.3	0.5	-2.1	-0.4
Tertiary	3370	4158	4689	4373	4399	2.1	1.2	-0.7	0.1
Transport	7704	9662	10616	9559	9873	2.3	0.9	-1.0	0.3
by fuel									
Solids	3783	3373	2010	500	374	-1.1	-5.0	-13.0	-2.9
Oil	14734	16038	16763	12755	12436	0.9	0.4	-2.7	-0.3
Gas	6993	9615	10219	8470	8736	3.2	0.6	-1.9	0.3
Electricity	4986	6667	8094	9120	8996	2.9	2.0	1.2	-0.1
Heat (from CHP and District Heating)	566	1046	1252	1178	1243	6.3	1.8	-0.6	0.5
Other	293	316	532	1172	1252	0.8	5.4	8.2	0.7
CO_2 Emissions (Mt of CO_2)	**105.9**	**114.7**	**107.5**	**84.2**	**89.9**	**0.8**	**-0.6**	**-2.4**	**0.7**
Power generation/District heating	22.4	23.5	19.4	20.2	27.0	0.5	-1.9	0.4	2.9
Energy Branch	5.3	5.3	4.6	3.5	3.4	0.0	-1.4	-2.7	-0.3
Industry	29.3	29.1	23.8	13.0	12.8	-0.1	-2.0	-5.9	-0.2
Residential	18.7	20.0	19.8	13.2	12.0	0.7	-0.1	-4.0	-0.9
Tertiary	7.5	8.2	9.0	7.5	7.4	0.9	1.0	-1.8	-0.1
Transport	22.6	28.6	30.9	26.7	27.3	2.4	0.8	-1.4	0.2
CO_2 Emissions Index (1990=100)	**100.0**	**108.3**	**101.5**	**79.5**	**85.0**				

Source: PRIMES

BELGIUM: Bpk15s **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	193.8	134.3	103.2	-0.2	-1.7	-3.6	-2.6
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.56	4.61	4.06	1.6	0.0	-1.9	-1.3
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9173	10209	9924	1.4	1.3	1.1	-0.3
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.83	1.69	2.02	-1.1	-0.9	-0.8	1.8
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.18	7.80	8.19	0.5	-0.9	-2.6	0.5
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	354.8	227.4	208.3	-1.3	-2.6	-4.4	-0.9
Import Dependency %	75.7	77.7	77.5	77.6	90.5				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.4	58.5	50.2	-0.2	-1.6	-3.5	-1.5
Residential (Energy on Private Income)	100.0	92.7	82.4	56.4	47.5	-0.8	-1.2	-3.7	-1.7
Tertiary (Energy on Value added)	100.0	99.5	89.6	68.0	58.5	0.0	-1.0	-2.7	-1.5
Transport (Energy on GDP)	100.0	101.2	91.0	67.1	59.4	0.1	-1.1	-3.0	-1.2
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.17	0.16	0.22	-1.7	-3.4	-0.6	3.0
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.82	1.80	-0.7	-0.8	-1.6	-0.1
Industry	2.46	2.12	1.76	1.17	1.17	-1.5	-1.8	-4.0	0.0
Residential	2.24	2.11	1.98	1.63	1.54	-0.6	-0.7	-1.9	-0.6
Tertiary	2.22	1.96	1.92	1.71	1.69	-1.2	-0.2	-1.1	-0.2
Transport	2.94	2.96	2.91	2.80	2.76	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk15s **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**103994**	**115352**	**112773**	**1.8**	**1.0**	**-0.2**
Final energy consumption	77525	94113	106049	104606	2.0	1.2	-0.1
Industry	39861	49963	55551	52643	2.3	1.1	-0.5
Households	23734	28090	32151	33634	1.7	1.4	0.5
Tertiary	12491	14521	16847	16982	1.5	1.5	0.1
Transport	1440	1539	1500	1347	0.7	-0.3	-1.1
Energy branch	5757	5927	5319	4449	0.3	-1.1	-1.8
Transmission and distribution losses	3682	3954	3984	3718	0.7	0.1	-0.7
Electricity supply (GWh)	**86964**	**103994**	**115352**	**112773**	**1.8**	**1.0**	**-0.2**
Net imports	4325	7182	5201	3770	5.2	-3.2	-3.2
Domestic production	82639	96813	110151	109003	1.6	1.3	-0.1
Electricity generation by fuel type (GWh)	**82639**	**96813**	**110151**	**109003**	**1.6**	**1.3**	**-0.1**
Nuclear energy	48148	50103	34898	0	0.4	-3.6	
Renewables	1693	5308	18167	30883	12.1	13.1	5.4
Hydro	459	458	486	458	0.0	0.6	-0.6
Wind	15	2871	9119	16763	69.1	12.3	6.3
Solar	0	7	2357	5541		79.5	8.9
Biomass & waste	1219	1972	6205	8121	4.9	12.1	2.7
Fossil fuels	32798	41402	57085	78120	2.4	3.3	3.2
Coal	12903	4323	0	0	-10.4		
Petroleum products	738	396	1193	2041	-6.0	11.7	5.5
Natural gas	16086	34224	53838	74492	7.8	4.6	3.3
Coke & blast-furnace gasses	3071	2459	2055	1586	-2.2	-1.8	-2.6
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	47.1	57.6	58.4			
Load factor for gross electric capacities (%)	63.0	60.5	51.3	41.5			
CHP indicator (% of electricity from CHP)	7.9	12.4	13.4	14.5			
Non fossil fuels in electricity generation (%)	60.3	57.2	48.2	28.3			
- nuclear	58.3	51.8	31.7	0.0			
- renewable energy forms	2.0	5.5	16.5	28.3			

Source: PRIMES

BELGIUM: Bpk15ns **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14544**	**16540**	**20538**	**0.7**	**0.8**	**1.3**	**2.2**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	13477	16399	1.5	0.4	0.4	2.0
Renewable energy sources	727	856	1617	3064	4139	1.6	6.6	6.6	3.1
Hydro	23	39	39	39	39	5.6	0.0	0.0	0.0
Biomass & Waste	701	810	1308	2187	2561	1.4	4.9	5.3	1.6
Wind	1	1	247	777	1442	7.9	69.1	12.1	6.4
Solar and others	2	5	23	60	97	10.0	16.7	10.2	4.9
Net Imports (ktoe)	**38857**	**48547**	**49967**	**47301**	**45124**	**2.3**	**0.3**	**-0.5**	**-0.5**
Solids	9492	7566	4073	1954	1448	-2.2	-6.0	-7.1	-2.9
Oil	21468	27331	28271	26541	25993	2.4	0.3	-0.6	-0.2
Natural gas	8217	13278	17005	18359	17358	4.9	2.5	0.8	-0.6
Electricity	-320	372	618	448	325		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**58631**	**57538**	**59131**	**1.9**	**0.3**	**-0.2**	**0.3**
Solids	10244	8200	4073	1954	1448	-2.2	-6.8	-7.1	-2.9
Oil	17730	21949	22392	20238	19462	2.2	0.2	-1.0	-0.4
Natural gas	8169	13369	17005	18359	17358	5.0	2.4	0.8	-0.6
Nuclear	10707	12422	12926	13477	16399	1.5	0.4	0.4	2.0
Electricity	-320	372	618	448	325		5.2	-3.2	-3.2
Renewable energy forms	727	856	1617	3064	4139	1.6	6.6	6.6	3.1
as % in Gross Inland Consumption									
Solids	21.7	14.3	6.9	3.4	2.4				
Oil	37.5	38.4	38.2	35.2	32.9				
Natural gas	17.3	23.4	29.0	31.9	29.4				
Nuclear	22.7	21.7	22.0	23.4	27.7				
Renewable energy forms	1.5	1.5	2.8	5.3	7.0				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**7853**	**7692**	**6757**	**1.4**	**0.0**	**-0.2**	**-1.3**
Solids	3879	3030	887	0	0	-2.4	-11.6		
Oil	318	172	15	7	5	-6.0	-21.6	-8.0	-1.7
Gas	2239	4186	6210	6485	5256	6.5	4.0	0.4	-2.1
Biomass & Waste	403	488	740	1200	1496	1.9	4.3	5.0	2.2
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**35979**	**33482**	**32525**	**1.5**	**-1.2**	**-0.7**	**-0.3**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2270**	**2118**	**2059**	**0.3**	**-0.4**	**-0.7**	**-0.3**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5364**	**5128**	**5079**	**7.8**	**-0.8**	**-0.5**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38871**	**38560**	**38769**	**1.7**	**0.5**	**-0.1**	**0.1**
by sector									
Industry	11944	13769	13567	12917	12662	1.4	-0.1	-0.5	-0.2
Residential	8337	9465	9999	9659	9434	1.3	0.6	-0.3	-0.2
Tertiary	3370	4158	4689	5148	5560	2.1	1.2	0.9	0.8
Transport	7704	9662	10616	10836	11113	2.3	0.9	0.2	0.3
by fuel									
Solids	3783	3373	2010	1169	910	-1.1	-5.0	-5.3	-2.5
Oil	14734	16038	16763	15409	14826	0.9	0.4	-0.8	-0.4
Gas	6993	9615	10216	10538	10485	3.2	0.6	0.3	-0.1
Electricity	4986	6667	8098	9220	10177	2.9	2.0	1.3	1.0
Heat (from CHP and District Heating)	566	1046	1252	1332	1384	6.3	1.8	0.6	0.4
Other	293	316	532	892	988	0.8	5.4	5.3	1.0
CO2 Emissions (Mt of CO2)	**105.9**	**114.7**	**107.1**	**96.2**	**89.9**	**0.8**	**-0.7**	**-1.1**	**-0.7**
Power generation/District heating	22.4	23.5	19.0	15.9	12.8	0.5	-2.1	-1.8	-2.1
Energy Branch	5.3	5.3	4.6	4.0	3.8	0.0	-1.4	-1.4	-0.5
Industry	29.3	29.1	23.8	19.1	17.1	-0.1	-2.0	-2.2	-1.1
Residential	18.7	20.0	19.8	17.6	15.9	0.7	-0.1	-1.1	-1.0
Tertiary	7.5	8.2	9.0	9.2	9.4	0.9	1.0	0.3	0.2
Transport	22.6	28.6	30.9	30.4	30.8	2.4	0.8	-0.2	0.1
CO2 Emissions Index (1990=100)	**100.0**	**108.3**	**101.1**	**90.9**	**84.9**				

Source: PRIMES

BELGIUM: Bpk15ns **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
							Annual % Change		
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	193.6	155.4	137.0	-0.2	-1.7	-2.2	-1.3
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.56	5.33	5.38	1.6	0.0	-0.4	0.1
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9174	10370	11371	1.4	1.3	1.2	0.9
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.83	1.67	1.52	-1.1	-0.9	-0.9	-0.9
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.14	8.92	8.19	0.5	-1.0	-1.3	-0.9
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	353.5	260.0	208.3	-1.3	-2.7	-3.0	-2.2
Import Dependency %	75.7	77.7	77.5	74.1	68.7				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.4	67.7	58.0	-0.2	-1.6	-2.1	-1.5
Residential (Energy on Private Income)	100.0	92.7	82.5	67.3	57.4	-0.8	-1.2	-2.0	-1.6
Tertiary (Energy on Value added)	100.0	99.5	89.6	80.0	74.0	0.0	-1.0	-1.1	-0.8
Transport (Energy on GDP)	100.0	101.2	91.0	76.0	66.9	0.1	-1.1	-1.8	-1.3
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.17	0.12	0.09	-1.7	-3.6	-3.1	-3.1
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.98	1.89	-0.7	-0.8	-0.8	-0.5
Industry	2.46	2.12	1.76	1.48	1.35	-1.5	-1.9	-1.7	-0.9
Residential	2.24	2.11	1.98	1.82	1.69	-0.6	-0.7	-0.8	-0.8
Tertiary	2.22	1.96	1.92	1.79	1.69	-1.2	-0.2	-0.7	-0.6
Transport	2.94	2.96	2.91	2.80	2.77	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk15ns **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**104003**	**117096**	**128679**	**1.8**	**1.2**	**0.9**
Final energy consumption	77525	94157	107205	118333	2.0	1.3	1.0
Industry	39861	49996	55488	58948	2.3	1.0	0.6
Households	23734	28098	32073	36520	1.7	1.3	1.3
Tertiary	12491	14524	18143	21464	1.5	2.2	1.7
Transport	1440	1539	1501	1401	0.7	-0.3	-0.7
Energy branch	5757	5889	5858	6142	0.2	-0.1	0.5
Transmission and distribution losses	3682	3956	4033	4204	0.7	0.2	0.4
Electricity supply (GWh)	**86964**	**104003**	**117096**	**128679**	**1.8**	**1.2**	**0.9**
Net imports	4325	7182	5204	3775	5.2	-3.2	-3.2
Domestic production	82639	96821	111892	124904	1.6	1.5	1.1
Electricity generation by fuel type (GWh)	**82639**	**96821**	**111892**	**124904**	**1.6**	**1.5**	**1.1**
Nuclear energy	48148	50103	52235	63561	0.4	0.4	2.0
Renewables	1693	5307	15845	25380	12.1	11.6	4.8
Hydro	459	458	458	458	0.0	0.0	0.0
Wind	15	2871	9036	16763	69.1	12.1	6.4
Solar	0	7	25	54		13.8	8.2
Biomass & waste	1219	1971	6326	8105	4.9	12.4	2.5
Fossil fuels	32798	41411	43812	35963	2.4	0.6	-2.0
Coal	12903	3769	0	0	-11.6		
Petroleum products	738	79	34	29	-20.0	-8.0	-1.7
Natural gas	16086	35104	41646	34355	8.1	1.7	-1.9
Coke & blast-furnace gasses	3071	2459	2132	1579	-2.2	-1.4	-3.0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	47.5	56.1	56.1			
Load factor for gross electric capacities (%)	63.0	60.2	58.2	51.1			
CHP indicator (% of electricity from CHP)	7.9	12.6	16.2	15.0			
Non fossil fuels in electricity generation (%)	60.3	57.2	60.8	71.2			
- nuclear	58.3	51.7	46.7	50.9			
- renewable energy forms	2.0	5.5	14.2	20.3			

Source: PRIMES

BELGIUM: Bpk30 **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14550**	**12438**	**4611**	**0.7**	**0.8**	**-1.6**	**-9.4**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Renewable energy sources	727	856	1623	3434	4611	1.6	6.6	7.8	3.0
Hydro	23	39	39	41	39	5.6	0.0	0.4	-0.4
Biomass & Waste	701	810	1308	2441	2840	1.4	4.9	6.4	1.5
Wind	1	1	253	784	1442	7.9	69.5	12.0	6.3
Solar and others	2	5	23	168	290	10.0	16.7	22.2	5.6
Net Imports (ktoe)	**38857**	**48547**	**51118**	**47206**	**52219**	**2.3**	**0.5**	**-0.8**	**1.0**
Solids	9492	7566	5036	2119	6258	-2.2	-4.0	-8.3	11.4
Oil	21468	27331	28553	25335	24910	2.4	0.4	-1.2	-0.2
Natural gas	8217	13278	16912	19305	20727	4.9	2.4	1.3	0.7
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**59789**	**53341**	**50299**	**1.9**	**0.4**	**-1.1**	**-0.6**
Solids	10244	8200	5036	2119	6258	-2.2	-4.8	-8.3	11.4
Oil	17730	21949	22674	19032	18379	2.2	0.3	-1.7	-0.3
Natural gas	8169	13369	16912	19305	20727	5.0	2.4	1.3	0.7
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Renewable energy forms	727	856	1623	3434	4611	1.6	6.6	7.8	3.0
as % in Gross Inland Consumption									
Solids	21.7	14.3	8.4	4.0	12.4				
Oil	37.5	38.4	37.9	35.7	36.5				
Natural gas	17.3	23.4	28.3	36.2	41.2				
Nuclear	22.7	21.7	21.6	16.9	0.0				
Renewable energy forms	1.5	1.5	2.7	6.4	9.2				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**8961**	**11026**	**17003**	**1.4**	**1.3**	**2.1**	**4.4**
Solids	3879	3030	1846	830	5404	-2.4	-4.8	-7.7	20.6
Oil	318	172	298	627	475	-6.0	5.6	7.7	-2.7
Gas	2239	4186	6078	8414	9787	6.5	3.8	3.3	1.5
Biomass & Waste	403	488	740	1155	1338	1.9	4.2	4.6	1.5
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**36317**	**31549**	**30830**	**1.5**	**-1.1**	**-1.4**	**-0.2**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2302**	**2157**	**2174**	**0.3**	**-0.3**	**-0.6**	**0.1**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5362**	**5137**	**5080**	**7.8**	**-0.8**	**-0.4**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38848**	**35357**	**35128**	**1.7**	**0.5**	**-0.9**	**-0.1**
by sector									
Industry	11944	13769	13560	11879	11542	1.4	-0.2	-1.3	-0.3
Residential	8337	9465	9989	8637	8348	1.3	0.5	-1.4	-0.3
Tertiary	3370	4158	4683	4663	4731	2.1	1.2	0.0	0.1
Transport	7704	9662	10616	10178	10507	2.3	0.9	-0.4	0.3
by fuel									
Solids	3783	3373	2011	679	458	-1.1	-5.0	-10.3	-3.9
Oil	14734	16038	16765	13846	13448	0.9	0.4	-1.9	-0.3
Gas	6993	9615	10256	9226	9082	3.2	0.6	-1.1	-0.2
Electricity	4986	6667	8033	9196	9463	2.9	1.9	1.4	0.3
Heat (from CHP and District Heating)	566	1046	1251	1206	1242	6.3	1.8	-0.4	0.3
Other	293	316	532	1203	1435	0.8	5.4	8.5	1.8
CO2 Emissions (Mt of CO2)	**105.9**	**114.7**	**111.5**	**76.0**	**73.8**	**0.8**	**-0.3**	**-3.8**	**-0.3**
Power generation/District heating	22.4	23.5	23.3	6.0	6.5	0.5	-0.1	-12.7	0.8
Energy Branch	5.3	5.3	4.6	3.7	3.6	0.0	-1.4	-2.2	-0.3
Industry	29.3	29.1	23.9	14.5	12.8	-0.1	-2.0	-4.9	-1.2
Residential	18.7	20.0	19.8	15.0	13.7	0.7	-0.1	-2.7	-0.9
Tertiary	7.5	8.2	9.0	8.3	8.2	0.9	1.0	-0.8	-0.2
Transport	22.6	28.6	30.9	28.5	29.0	2.4	0.8	-0.8	0.2
CO2 Emissions Index (1990=100)	**100.0**	**108.3**	**105.4**	**71.8**	**69.8**				

Source: PRIMES

BELGIUM: Bpk30 **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	197.4	144.1	116.5	-0.2	-1.5	-3.1	-2.1
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.67	4.94	4.58	1.6	0.2	-1.4	-0.8
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9132	10482	10768	1.4	1.3	1.4	0.3
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.87	1.43	1.47	-1.1	-0.7	-2.7	0.3
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.57	7.04	6.72	0.5	-0.6	-4.0	-0.5
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	368.3	205.4	171.1	-1.3	-2.3	-5.7	-1.8
Import Dependency %	75.7	77.7	77.8	79.1	91.9				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.3	62.3	52.9	-0.2	-1.6	-2.9	-1.6
Residential (Energy on Private Income)	100.0	92.7	82.4	60.2	50.8	-0.8	-1.2	-3.1	-1.7
Tertiary (Energy on Value added)	100.0	99.5	89.5	72.5	62.9	0.0	-1.1	-2.1	-1.4
Transport (Energy on GDP)	100.0	101.2	91.0	71.4	63.2	0.1	-1.1	-2.4	-1.2
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.21	0.05	0.05	-1.7	-1.6	-13.9	0.4
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.88	1.81	-0.7	-0.7	-1.4	-0.3
Industry	2.46	2.12	1.76	1.22	1.11	-1.5	-1.8	-3.6	-0.9
Residential	2.24	2.11	1.98	1.74	1.64	-0.6	-0.6	-1.3	-0.6
Tertiary	2.22	1.96	1.92	1.78	1.73	-1.2	-0.2	-0.8	-0.3
Transport	2.94	2.96	2.91	2.80	2.76	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk30 **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**103566**	**118301**	**122044**	**1.8**	**1.3**	**0.3**
Final energy consumption	77525	93408	106935	110033	1.9	1.4	0.3
Industry	39861	49503	58166	58425	2.2	1.6	0.0
Households	23734	27915	30633	32848	1.6	0.9	0.7
Tertiary	12491	14453	16658	17423	1.5	1.4	0.5
Transport	1440	1536	1479	1337	0.7	-0.4	-1.0
Energy branch	5757	6233	7347	8101	0.8	1.7	1.0
Transmission and distribution losses	3682	3925	4019	3911	0.6	0.2	-0.3
Electricity supply (GWh)	**86964**	**103566**	**118301**	**122044**	**1.8**	**1.3**	**0.3**
Net imports	4325	7181	5201	3771	5.2	-3.2	-3.2
Domestic production	82639	96384	113100	118274	1.6	1.6	0.4
Electricity generation by fuel type (GWh)	**82639**	**96384**	**113100**	**118274**	**1.6**	**1.6**	**0.4**
Nuclear energy	48148	50103	34898	0	0.4	-3.6	
Renewables	1693	5376	16990	26903	12.2	12.2	4.7
Hydro	459	458	475	458	0.0	0.4	-0.4
Wind	15	2940	9119	16763	69.5	12.0	6.3
Solar	0	7	1217	2240		68.0	6.3
Biomass & waste	1219	1970	6179	7441	4.9	12.1	1.9
Fossil fuels	32798	40906	61212	91371	2.2	4.1	4.1
Coal	12903	7861	3616	24041	-4.8	-7.5	20.9
Petroleum products	738	1571	2986	2261	7.9	6.6	-2.7
Natural gas	16086	29015	52475	63495	6.1	6.1	1.9
Coke & blast-furnace gasses	3071	2460	2136	1574	-2.2	-1.4	-3.0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	41.1	52.6	50.0			
Load factor for gross electric capacities (%)	63.0	69.1	53.7	47.2			
CHP indicator (% of electricity from CHP)	7.9	13.0	14.8	12.8			
Non fossil fuels in electricity generation (%)	60.3	57.6	45.9	22.7			
- nuclear	58.3	52.0	30.9	0.0			
- renewable energy forms	2.0	5.6	15.0	22.7			

Source: PRIMES

BELGIUM: Bpk30n **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
							Annual % Change		
Primary Production (ktoe)	**12528**	**13471**	**14544**	**16693**	**20506**	**0.7**	**0.8**	**1.4**	**2.1**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	13485	16399	1.5	0.4	0.4	2.0
Renewable energy sources	727	856	1617	3207	4107	1.6	6.6	7.1	2.5
Hydro	23	39	39	39	39	5.6	0.0	0.0	0.0
Biomass & Waste	701	810	1308	2322	2528	1.4	4.9	5.9	0.9
Wind	1	1	247	784	1442	7.9	69.1	12.3	6.3
Solar and others	2	5	23	62	98	10.0	16.7	10.5	4.8
Net Imports (ktoe)	**38857**	**48547**	**50035**	**46492**	**44476**	**2.3**	**0.3**	**-0.7**	**-0.4**
Solids	9492	7566	4324	1652	1822	-2.2	-5.4	-9.2	1.0
Oil	21468	27331	28268	26046	25499	2.4	0.3	-0.8	-0.2
Natural gas	8217	13278	16824	18346	16831	4.9	2.4	0.9	-0.9
Electricity	-320	372	618	447	325		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**58699**	**56882**	**58451**	**1.9**	**0.3**	**-0.3**	**0.3**
Solids	10244	8200	4324	1652	1822	-2.2	-6.2	-9.2	1.0
Oil	17730	21949	22390	19744	18968	2.2	0.2	-1.2	-0.4
Natural gas	8169	13369	16824	18346	16831	5.0	2.3	0.9	-0.9
Nuclear	10707	12422	12926	13485	16399	1.5	0.4	0.4	2.0
Electricity	-320	372	618	447	325		5.2	-3.2	-3.2
Renewable energy forms	727	856	1617	3207	4107	1.6	6.6	7.1	2.5
as % in Gross Inland Consumption									
Solids	21.7	14.3	7.4	2.9	3.1				
Oil	37.5	38.4	38.1	34.7	32.5				
Natural gas	17.3	23.4	28.7	32.3	28.8				
Nuclear	22.7	21.7	22.0	23.7	28.1				
Renewable energy forms	1.5	1.5	2.8	5.6	7.0				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**7918**	**8219**	**7789**	**1.4**	**0.1**	**0.4**	**-0.5**
Solids	3879	3030	1139	0	762	-2.4	-9.3		
Oil	318	172	16	7	475	-6.0	-21.1	-7.4	51.6
Gas	2239	4186	6025	7114	5442	6.5	3.7	1.7	-2.6
Biomass & Waste	403	488	738	1098	1109	1.9	4.2	4.0	0.1
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**35976**	**32661**	**31651**	**1.5**	**-1.2**	**-1.0**	**-0.3**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2275**	**2168**	**2150**	**0.3**	**-0.4**	**-0.5**	**-0.1**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5364**	**5134**	**5085**	**7.8**	**-0.8**	**-0.4**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38871**	**37424**	**37213**	**1.7**	**0.5**	**-0.4**	**-0.1**
by sector									
Industry	11944	13769	13567	12571	12147	1.4	-0.1	-0.8	-0.3
Residential	8337	9465	9999	9257	9033	1.3	0.5	-0.8	-0.2
Tertiary	3370	4158	4689	4966	5289	2.1	1.2	0.6	0.6
Transport	7704	9662	10616	10630	10745	2.3	0.9	0.0	0.1
by fuel									
Solids	3783	3373	2010	943	617	-1.1	-5.0	-7.3	-4.1
Oil	14734	16038	16761	14876	14027	0.9	0.4	-1.2	-0.6
Gas	6993	9615	10220	9893	9549	3.2	0.6	-0.3	-0.4
Electricity	4986	6667	8093	9306	10373	2.9	2.0	1.4	1.1
Heat (from CHP and District Heating)	566	1046	1253	1277	1304	6.3	1.8	0.2	0.2
Other	293	316	533	1129	1343	0.8	5.4	7.8	1.7
CO2 Emissions (Mt of CO2)	**105.9**	**114.7**	**107.6**	**85.4**	**74.2**	**0.8**	**-0.6**	**-2.3**	**-1.4**
Power generation/District heating	22.4	23.5	19.5	9.2	3.2	0.5	-1.8	-7.2	-10.1
Energy Branch	5.3	5.3	4.6	4.0	3.6	0.0	-1.4	-1.5	-0.8
Industry	29.3	29.1	23.8	17.0	14.0	-0.1	-2.0	-3.3	-1.9
Residential	18.7	20.0	19.8	16.6	14.8	0.7	-0.1	-1.8	-1.1
Tertiary	7.5	8.2	9.0	8.8	8.8	0.9	1.0	-0.2	0.0
Transport	22.6	28.6	30.9	29.8	29.8	2.4	0.8	-0.4	0.0
CO2 Emissions Index (1990=100)	**100.0**	**108.3**	**101.7**	**80.6**	**70.1**				

Source: PRIMES

BELGIUM: Bpk30n **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
							Annual % Change		
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	193.8	153.7	135.4	-0.2	-1.7	-2.3	-1.3
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.56	5.27	5.32	1.6	0.0	-0.5	0.1
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9175	10542	11710	1.4	1.3	1.4	1.1
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.83	1.50	1.27	-1.1	-0.9	-2.0	-1.7
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.20	7.91	6.75	0.5	-0.9	-2.5	-1.6
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	355.3	230.6	171.8	-1.3	-2.6	-4.2	-2.9
Import Dependency %	75.7	77.7	77.5	73.6	68.4				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.4	65.9	55.6	-0.2	-1.6	-2.3	-1.7
Residential (Energy on Private Income)	100.0	92.7	82.4	64.5	54.9	-0.8	-1.2	-2.4	-1.6
Tertiary (Energy on Value added)	100.0	99.5	89.6	77.2	70.4	0.0	-1.0	-1.5	-0.9
Transport (Energy on GDP)	100.0	101.2	91.0	74.6	64.7	0.1	-1.1	-2.0	-1.4
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.17	0.07	0.02	-1.7	-3.4	-8.6	-11.0
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.93	1.81	-0.7	-0.8	-1.1	-0.6
Industry	2.46	2.12	1.76	1.35	1.15	-1.5	-1.8	-2.6	-1.6
Residential	2.24	2.11	1.98	1.79	1.64	-0.6	-0.7	-1.0	-0.9
Tertiary	2.22	1.96	1.92	1.78	1.67	-1.2	-0.2	-0.7	-0.6
Transport	2.94	2.96	2.91	2.81	2.77	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk30n **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**104018**	**118954**	**132399**	**1.8**	**1.4**	**1.1**
Final energy consumption	77525	94108	108211	120619	2.0	1.4	1.1
Industry	39861	49951	57268	61852	2.3	1.4	0.8
Households	23734	28095	31685	36563	1.7	1.2	1.4
Tertiary	12491	14522	17762	20843	1.5	2.0	1.6
Transport	1440	1539	1496	1361	0.7	-0.3	-0.9
Energy branch	5757	5956	6674	7498	0.3	1.1	1.2
Transmission and distribution losses	3682	3954	4069	4282	0.7	0.3	0.5
Electricity supply (GWh)	**86964**	**104018**	**118954**	**132399**	**1.8**	**1.4**	**1.1**
Net imports	4325	7182	5203	3774	5.2	-3.2	-3.2
Domestic production	82639	96836	113752	128626	1.6	1.6	1.2
Electricity generation by fuel type (GWh)	**82639**	**96836**	**113752**	**128626**	**1.6**	**1.6**	**1.2**
Nuclear energy	48148	50103	52269	63561	0.4	0.4	2.0
Renewables	1693	5304	15352	22976	12.1	11.2	4.1
Hydro	459	458	458	458	0.0	0.0	0.0
Wind	15	2871	9119	16763	69.1	12.3	6.3
Solar	0	7	25	54		13.8	8.2
Biomass & waste	1219	1967	5749	5701	4.9	11.3	-0.1
Fossil fuels	32798	41430	46131	42089	2.4	1.1	-0.9
Coal	12903	4842	0	3393	-9.3		
Petroleum products	738	79	39	2296	-20.0	-6.8	50.2
Natural gas	16086	34050	43959	34820	7.8	2.6	-2.3
Coke & blast-furnace gasses	3071	2459	2133	1579	-2.2	-1.4	-3.0
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	47.1	54.3	52.8			
Load factor for gross electric capacities (%)	63.0	60.3	57.8	50.6			
CHP indicator (% of electricity from CHP)	7.9	14.2	14.6	9.6			
Non fossil fuels in electricity generation (%)	60.3	57.2	59.4	67.3			
- nuclear	58.3	51.7	46.0	49.4			
- renewable energy forms	2.0	5.5	13.5	17.9			

Source: PRIMES

BELGIUM: Bpk30s **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14550**	**12918**	**5181**	**0.7**	**0.8**	**-1.2**	**-8.7**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Renewable energy sources	727	856	1623	3914	5181	1.6	6.6	9.2	2.8
Hydro	23	39	39	42	39	5.6	0.0	0.6	-0.6
Biomass & Waste	701	810	1308	2402	2758	1.4	4.9	6.3	1.4
Wind	1	1	253	784	1442	7.9	69.5	12.0	6.3
Solar and others	2	5	23	686	942	10.0	16.7	40.6	3.2
Net Imports (ktoe)	**38857**	**48547**	**50953**	**37332**	**40597**	**2.3**	**0.5**	**-3.1**	**0.8**
Solids	9492	7566	5064	237	302	-2.2	-3.9	-26.4	2.4
Oil	21468	27331	28361	21045	20983	2.4	0.4	-2.9	0.0
Natural gas	8217	13278	16910	15602	18987	4.9	2.4	-0.8	2.0
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**59624**	**43947**	**39247**	**1.9**	**0.4**	**-3.0**	**-1.1**
Solids	10244	8200	5064	237	302	-2.2	-4.7	-26.4	2.4
Oil	17730	21949	22482	14743	14452	2.2	0.2	-4.1	-0.2
Natural gas	8169	13369	16910	15602	18987	5.0	2.4	-0.8	2.0
Nuclear	10707	12422	12926	9004	0	1.5	0.4	-3.6	
Electricity	-320	372	618	447	324		5.2	-3.2	-3.2
Renewable energy forms	727	856	1623	3914	5181	1.6	6.6	9.2	2.8
as % in Gross Inland Consumption									
Solids	21.7	14.3	8.5	0.5	0.8				
Oil	37.5	38.4	37.7	33.5	36.8				
Natural gas	17.3	23.4	28.4	35.5	48.4				
Nuclear	22.7	21.7	21.7	20.5	0.0				
Renewable energy forms	1.5	1.5	2.7	8.9	13.2				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**8799**	**8497**	**11629**	**1.4**	**1.1**	**-0.3**	**3.2**
Solids	3879	3030	1874	0	0	-2.4	-4.7		
Oil	318	172	102	0	0	-6.0	-5.1	-43.0	-5.0
Gas	2239	4186	6083	6255	7886	6.5	3.8	0.3	2.3
Biomass & Waste	403	488	740	1066	1347	1.9	4.3	3.7	2.4
Other (hydrogen,…)	0	0	0	1177	2396				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**36092**	**26629**	**28193**	**1.5**	**-1.2**	**-3.0**	**0.6**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2299**	**1693**	**1590**	**0.3**	**-0.3**	**-3.0**	**-0.6**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5362**	**5115**	**5037**	**7.8**	**-0.8**	**-0.5**	**-0.2**
Final Energy Demand (ktoe)	**31355**	**37055**	**38853**	**27764**	**27863**	**1.7**	**0.5**	**-3.3**	**0.0**
by sector									
Industry	11944	13769	13560	9539	9734	1.4	-0.2	-3.5	0.2
Residential	8337	9465	9991	6647	6371	1.3	0.5	-4.0	-0.4
Tertiary	3370	4158	4684	3396	3418	2.1	1.2	-3.2	0.1
Transport	7704	9662	10616	8182	8340	2.3	0.9	-2.6	0.2
by fuel									
Solids	3783	3373	2011	228	202	-1.1	-5.0	-19.5	-1.2
Oil	14734	16038	16766	10240	10067	0.9	0.4	-4.8	-0.2
Gas	6993	9615	10253	6062	6523	3.2	0.6	-5.1	0.7
Electricity	4986	6667	8039	8945	8592	2.9	1.9	1.1	-0.4
Heat (from CHP and District Heating)	566	1046	1252	991	1076	6.3	1.8	-2.3	0.8
Other	293	316	532	1298	1403	0.8	5.4	9.3	0.8
CO2 Emissions (Mt of CO2)	**105.9**	**114.7**	**111.0**	**66.8**	**74.3**	**0.8**	**-0.3**	**-5.0**	**1.1**
Power generation/District heating	22.4	23.5	22.8	14.6	18.6	0.5	-0.3	-4.4	2.4
Energy Branch	5.3	5.3	4.6	6.1	9.3	0.0	-1.4	2.9	4.2
Industry	29.3	29.1	23.9	9.1	9.7	-0.1	-2.0	-9.2	0.7
Residential	18.7	20.0	19.8	8.5	8.3	0.7	-0.1	-8.0	-0.3
Tertiary	7.5	8.2	9.0	5.6	5.5	0.9	1.0	-4.7	-0.1
Transport	22.6	28.6	30.9	22.8	23.0	2.4	0.8	-3.0	0.1
CO2 Emissions Index (1990=100)	**100.0**	**108.3**	**104.9**	**63.1**	**70.2**				

Source: PRIMES

BELGIUM: Bpk30s **Indicators**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	196.9	118.7	90.9	-0.2	-1.6	-4.9	-2.6
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.65	4.07	3.57	1.6	0.1	-3.2	-1.3
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9137	9965	9422	1.4	1.3	0.9	-0.6
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.86	1.52	1.89	-1.1	-0.7	-2.0	2.2
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.52	6.19	6.76	0.5	-0.6	-5.2	0.9
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	366.6	180.4	172.1	-1.3	-2.3	-6.8	-0.5
Import Dependency %	75.7	77.7	77.8	74.3	88.7				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.3	50.0	44.6	-0.2	-1.6	-5.0	-1.1
Residential (Energy on Private Income)	100.0	92.7	82.4	46.3	38.7	-0.8	-1.2	-5.6	-1.8
Tertiary (Energy on Value added)	100.0	99.5	89.6	52.8	45.5	0.0	-1.1	-5.1	-1.5
Transport (Energy on GDP)	100.0	101.2	91.0	57.4	50.2	0.1	-1.1	-4.5	-1.3
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.21	0.12	0.16	-1.7	-1.8	-5.0	2.7
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.66	1.67	-0.7	-0.7	-2.6	0.1
Industry	2.46	2.12	1.76	0.95	1.00	-1.5	-1.8	-6.0	0.5
Residential	2.24	2.11	1.98	1.29	1.30	-0.6	-0.6	-4.2	0.1
Tertiary	2.22	1.96	1.92	1.64	1.61	-1.2	-0.2	-1.5	-0.2
Transport	2.94	2.96	2.91	2.79	2.75	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk30s **Electricity and steam generation sector**

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**103616**	**112716**	**107255**	**1.8**	**0.8**	**-0.5**
Final energy consumption	77525	93478	104016	99909	1.9	1.1	-0.4
Industry	39861	49509	53840	51843	2.2	0.8	-0.4
Households	23734	27959	34423	32281	1.7	2.1	-0.6
Tertiary	12491	14472	14223	14472	1.5	-0.2	0.2
Transport	1440	1537	1529	1314	0.7	-0.1	-1.5
Energy branch	5757	6210	4799	3798	0.8	-2.5	-2.3
Transmission and distribution losses	3682	3928	3901	3547	0.6	-0.1	-0.9
Electricity supply (GWh)	**86964**	**103616**	**112716**	**107255**	**1.8**	**0.8**	**-0.5**
Net imports	4325	7181	5199	3766	5.2	-3.2	-3.2
Domestic production	82639	96434	107517	103488	1.6	1.1	-0.4
Electricity generation by fuel type (GWh)	**82639**	**96434**	**107517**	**103488**	**1.6**	**1.1**	**-0.4**
Nuclear energy	48148	50103	34898	0	0.4	-3.6	
Renewables	1693	5377	22156	33898	12.2	15.2	4.3
Hydro	459	458	486	458	0.0	0.6	-0.6
Wind	15	2940	9119	16763	69.5	12.0	6.3
Solar	0	7	6908	9373		99.8	3.1
Biomass & waste	1219	1971	5642	7304	4.9	11.1	2.6
Fossil fuels	32798	40955	50463	69591	2.2	2.1	3.3
Coal	12903	7982	0	0	-4.7	-100.0	
Petroleum products	738	538	2	1	-3.1	-43.0	-5.0
Natural gas	16086	29975	43848	55545	6.4	3.9	2.4
Coke & blast-furnace gasses	3071	2460	0	472	-2.2	-100.0	
Other fuels (hydrogen, etc)	0	0	6613	13572			
Indicators							
Efficiency for thermal electricity production (%)	37.1	42.0	56.8	56.9			
Load factor for gross electric capacities (%)	63.0	67.6	43.0	36.5			
CHP indicator (% of electricity from CHP)	7.9	12.5	12.5	14.1			
Non fossil fuels in electricity generation (%)	60.3	57.5	53.1	32.8			
- nuclear	58.3	52.0	32.5	0.0			
- renewable energy forms	2.0	5.6	20.6	32.8			

Source: PRIMES

BELGIUM: Bpk30ns **Summary Energy Balance**

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Primary Production (ktoe)	**12528**	**13471**	**14529**	**16957**	**21079**	**0.7**	**0.8**	**1.6**	**2.2**
Fossil fuels	1094	193	0	0	0	-15.9			
Nuclear	10707	12422	12926	13476	16399	1.5	0.4	0.4	2.0
Renewable energy sources	727	856	1603	3480	4680	1.6	6.5	8.1	3.0
Hydro	23	39	39	41	39	5.6	0.0	0.4	-0.4
Biomass & Waste	701	810	1308	2422	2801	1.4	4.9	6.4	1.5
Wind	1	1	233	784	1442	7.9	68.1	12.9	6.3
Solar and others	2	5	23	233	398	10.0	16.7	26.2	5.5
Net Imports (ktoe)	**38857**	**48547**	**49969**	**41925**	**39588**	**2.3**	**0.3**	**-1.7**	**-0.6**
Solids	9492	7566	4059	1012	683	-2.2	-6.0	-13.0	-3.9
Oil	21468	27331	28277	23731	23415	2.4	0.3	-1.7	-0.1
Natural gas	8217	13278	17016	16734	15166	4.9	2.5	-0.2	-1.0
Electricity	-320	372	618	447	325		5.2	-3.2	-3.2
Gross Inland Consumption (ktoe)	**47257**	**57168**	**58620**	**52579**	**54136**	**1.9**	**0.3**	**-1.1**	**0.3**
Solids	10244	8200	4059	1012	683	-2.2	-6.8	-13.0	-3.9
Oil	17730	21949	22398	17429	16884	2.2	0.2	-2.5	-0.3
Natural gas	8169	13369	17016	16734	15166	5.0	2.4	-0.2	-1.0
Nuclear	10707	12422	12926	13476	16399	1.5	0.4	0.4	2.0
Electricity	-320	372	618	447	325		5.2	-3.2	-3.2
Renewable energy forms	727	856	1603	3480	4680	1.6	6.5	8.1	3.0
as % in Gross Inland Consumption									
Solids	21.7	14.3	6.9	1.9	1.3				
Oil	37.5	38.4	38.2	33.1	31.2				
Natural gas	17.3	23.4	29.0	31.8	28.0				
Nuclear	22.7	21.7	22.1	25.6	30.3				
Renewable energy forms	1.5	1.5	2.7	6.6	8.6				
Fuel Inputs for Thermal Power & Steam Generation (ktoe)	**6839**	**7876**	**7849**	**7792**	**6694**	**1.4**	**0.0**	**-0.1**	**-1.5**
Solids	3879	3030	874	0	0	-2.4	-11.7		
Oil	318	172	21	2	1	-6.0	-18.8	-22.2	-3.6
Gas	2239	4186	6256	6642	5228	6.5	4.1	0.6	-2.4
Biomass & Waste	403	488	698	1148	1465	1.9	3.6	5.1	2.5
Other (hydrogen,...)	0	0	0	0	0				
Fuel Input in other transformation processes (ktoe)	**35153**	**40739**	**35986**	**29405**	**28933**	**1.5**	**-1.2**	**-2.0**	**-0.2**
Energy Branch Consumption (ktoe)	**2310**	**2370**	**2271**	**1948**	**1916**	**0.3**	**-0.4**	**-1.5**	**-0.2**
Non-Energy Uses (ktoe)	**2739**	**5814**	**5364**	**5136**	**5082**	**7.8**	**-0.8**	**-0.4**	**-0.1**
Final Energy Demand (ktoe)	**31355**	**37055**	**38873**	**33694**	**33844**	**1.7**	**0.5**	**-1.4**	**0.0**
by sector									
Industry	11944	13769	13569	11331	11171	1.4	-0.1	-1.8	-0.1
Residential	8337	9465	9999	8254	8020	1.3	0.5	-1.9	-0.3
Tertiary	3370	4158	4689	4464	4701	2.1	1.2	-0.5	0.5
Transport	7704	9662	10616	9645	9952	2.3	0.9	-1.0	0.3
by fuel									
Solids	3783	3373	2010	503	327	-1.1	-5.0	-12.9	-4.2
Oil	14734	16038	16751	12883	12439	0.9	0.4	-2.6	-0.4
Gas	6993	9615	10191	8404	8120	3.2	0.6	-1.9	-0.3
Electricity	4986	6667	8094	9533	10490	2.9	2.0	1.7	1.0
Heat (from CHP and District Heating)	566	1046	1253	1176	1198	6.3	1.8	-0.6	0.2
Other	293	316	574	1194	1270	0.8	6.2	7.6	0.6
CO_2 Emissions (Mt of CO_2)	**105.9**	**114.7**	**107.0**	**80.4**	**74.0**	**0.8**	**-0.7**	**-2.8**	**-0.8**
Power generation/District heating	22.4	23.5	19.0	16.2	12.7	0.5	-2.1	-1.6	-2.3
Energy Branch	5.3	5.3	4.6	3.5	3.4	0.0	-1.4	-2.7	-0.4
Industry	29.3	29.1	23.7	12.8	11.5	-0.1	-2.0	-6.0	-1.1
Residential	18.7	20.0	19.8	13.3	11.5	0.7	-0.1	-3.9	-1.5
Tertiary	7.5	8.2	9.0	7.6	7.4	0.9	1.0	-1.7	-0.3
Transport	22.6	28.6	30.9	27.0	27.5	2.4	0.8	-1.3	0.2
CO_2 Emissions Index (1990=100)	**100.0**	**108.3**	**101.1**	**75.9**	**69.9**				

Source: PRIMES

BELGIUM: Bpk30ns — Indicators

	1990	2000	2010	2020	2030	00//90	10//00	20//10	30//20
						Annual % Change			
Main Energy System Indicators									
Population (Million)	9.968	10.246	10.554	10.790	10.984	0.3	0.3	0.2	0.2
GDP (in 000 MEUR'00)	200.1	247.9	302.9	370.1	431.7	2.2	2.0	2.0	1.5
Gross Inl. Cons./GDP (toe/MEUR'00)	236.2	230.6	193.6	142.0	125.4	-0.2	-1.7	-3.0	-1.2
Gross Inl. Cons./Capita (toe/inhabitant)	4.74	5.58	5.55	4.87	4.93	1.6	0.0	-1.3	0.1
Electricity Generated/Capita (kWh/inhabitant)	7043	8066	9169	10706	11698	1.4	1.3	1.6	0.9
Carbon intensity (t of CO_2/toe of GIC)	2.24	2.01	1.83	1.53	1.37	-1.1	-0.9	-1.8	-1.1
CO_2 Emissions/Capita (t of CO_2/inhabitant)	10.62	11.19	10.14	7.45	6.74	0.5	-1.0	-3.0	-1.0
CO_2 Emissions to GDP (t of CO_2/MEUR'00)	529.0	462.6	353.4	217.1	171.4	-1.3	-2.7	-4.8	-2.3
Import Dependency %	75.7	77.7	77.5	71.2	65.3				
Energy intensity indicators (1990=100)									
Industry (Energy on Value added)	100.0	97.5	83.4	59.4	51.2	-0.2	-1.6	-3.3	-1.5
Residential (Energy on Private Income)	100.0	92.7	82.4	57.5	48.8	-0.8	-1.2	-3.5	-1.6
Tertiary (Energy on Value added)	100.0	99.5	89.6	69.4	62.5	0.0	-1.0	-2.5	-1.0
Transport (Energy on GDP)	100.0	101.2	91.0	67.7	59.9	0.1	-1.1	-2.9	-1.2
Carbon Intensity indicators									
Electricity and Steam production (t of CO_2/MWh)	0.29	0.25	0.17	0.12	0.09	-1.7	-3.6	-3.1	-3.3
Final energy demand (t of CO_2/toe)	2.49	2.32	2.15	1.80	1.71	-0.7	-0.8	-1.7	-0.5
Industry	2.46	2.12	1.75	1.13	1.03	-1.5	-1.9	-4.3	-0.9
Residential	2.24	2.11	1.98	1.61	1.43	-0.6	-0.7	-2.0	-1.2
Tertiary	2.22	1.96	1.92	1.70	1.57	-1.2	-0.2	-1.2	-0.8
Transport	2.94	2.96	2.91	2.80	2.76	0.1	-0.2	-0.4	-0.1

Source: PRIMES

BELGIUM: Bpk30ns — Electricity and steam generation sector

	2000	2010	2020	2030	10//00	20//10	30//20
					Annual % Change		
Electricity demand (GWh)	**86964**	**103947**	**120723**	**132270**	**1.8**	**1.5**	**0.9**
Final energy consumption	77525	94113	110853	121982	2.0	1.7	1.0
Industry	39861	49955	58285	61227	2.3	1.6	0.5
Households	23734	28095	33504	38687	1.7	1.8	1.4
Tertiary	12491	14523	17537	20627	1.5	1.9	1.6
Transport	1440	1539	1527	1441	0.7	-0.1	-0.6
Energy branch	5757	5881	5709	5962	0.2	-0.3	0.4
Transmission and distribution losses	3682	3954	4162	4326	0.7	0.5	0.4
Electricity supply (GWh)	**86964**	**103947**	**120723**	**132270**	**1.8**	**1.5**	**0.9**
Net imports	4325	7182	5202	3774	5.2	-3.2	-3.2
Domestic production	82639	96766	115521	128496	1.6	1.8	1.1
Electricity generation by fuel type (GWh)	**82639**	**96766**	**115521**	**128496**	**1.6**	**1.8**	**1.1**
Nuclear energy	48148	50103	52234	63561	0.4	0.4	2.0
Renewables	1693	5031	17689	28712	11.5	13.4	5.0
Hydro	459	458	475	458	0.0	0.4	-0.4
Wind	15	2705	9119	16763	68.1	12.9	6.3
Solar	0	7	1961	3507		76.2	6.0
Biomass & waste	1219	1860	6133	7984	4.3	12.7	2.7
Fossil fuels	32798	41632	45599	36223	2.4	0.9	-2.3
Coal	12903	3711	0	0	-11.7		
Petroleum products	738	96	9	6	-18.4	-20.9	-3.6
Natural gas	16086	35366	43627	34638	8.2	2.1	-2.3
Coke & blast-furnace gasses	3071	2459	1963	1579	-2.2	-2.2	-2.2
Other fuels (hydrogen, etc)	0	0	0	0			
Indicators							
Efficiency for thermal electricity production (%)	37.1	47.7	57.1	56.8			
Load factor for gross electric capacities (%)	63.0	60.6	53.3	46.0			
CHP indicator (% of electricity from CHP)	7.9	12.4	13.5	12.4			
Non fossil fuels in electricity generation (%)	60.3	57.0	60.5	71.8			
- nuclear	58.3	51.8	45.2	49.5			
- renewable energy forms	2.0	5.2	15.3	22.3			

Source: PRIMES

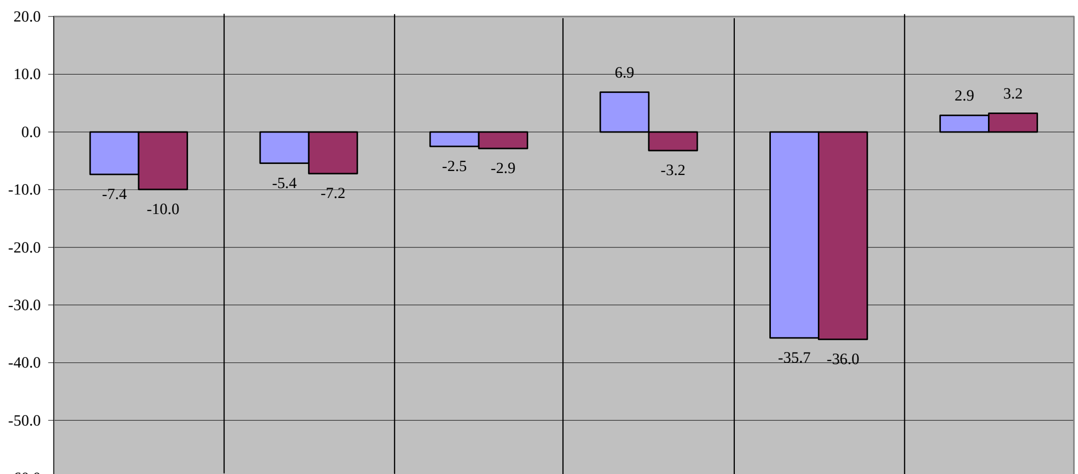
E. Sensitivity analyses: some more results

In what follows, some more sensitivity analyses are presented taking the form of coupled analyses in which an alternative scenario is put next to its higher price variant. To be noted is that higher prices not only have an impact on the different indicators, but also on the carbon value that is associated with the scenario: the carbon value (CV) of the Bpk15 scenario boils down to 123€/tCO_2, while the CV of the Bpk15h variant reaches only 98€/tCO_2. This is because at soaring fuel prices, part of the carbon value effect is already satisfied as carbon values, in the end, raise polluting fuel prices in order to change consumer behaviour. When fuel prices are raised “on their own” (because of e.g. international conditions), this price raising/consumption deterring effect already takes place and hence, allows the carbon value attached to the variant to become somewhat lower.

Bpk15 vs. Bpk15h

The effect that higher fuel prices initiate on the Bpk15 scenario is very similar to the one the hohg-variant induced on the baseline.

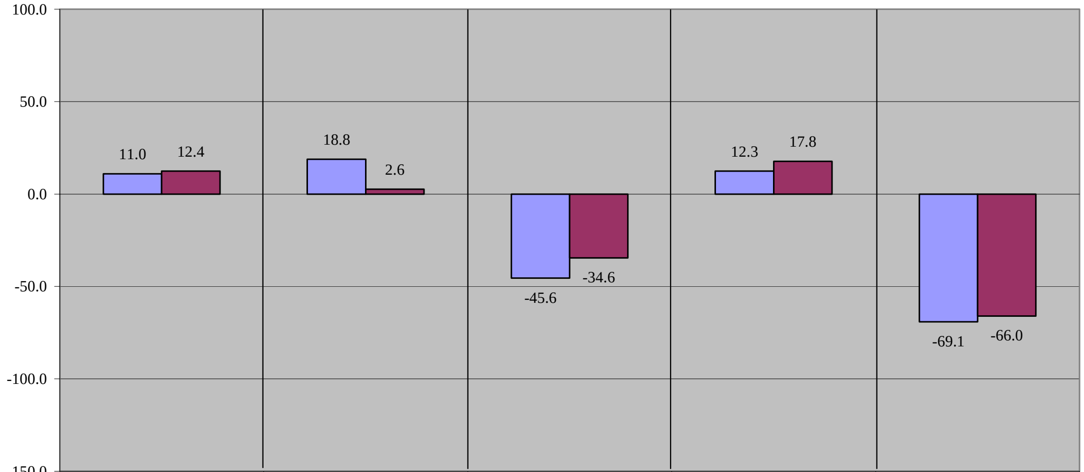
Belgian reduction of energy CO2 emissions by 15%, Relative impact of soaring prices, year 2030



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK15	-7.4	-5.4	-2.5	6.9	-35.7	2.9
BPK15h	-10.0	-7.2	-2.9	-3.2	-36.0	3.2

Source: PRIMES

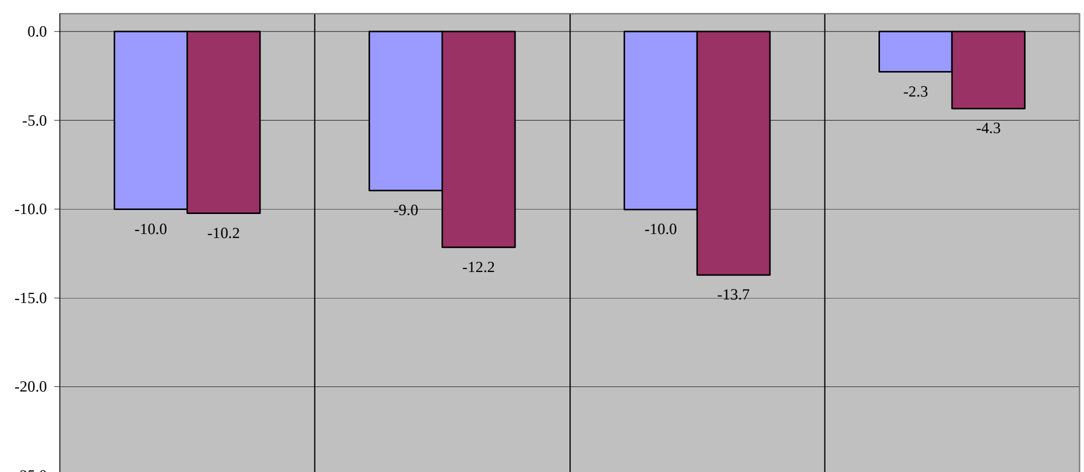
Belgian reduction of energy CO2 emissions by 15%, Relative impact of soaring prices, year 2030



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK15	11.0	18.8	-45.6	12.3	-69.1
BPK15h	12.4	2.6	-34.6	17.8	-66.0

Source: PRIMES

Belgian reduction of energy CO2 emissions by 15%, Relative impact of soaring prices, year 2030

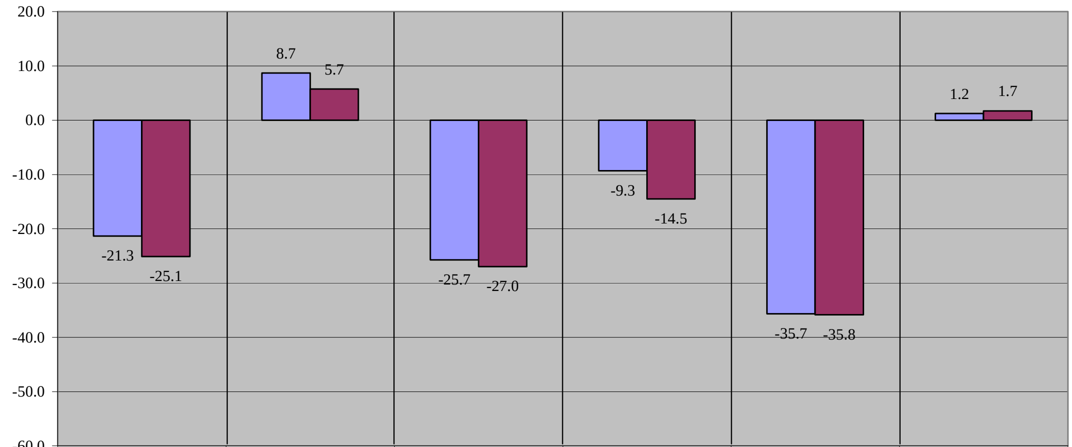


	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK15	-10.0	-9.0	-10.0	-2.3
BPK15h	-10.2	-12.2	-13.7	-4.3

Source: PRIMES

Bpk15n vs. Bpk15nh

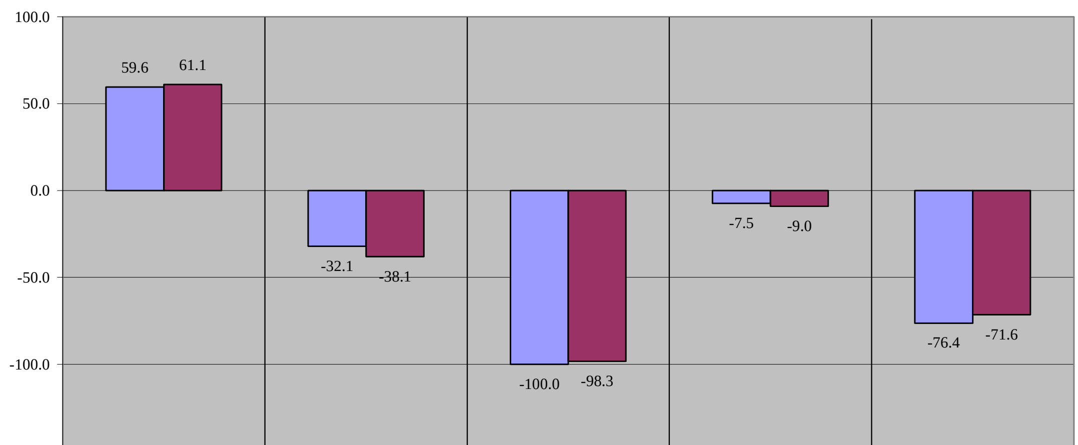
Belgian reduction of energy CO2 emissions by 15%, Relative impact of soaring prices when nuclear allowed, year 2030



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK15n	-21.3	8.7	-25.7	-9.3	-35.7	1.2
BPK15nh	-25.1	5.7	-27.0	-14.5	-35.8	1.7

Source: PRIMES

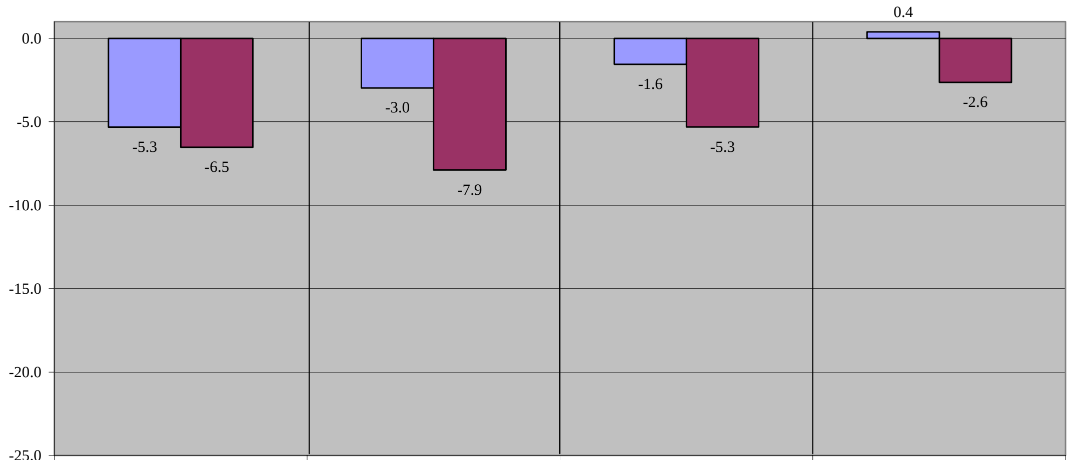
Belgian reduction of energy CO2 emissions by 15%, Relative impact of soaring prices when nuclear allowed, year 2030



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK15n	59.6	-32.1	-100.0	-7.5	-76.4
BPK15nh	61.1	-38.1	-98.3	-9.0	-71.6

Source: PRIMES

Belgian reduction of energy CO2 emissions by 15%, Relative impact of soaring prices when nuclear allowed, year 2030



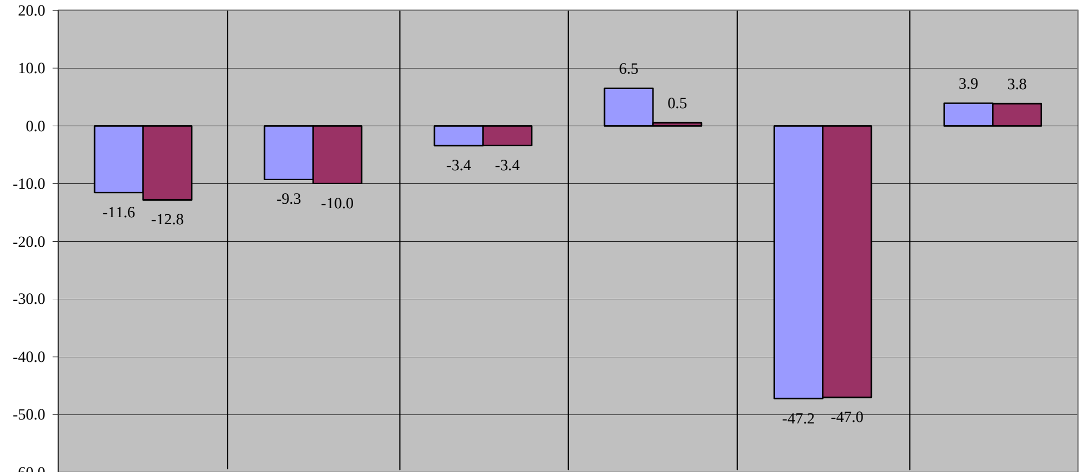
	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK15n	-5.3	-3.0	-1.6	0.4
BPK15nh	-6.5	-7.9	-5.3	-2.6

Source: PRIMES

Bpk30 vs. Bpk30h

Trends that become obvious when comparing the Bpk30 and the Bpk30h cases are similar to the effect discerned in comparing the hohg-variant and the baseline. Also in this exercise, the carbon value is lower in the Bpk30h variant (266€/tCO2) than in the Bpk30 scenario (320€/tCO2).

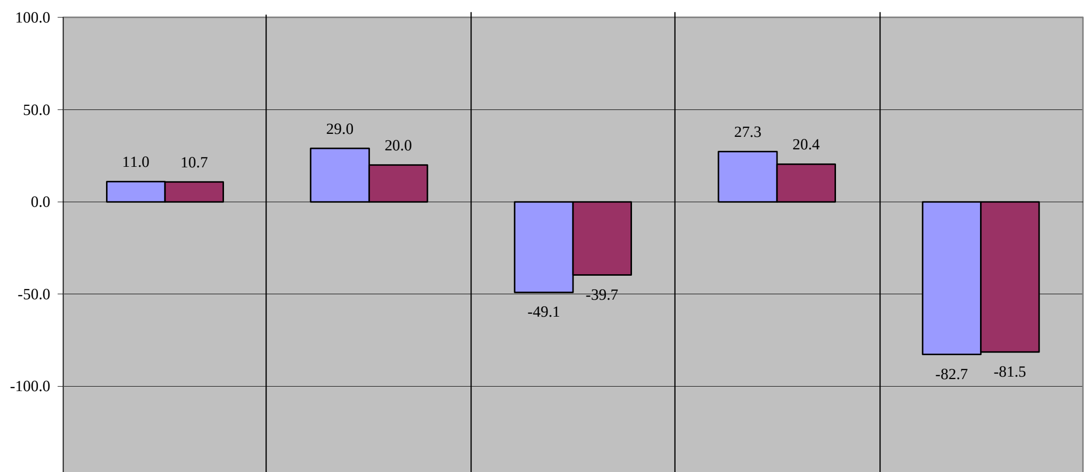
Belgian reduction of energy CO2 emissions by 30%, Relative impact of soaring prices, year 2030



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK30	-11.6	-9.3	-3.4	6.5	-47.2	3.9
BPK30h	-12.8	-10.0	-3.4	0.5	-47.0	3.8

Source: PRIMES

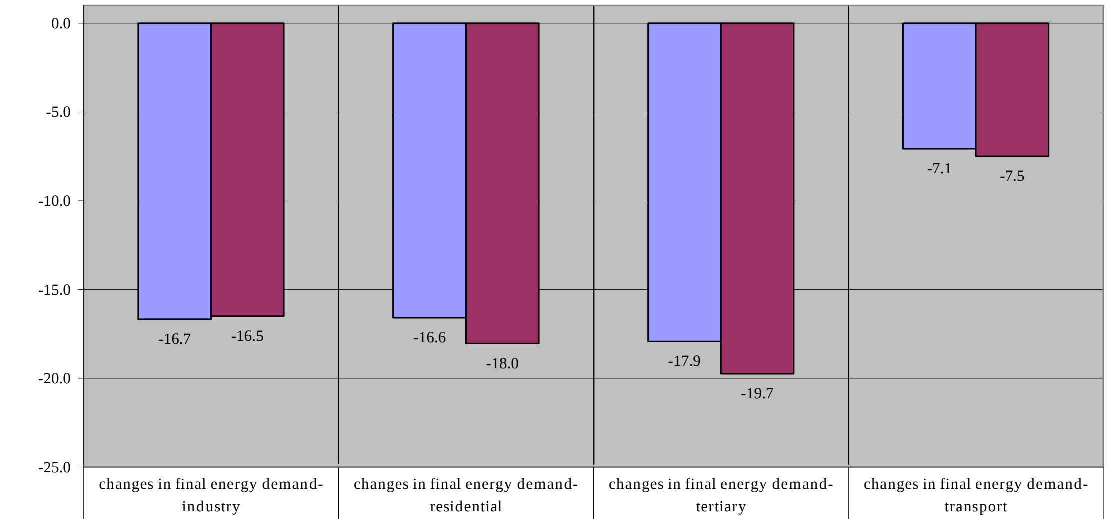
Belgian reduction of energy CO2 emissions by 30%, Relative impact of soaring prices, year 2030



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK30	11.0	29.0	-49.1	27.3	-82.7
BPK30h	10.7	20.0	-39.7	20.4	-81.5

Source: PRIMES

Belgian reduction of energy CO2 emissions by 30%, Relative impact of soaring prices, year 2030

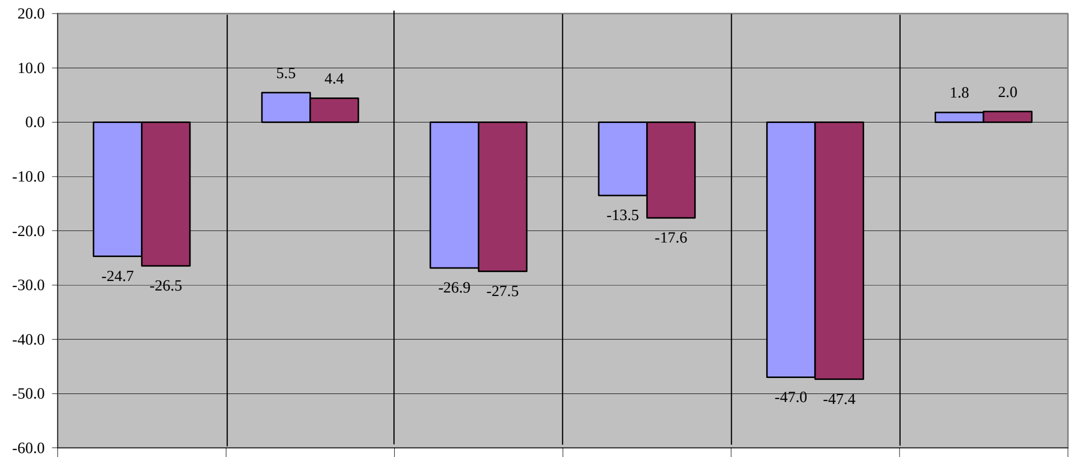


	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK30	-16.7	-16.6	-17.9	-7.1
BPK30h	-16.5	-18.0	-19.7	-7.5

Source: PRIMES

Bpk30n vs. Bpk30nh

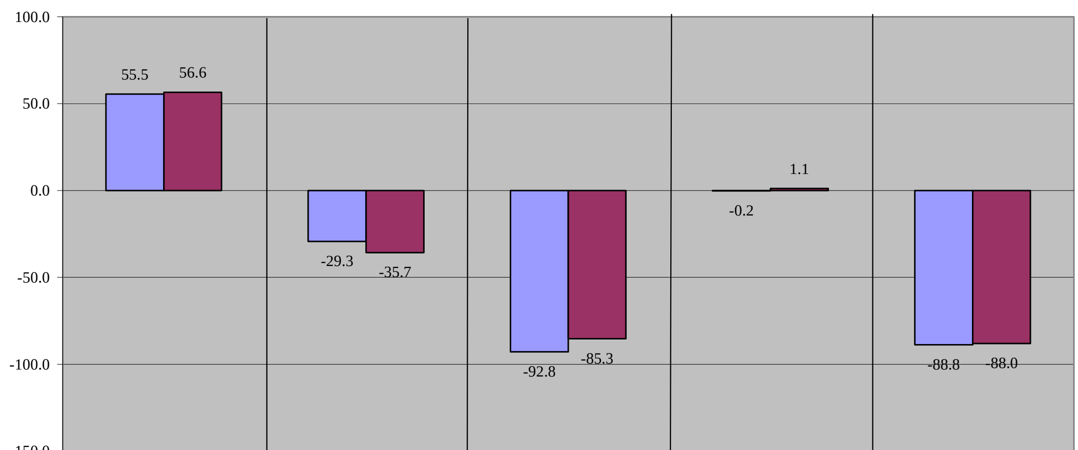
Belgian reduction of energy CO2 emissions by 30%, Relative impact of soaring prices when nuclear allowed, year 2030



	Net imports of energy	Energy intensity of GDP	Import dependency (*)	Total gas needs	CO2 emissions	Renewables share in GIC (*)
BPK30n	-24.7	5.5	-26.9	-13.5	-47.0	1.8
BPK30nh	-26.5	4.4	-27.5	-17.6	-47.4	2.0

Source: PRIMES

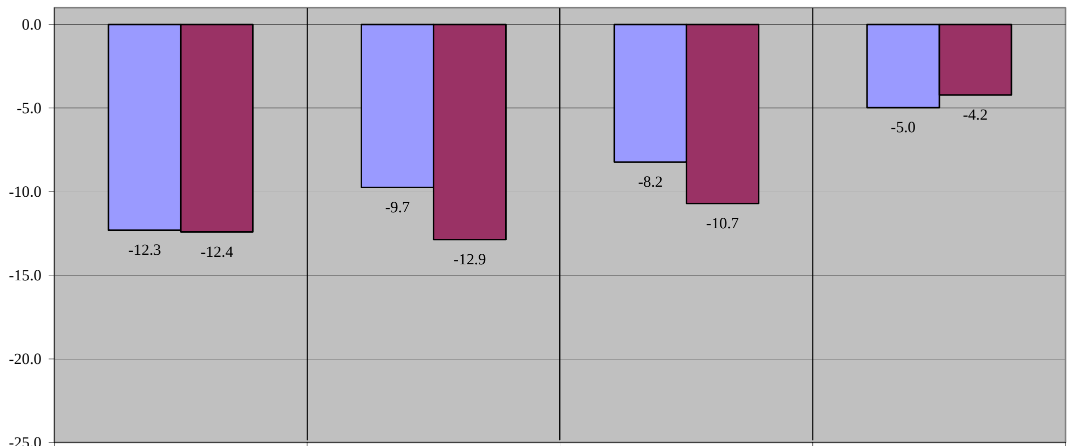
Belgian reduction of energy CO2 emissions by 30%, Relative impact of soaring prices when nuclear allowed, year 2030



	Carbon free share in power (*)	Gas for power	Coal for power	Power capacity extension	CO2 per MWh
BPK30n	55.5	-29.3	-92.8	-0.2	-88.8
BPK30nh	56.6	-35.7	-85.3	1.1	-88.0

Source: PRIMES

Belgian reduction of energy CO2 emissions by 30%, Relative impact of soaring prices when nuclear allowed, year 2030



	changes in final energy demand-industry	changes in final energy demand-residential	changes in final energy demand-tertiary	changes in final energy demand-transport
BPK30n	-12.3	-9.7	-8.2	-5.0
BPK30nh	-12.4	-12.9	-10.7	-4.2

Source: PRIMES

F. The PRIMES model in a nutshell

The PRIMES model was developed under research projects funded by the European Commission Joule programme. The design was influenced by the previous generation of energy models (EFOM, MIDAS and MEDEE). The PRIMES model was developed to make energy projections, evaluate scenarios and analyse the impact of energy policy measures. The PRIMES model can be used to simulate trends in supply, demand, prices and emissions of pollutants for the various fuels, taking account of the fact that international energy prices and macroeconomic variables (GDP, disposable income, inflation, interest rates and so forth) are incorporated exogenously.

PRIMES is a partial equilibrium model because changes in the energy supply and prices and constraints on the emission of pollutants cannot in turn influence the economic sphere. PRIMES is a market-driven model which simultaneously simulates a balance between supply and demand both at European level and for the 15 countries individually. Equilibrium is reached when prices ensure a balance between demand and supply for the different forms of energy. Convergence towards equilibrium occurs iteratively. Based on an estimate of the prices for the various forms of energy, PRIMES provides an initial estimate of demand. This determines the requisite capacity and level of the various forms of energy. The choice of production technology is then determined endogenously on a "least production costs" basis. PRIMES calculates the production costs which, after duties are added, provide an initial estimate of energy prices. Prices are then compared to the previous iteration and the convergence process terminates once they are sufficiently close. If not, a fresh estimate of demand is made and the back coupling process continues.

Demand comprises a series of non-linear equations. The model for final energy demand for energy is based on a bottom-up approach (engineering approach), but includes a minimisation of energy users' costs. The model uses a detailed sector breakdown, allowing for 24 different energy forms.

The model distinguishes between 9 branches of activity in the industrial sector. Each segment is broken down into different sub sectors (some 30 sub sectors in all, including recycling); at the sub sector level, various kinds of energy use are distinguished according to the production process (blast-furnaces, electrical furnaces, electrolysis, etc.).

For the residential sector, 5 different types of buildings are distinguished according to the heating system used (central heating, partial central heating, electric heating, district heating and independent gas heating). In addition to the type of heating, the model also considers three kinds of household energy use: hot water, cooking and specific electricity use. Household demand depends on different variables, including disposable household income, the number of degree-days, the type of heating system, and parameters that reflect the technology and features of the house insulation.

Within the tertiary sector, a distinction is made between the commercial sector, the non-market sector and trade services. Various types of energy use are considered, according to the technology used. The model also considers energy consumption for the agricultural sector separately.

PRIMES distinguishes between passenger and freight transport. Four means of transport are considered: air, rail, road and sea. For road passenger transport, a distinction is made between public transport (buses) and private transport (cars and motorcycles). Between six and ten different technologies are considered for cars, trucks and buses. A lesser number of technologies is considered for rail, air and sea transport. The total transport volume is determined by the growth in income and GDP. The distribution among the various forms of transport depends on their relative prices, which are in turn influenced by the technology of new investments and the existing fleet.

The energy supply in PRIMES consists primarily of three modules for electricity and steam generation, oil refining and other transformation sectors. To accommodate the demand curves, the module for electricity and steam generation determines the choice of the production processes, the extension and decommissioning of the required means of production and the choice of fuel. The model takes account of a large number of technologies for electricity production (by combining the various technologies, fuels, sizes and forms, a choice of more than 900 power stations is possible). Particular attention is focused on the combined heat and power production, renewable energy sources and new forms of energy. Refineries operate nationally, but capacity, market share and prices are determined by competition at European level.

For primary energy, the model determines the optimum share of imports and domestic production to be able to meet demand. The model considers the global petroleum market as being exogenous.

A key feature of the model is a tariff module ensuring a balance between demand and supply. This module calculates the revenue that the sector requires (on the basis of total expenses and other accounting expenses) and allocates charges to users in accordance with the Ramsey pricing principle. The consumer price is then deduced by adding distribution and transport costs, margins and duties.

More details about the PRIMES model can be found on the following web site: http://www.e3mlab.ntua.gr/downloads.php

G. Energy savings in the PRIMES model: potentials, modelling and interpretation of results

i Introduction

Detailed technological models, often based on bottom-up approaches, points to the existence of energy saving potentials that may be achieved without extra cost to the energy system (i.e. fuel savings more than counterbalance the additional investment costs associated to the purchase of more efficient equipments). However, there is no evidence in real evolution (i.e. energy consumption statistics) about the realisation of such cost-efficient energy saving potential: this is often referred to as the efficiency gap.

Microeconomic analyses suggest that the gap can be explained by specific conditions prevailing in the markets (e.g. lack of information) and by the differentiated behaviour of economic agents. This issue is underlined in the recent report: the Stern Review "The Economics of Climate Change": "…*Even where measures to reduce emissions are cost-effective, there may be barriers preventing action. These include a lack of reliable information, transaction costs, and behavioural and organisational inertia. The impact of these barriers can be most clearly seen in the frequent failure to realise the potential for cost-effective energy efficiency measures".*

ii Modelling energy consumption and savings in PRIMES

The PRIMES model not only represents a detailed set of technologies for the transformation and consumption of energy but also models market mechanisms and the behaviour of economic agents. The latter feature is particularly relevant when modelling the decisions of households as regards investments and level of energy consumption (i.e. intensity of use of equipment): decisions depend both on technological and behavioural components. Technological components are necessary to capture the physical constraints on energy use and savings, while behavioural components are necessary to explain consumer expectations and their influence on equipment choice as well as to explain the influence of energy prices on energy consumption. The dynamic of equipment penetration and replacement is also driven by the capital turnover.

Based on studies made by Ecofys and the Wuppertal Institute for the European Commission, the PRIMES model specifies, for each "use/technology" pair, an ultimate energy saving potential that corresponds to the use of the best available technology.

However, as underlined above, the fraction of the ultimate energy saving potential that will be implemented by the model depends not only on (fuel) prices and (equipment) costs but also on behavioural indicators. One of these behavioural indicators is the discount rate. Based on empirical observations, small consumers use high subjective discount rates whereas industry uses comparatively lower discount rates. More precisely, the following figures are used in PRIMES: 8% for large utilities, 12% for industrial and commercial activities and 17.5% for household's investments. Higher discount rates mimic the fact that most households opt for short payback periods.

The presence of behavioural indicators explains why all the cost-efficient energy saving potential is not implemented and why significant fuel price increases are required to realise it: price signals alone may be too muted to have a significant impact (Stern Review, 2006). Appropriate policies and measures are required to remove existing market barriers and imperfections that impede the efficient use of energy and make price signals work properly, and to shape consumers' behaviour towards more energy savings. Relevant policies and measures include regulatory measures (e.g. minimum standards for buildings and appliances), financial measures but also information and education. However, these policies and measures have a cost, a cost for the public finances and for the consumers. The analysis of the economic impact of these policy instruments would require fully capturing cost elements that are sometimes difficult to estimate and that are presently outside the scope of the PRIMES model.

Of course, it is possible to evaluate, with the PRIMES model, the impact of targeted actions that improve the perception of energy consumers of energy costs by changing the behavioural parameters so that more efficient solutions are chosen despite of higher initial costs. That is what has been done in the scenarios “with additional measures” in the study for Minister Tobback and in the “energy efficiency” scenarios for DG TREN. However, the evaluation is limited to the impacts on the energy system, the emissions and the energy related costs; it does not provide a complete representation of the economic effects.

iii Interpretation of PRIMES results

As stressed in the report (but also in the various reports drafted by NTUA for the European Commission), the carbon values do not represent costs of policy implementation, they are only indicative of the relative difficulty of achieving targets. The carbon values represent the marginal abatement costs for CO_2 reductions of -15% and -30% in 2030 compared to the 1990 level, i.e. the cost of the last ton reduced in order to achieve the reduction objectives. In the scenarios without nuclear and CCS, the flexibility of the power and steam generation sector to respond to CO_2 constraints becomes narrow (essentially some further development of RES up to the limits set) and some changes are rather expensive (solar PV). Consequently, the focus is more on the demand side where, given the inertia of the system (reflected through appropriate behavioural indicators), higher carbon values are required in the absence of specific policies. High carbon values simply reflect the higher costs involved in the different sectors.

This result can be seen as an overestimation of the actual cost of energy savings if one expects appropriate policies to take place in order to remove market failures and barriers to behavioural change. But it is most probably not if policy makers do not take strong action now to that effect.

iv References

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