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# 2030 Climate and Energy Framework for Belgium

## Impact assessment of a selection of policy scenarios up to 2050

April 2015

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**Abstract** - On October 17, 2014, the Federal Planning Bureau published the fifth edition of its triennial long-term energy outlook (FPB, 2014). The report describes a *Reference* scenario up to 2050 simulating the evolution of the Belgian energy system under current trends and adopted policies in the field of climate, energy and transport while integrating the 2020 Climate/Energy binding objectives. Analysing its results demonstrates the large discrepancy between this *Reference* and what is necessary to be on track for the EU 2030 Climate and Energy Framework as well as the low-carbon economy by 2050, hence the need for additional policies and measures. This observation led to the writing of this paper in which three policy driven scenarios that are compatible with both the 2030 and 2050 greenhouse gas emission reduction challenges outlined by the European Council are scrutinised. The three scenarios differ in the level of ambition in the field of energy efficiency and renewable energy deployment. This paper gives an insight in the divergences in some of the indicators discussed in FPB (2014) between the policy driven scenarios and the *Reference* and thereby reveals the main impacts of future climate and energy policies on the Belgian energy system.

**Jel Classification** - C6, O2, Q4

**Keywords** - Energy policy, greenhouse gas emissions, renewable energy sources, long-term energy projections

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# Executive summary

On October 17, 2014, the Federal Planning Bureau published the fifth edition of its triennial long-term energy outlook (FPB, 2014). The report describes a Reference scenario (or *REF*) up to 2050 simulating the evolution of the Belgian energy system under current trends and adopted policies in the field of climate, energy and transport while integrating the 2020 Climate/Energy binding objectives. Analysing its results demonstrates the large discrepancy between this *REF* and what is necessary to be on track for the EU 2030 Climate/Energy Framework as well as for the low-carbon economy by 2050, hence the need for additional policies and measures. This observation led to the writing of this paper in which three policy driven scenarios that are compatible both with the 2030 and 2050 greenhouse gas emission reduction challenge outlined by the European Council are being scrutinised.

These three scenarios all suppose so-called *enabling* conditions (which is not the case in *REF*). These conditions relate to assumptions reflecting effective structural changes in all sectors of the economy next to timely and sound coordination of the various changes and public acceptance. Enabling conditions need to be delivered through policy efforts and this both on sectoral (e.g. removal of market failures and barriers to efficient energy consumption and renewable energy development) and public level (e.g. R&D and innovation funding). Lacking these conditions infers that actors could, because of market and policy uncertainties, opt for decisions that, in the long term, prove sub-optimal, resulting in technology and infrastructure lock-ins and higher overall costs for the transformation towards a low-carbon economy.

These three scenarios (*GHG40*, *GHG40EE* and *GHG40EERES30*) differ in the level of ambition in the field of energy efficiency and renewable energy deployment. The first scenario (*GHG40*) focuses exclusively on the 2030 and 2050 greenhouse gas (GHG) emission reduction targets and is driven by the application of carbon prices and carbon values, the second (*GHG40EE*) adds ambitious energy efficiency (EE) policies and measures to the former whilst the third (*GHG40EERES30*) complements the second with a binding EU renewables (RES) target of 30% in 2030. In what follows, different impacts of these three scenarios on the Belgian energy system are described for two particular years: 2030 and 2050.

### Impacts in 2030

Total GHG emissions decrease by 27% in *GHG40* and by about 30% in *GHG40EE* and *GHG40EERES30* with respect to the 1990 level (against 20% in REF). The three policy scenarios show similar GHG reductions in the ETS and non-ETS sectors compared to 2005: from 27 to 31% in the former and from 25 to 32% in the latter. Compared to *REF*, the additional emission reductions in 2030 are however more significant in the non-ETS than in the ETS sectors, and all the more so in the two policy scenarios characterized by ambitious energy efficiency measures (*GHG40EE* and *GHG40EERES30*). The additional GHG reductions range from 3 to 7 percentage points in the ETS sectors while they lie between 9 and 17 percentage points in the non-ETS sectors.

The biggest (resp. smallest) energy related $CO_2$ emission reductions, in relative terms, are experienced by the tertiary sector (resp. transport). They range from 31 to 55% (resp. from 10 to 18%) in the policy scenarios compared to 2010. For industry and the residential sector, the corresponding figures are 20 to

32% and 20 to 29% respectively. The upper values of the intervals correspond to the policy scenarios involving ambitious energy efficiency measures. Emission reductions in the power sector lie between 25 and 35%.

Final energy demand is reduced by 9 and 17% respectively in *GHG40* and *EE scenarios* (both *GHG40EE* and *GHG40EERES30*) compared to the level in 2010 (36.4 Mtoe). In absolute terms, the figures are respectively 33.0 Mtoe and 30.2 Mtoe, i.e. close to or even lower than the indicative national efficiency target of 32.5 Mtoe in 2020. In comparison with *REF*, energy savings ranging from 1.7 to 4.5 Mtoe are achieved in the policy scenarios. Between 2010 and 2030, the changes in the energy mix are comparable in *REF* and *GHG40*, i.e. a decrease in the shares of fossil fuels (coal, oil, and natural gas) and an increase in the shares of electricity, distributed heat and RES. In other words, the carbon value in the non-ETS, which differentiates the *GHG40* scenario from *REF*, leads to more energy savings rather than to fuel switching. By contrast, scenarios with ambitious EE and RES policies typically result in a higher share of electricity (24% against slightly more than 21% in *REF* and *GHG40*) at the expense of oil and natural gas. *GHG40EERES30* also shows a higher contribution of RES (biomass, geothermal and solar thermal[1]) in total final energy demand.

The residential and tertiary sectors experience the strongest reductions in final energy demand in all policy scenarios. In the scenario mainly driven by carbon prices and carbon values (*GHG40*), energy consumption falls by 13% (resp. 16%) in the residential (resp. tertiary) sector compared to the 2010 level. In the policy scenarios where ambitious energy efficiency policies are implemented on top of the price signals (*GHG40EE* and *GHG40EERES30*), energy demand decreases even further by 21% (resp. 29%) in the residential (resp. tertiary) sector. On the other hand, the transport sector shows the smallest reductions in final energy demand, namely 4% and 11% respectively in the *GHG40* and *EE scenarios* compared to the level in 2010.

Electricity demand picks up after a dip in 2025, the year in which all nuclear power plants are being phased out. Starting from 90 TWh in 2010, called-up electrical power in the *EE scenarios* reaches the same level as *REF* (93 TWh) in 2030, but is somewhat lower in *GHG40* (91 TWh). The level of net imports does vary a lot in the period 2010-2030. In fact, it takes a U-formed shape with a low being reached in 2020 followed by a steep rise to attain 22 TWh in 2030. Net electricity generation drops significantly compared to 2010 (90 TWh); it ranges between 70 (*GHG40*) and 72 TWh (*EE scenarios*), thereby demonstrating the same evolution as depicted in *REF* (73 TWh). Three (interrelated) factors cause this dip in domestic production: 1) the nuclear phase-out, 2) the significant penetration of RES in the power system (between 48% and 55% in the policy scenarios), 3) the relatively higher production costs of domestically produced electricity compared to imported electricity: the average cost of domestic electricity generation shoots from 64 €/MWh in 2010 to levels between 104 (*GHG40EE*) and 109 €/MWh (*GHG40*). *REF*'s average production cost leans to the higher end of the interval (108 €/MWh) since the three determinants also hold in the *REF* case.

The evolution of net electricity generation therefore does not seem to be largely affected by the implementation of the 2030 EU climate (and RES) targets. What does change, however, is the electricity mix. Natural gas generated electricity is generally lower than in *REF* (36 TWh) and can be situated between

[1] Solar PV is accounted for in the power generation sector.

30 (*GHG40EERES30*) and 35 TWh (*GHG40EE*), thereby occupying between 41% and 49% in the respective generation mixes. RES-based electricity then fills the gap: renewable electricity production levels take off triggered by the installation of the EU binding climate (and RES) targets in combination with decreasing learning curves and a number of facilitating conditions (e.g. cross-border balancing). Wind becomes the prime resource with production levels between 20 (*GHG40EE* and *REF*) and 24 TWh (*GHG40EERES30*).

Despite the drop in power production, power generation capacity grows. From 17 GW in 2010, total installed capacity increases by around 58% in *GHG40* and *GHG40EE* (rather comparable to *REF* (+60%)) and by 65% in *GHG40EERES30* and this notwithstanding the decommissioning of the nuclear power plants. Capacity expansions are mainly composed of variable RES (i.e. wind and sun) (+11 à 12 GW), while some additional 5 to 6 GW of natural gas completes the future system. Monetary investments are estimated to be similar to *REF* in *GHG40* and *GHG40EE*, but they are significantly higher in *GHG40EERES30* because of additional investments in wind turbines and, to a lesser extent, biomass power plants. In the 2010-2030 period, investments amount to 32 billion € in *GHG40*, 31 billion € in *GHG40EE* and 36 billion € in *GHG40EERES30* (compared to 31 billion € in *REF*). The dramatic increase in variable RES capacity gives (further) rise to the *compression effect* of the natural gas fired power plants: utilisation rates (60% in 2010) are squeezed to somewhere between 32% (*GHG40* and *GHG40EERES30*) and 35% (*GHG40EE* and *REF*).

Renewable energy sources continue to enlarge their share in gross final energy consumption. Where the national binding target stipulated in the 2020 Climate/Energy package (and implemented in *REF*) was set at 13%, the shares attained in 2030 amount to 18% in *GHG40* and *GHG40EE* and even 23% in *GHG40EERES30* (versus 17% in *REF* and only 5% in 2010). RES cover different uses, i.e. transport, heating and cooling and electricity production. It is the development of the latter that mostly pulls the general RES share, a trend that was already apparent in *REF*.

Primary energy consumption notes a falling trend in all policy scenarios but the decline is much more outspoken in the scenarios with ambitious energy efficiency policies. The decrease with respect to 2010 ranges from 26 to 30%. This result converts into 40.1 Mtoe in *GHG40* and 37.6 Mtoe in the *EE scenarios* (against 42.2 Mtoe in *REF*). These consumption levels are below the indicative national energy efficiency objective of 43.7 Mtoe in 2020. The energy intensity of the Belgian economy decreases in all policy scenarios but most significantly in the *EE scenarios*: by 42% compared to 2010 in *GHG40* and by 45% in the *EE scenarios* (compared to 39% in *REF*).

The implementation of the 2030 and 2050 EU climate targets (in combination with ambitious energy efficiency policies and a RES target) leads to lower imports of energy compared to 2010 and to the 2030 level in *REF*. Whilst in *REF* around 53 Mtoe is imported (a similar level as in 2010), the policy scenarios only necessitate imports between 47 and 50 Mtoe. This difference of 3 to 6 Mtoe is caused by a contraction in the level of fossil fuel import (i.e. oil and natural gas), and this notwithstanding higher imports of both electricity and biomass.

Among the economic impacts, it is worth noting that the ratio of total energy system cost (i.e. capital costs related to energy production, consumption, transport and efficiency investments as well as energy purchase costs) to GDP increases from 13.5% in 2010 to respectively 16.2% and 17% in *GHG40* and the

*EE scenarios*. Compared to *REF*, the above cost figures are respectively 0.3 and 1.1 percentage points higher. The fossil fuel trade deficit as part of GDP does not evolve much compared to 2010 (around 3.8% of GDP). It is, however, 0.2 to 0.6 percentage point lower in the policy scenarios than in *REF*.

An additional impact of a renewal of the target definition of climate (and RES) objectives in 2030 (supplemented by ambitious energy efficiency measures) can be seen in the creation of new jobs. By 2030, additional job formation in the policy scenarios with respect to *REF* is estimated to be at somewhere between 26,000 and 28,000 full-time equivalents (FTE) in the *EE scenarios* and around 12,000 FTE in *GHG40*. Main job creation lever resides in energy efficiency endeavours which typically generate local jobs (e.g. building sector).

**Summary of key results, REF and policy scenarios, 2030**

| | REF | GHG40 | GHG40EE | GHG40EERES30 |
|---|---|---|---|---|
| Primary energy consumption (Mtoe) | 42.2 | 40.1 | 37.6 | 37.6 |
| Final energy demand (Mtoe) | 34.7 | 33.0 | 30.2 | 30.4 |
| GHG emissions non-ETS (% difference to 2005) | -15.1 | -24.5 | -32.2 | -30.6 |
| RES share in GFEC (%) | 16.8 | 18.0 | 18.4 | 23.4 |
| Import dependency (%) | 88.2 | 87.7 | 87.6 | 85.7 |
| Total energy system cost (% of GDP) | 15.9 | 16.2 | 17.0 | 17.0 |
| Fossil fuel trade balance (% of GDP) | -4.1 | -3.9 | -3.7 | -3.5 |
| Total GHG emissions (Mt $CO_2$-eq.) | 118.0 | 106.5 | 103.0 | 101.4 |
| Carbon intensity power sector ($tCO_2$/GWh) | 176 | 162 | 168 | 144 |
| Average cost of electricity generation (€'10/MWh) | 108.0 | 108.5 | 104.2 | 105.4 |
| RES share in net electricity generation (%) | 46.3 | 50.8 | 47.5 | 55.0 |
| Investment expenditure in power plants(*) (billion €'10) | 31 | 32 | 31 | 36 |

Note: GHG=Greenhouse Gas; RES=Renewable Energy Sources; GFEC=Gross Final Energy Consumption; ETS=Emission Trading Scheme.
(*) points to the fact that the indicated values do not represent yearly values, but denote the total investments required for the period 2010-2030.

### Impacts in 2050

Total GHG emissions are some 65% below the 1990 level, irrespective of the policy scenario (against 17% in *REF*). GHG emissions continue to drop both in the ETS and non-ETS. In the *GHG40* scenario where GHG emissions are mainly driven by carbon prices in the ETS and carbon values in the non-ETS, GHG emission reductions are comparable in both sectors: 65 and 68% compared to 2005. By contrast, GHG emission reductions are higher in the non-ETS than in the ETS in the *EE scenarios*: 71% versus 58% compared to 2005. In other words, ambitious energy efficiency policies dampen the reductions needed in the ETS. Compared to *REF*, additional GHG reductions range from 37 to 43 percentage points in the ETS sectors while they lie between 55 and 58 percentage points in the non-ETS sectors.

The residential and tertiary sectors are number one in the race towards achieving a low-carbon economy in 2050 with emission reductions ranging from 75 to 85% compared to 2010. They are followed by industry and transport where energy related $CO_2$ emissions are projected to be 50 to 65% below the 2010 level. Emission reductions in the power sector are the smallest and vary widely according to the policy scenario: 55% in *GHG40*, 47% in *GHG40EERES30* and 34% in *GHG40EE*.

Reductions in final energy demand intensify: 17% (resp. 29%) in *GHG40* (resp. the *EE scenarios*) compared to 2010 (36.4 Mtoe). In absolute terms, total final energy demand is projected to reach 30.4 Mtoe (resp. 26.0 Mtoe). In comparison with *REF*, energy savings ranging from 7.5 to 11.9 Mtoe are achieved in the policy scenarios. The policy scenarios demonstrate major differences in the energy mix compared to 2010 (and also to *REF* in 2050). For instance, the share of fossil fuels (coal, oil and gas) drops significantly at below 36% compared to almost 75% in 2010; fossil fuels are chiefly replaced by electricity (33-34%) and RES (22-25%) but new energy forms such as hydrogen also come into play. Taking off after 2040, hydrogen becomes a substitute to conventional energy sources in all final demand sectors and in all policy scenarios. The consumption of hydrogen in 2050 is allocated as follows: 32% in industry, 18% for transport and 50% in the residential and tertiary sectors.

The decreasing trend in final energy demand continues in the residential and tertiary sectors: energy consumption falls by more than 30% in *GHG40* and by almost 50% in the *EE scenarios*, compared to 2010. The evolution of final energy demand in industry diverges in the policy scenarios. In *GHG40*, energy consumption recovers to the level in 2020 but is still 3% below the 2010 level. In the *EE scenarios*, ambitious additional EE measures allow safeguarding the decreasing trend in the long term to 18% below the 2010 level. Finally, energy demand in transport stabilizes at its 2030 level. The most significant impact of the policy scenarios on transport is the substantial increase in the share of biofuels and electricity. The share of biofuels (resp. electricity) ranges from 36 to 39% (resp. from 15 to 16%) according to the scenario.

Called-up electrical power increases spectacularly in all policy scenarios. Adopting long-term climate targets has a very visible impact on the demand for electricity. It shoots to levels of around 125 TWh in the *EE scenarios* and even to an ultimate high of 145 TWh in *GHG40* (compared to 115 TWh in *REF* and 90 TWh in 2010). Three reasons are at the root of this spectacular demand increase in the policy scenarios: 1) a fuel switch towards less polluting energy forms prompted by high carbon prices and carbon values, 2) the large penetration of electromobility, mainly after 2030, 3) the arrival and success of hydrogen production based on electrolysis and used in several sectors. This rise in electricity demand is covered by both a surge in net imports (32 TWh) and an increase in domestically produced power. Net production levels in the *EE scenarios* (around 94 TWh) mount to levels similar to *REF* (95 TWh), whilst the production level in *GHG40* is approximately 20 TWh higher and attains 114 TWh (versus 90 TWh in 2010).

Not only do production levels differ, also mixes diverge. *GHG40*, although demonstrating significantly higher production levels, has a very similar mix to *REF*'s: 46% of natural gas, 34% wind, 10% solar and 8% biomass and waste. The two *EE scenarios*, although displaying similar production levels, (further) diverge in their generation mix. *GHG40EERES30* integrates more wind (44%) and biomass and waste (12%) but less natural gas (35%) than *GHG40EE* (37%, 10% and 42% respectively).

These different power production levels and mixes have a repercussion on required investments and consequently on the average cost of power production. Investments in the 2030-2050 period amount to 46 billion € in *GHG40*, 31 billion € in *GHG40EE* and 33 billion € in *GHG40EERES30* (compared to 31 billion € in *REF*). The tremendous amount of investment expenditures in *GHG40* is mostly due to additional investments covering the surge in power demand that is only somewhat being mitigated by demand response initiatives, contrary to *GHG40EE* and *GHG40EERES30* where demand response occupies a major role. The *EE scenarios* manage to reverse the upward trend of increasing average power production cost started in 2020 and strand in 2050 at a level of 95-96 €/MWh. *GHG40* on the other hand sees its average production cost keep on growing to reach 119 €/MWh by 2050. This is approximately 20% higher than is observed in *REF* where no climate (or other) targets are implemented beyond 2020.

Renewable energy sources continue on their growth path and reach shares of 41% (*GHG40*), 39% (*GHG40EE*) and 45% (*GHG40EERES30*) in gross final energy consumption (compared to 19% in *REF*). RES cover almost two thirds of final energy consumption in transport in the policy scenarios, between 26% and 38% in heating and cooling and between 39 and 46% for electricity uses.

Primary energy consumption is reduced by 29 to 40% compared to the level in 2010 (versus 15% in *REF*). It totals 38.2 Mtoe in *GHG40* and 32.4 Mtoe in the *EE scenarios* (against 45.2 Mtoe in *REF*). The energy intensity of the Belgian economy decreases further: by 60% compared to 2010 in *GHG40* and by 66% in the *EE scenarios* (compared to 54% in *REF*).

Energy imports remain below the 2010 level (53 Mtoe) while the gap in energy imports between *REF* and the policy scenarios continues to widen: it now encompasses an interval between 11 and 17 Mtoe. Whilst in REF around 56 Mtoe is being imported, the policy scenarios manage to shrink their energy imports to levels between 39 and 45 Mtoe. Main trends remain: imports of fossil fuels (i.e. oil and natural gas) decrease significantly in the policy scenarios, whereas electricity and biomass imports surge.

After a quasi-stabilisation in the 2010-2030 period at 3.8%, the fossil fuel trade deficit as part of GDP is significantly reduced in 2050. It varies from 1.6% to 2% of GDP, according to the policy scenario. The lower end of the range corresponds to the *GHG40EERES30* scenario. Compared to *REF*, the fossil fuel trade deficit boils down to between 1.4 and 1.8 percentage points.

All policy scenarios lead to additional energy system costs compared to *REF*. Total energy system costs as share of GDP are calculated to be respectively at 15.9% and around 16.4% in *GHG40* and the *EE scenarios*. These percentages are lower than those recorded in 2030, meaning that the energy system cost progresses at a slower pace than GDP in the long run. Compared to *REF*, the above cost figures are respectively 2.5 and 3 percentage points higher.

**Summary of key results, REF and policy scenarios, 2050**

| | REF | GHG40 | GHG40EE | GHG40EERES30 |
|---|---|---|---|---|
| Primary energy consumption (Mtoe) | 45.6 | 38.2 | 32.4 | 32.2 |
| Final energy demand (Mtoe) | 37.9 | 30.4 | 26.0 | 26.0 |
| GHG emissions non-ETS (% difference to 2005) | -13.4 | -68.1 | -70.6 | -71.1 |
| RES share in GFEC (%) | 19.2 | 40.6 | 38.8 | 45.2 |
| Import dependency (%) | 85.7 | 80.5 | 81.1 | 79.0 |
| Total energy system cost (% of GDP) | 13.4 | 15.9 | 16.5 | 16.4 |
| Fossil fuel trade balance (% of GDP) | -3.4 | -2.0 | -1.7 | -1.6 |
| Total GHG emissions (Mt $CO_2$-eq.) | 121.3 | 49.1 | 51.1 | 51.4 |
| Carbon intensity power sector ($tCO_2$/GWh) | 131 | 73 | 125 | 101 |
| Average cost of electricity generation (€’10/MWh) | 100.2 | 119.0 | 96.3 | 95.3 |
| RES share in net electricity generation (%) | 54.0 | 53.7 | 57.8 | 64.5 |
| Investment expenditure in power plants(*) (billion €’10) | 31 | 46 | 31 | 33 |

Note: GHG=Greenhouse Gas; RES=Renewable Energy Sources; GFEC=Gross Final Energy Consumption; ETS=Emission Trading Scheme.

(*) points to the fact that the indicated values do not represent yearly values, but denote the total investments required for the period 2030-2050.

# Synthèse

Le 17 octobre 2014, le Bureau fédéral du Plan a publié la cinquième édition de ses perspectives énergétiques à long terme trisannuelles (BFP, 2014). Le rapport décrit un scénario de référence (en abrégé *REF*) jusqu'en 2050, qui montre l'évolution du système énergétique belge compte tenu des tendances actuelles et des politiques adoptées dans les domaines du climat, de l'énergie et du transport, tout en intégrant les objectifs contraignants du paquet Climat/Énergie 2020. L'analyse des résultats du scénario montre l'écart important entre ce *REF* et les efforts nécessaires pour respecter le Cadre européen Climat/Énergie 2030 et assurer la transition vers une économie bas carbone d'ici 2050. D'où la nécessité de mettre en œuvre de nouvelles politiques et mesures. C'est cette observation qui a conduit à l'élaboration de ce document consistant en l'analyse de trois scénarios alternatifs compatibles avec les objectifs de réduction des émissions de gaz à effet de serre d'ici 2030 et 2050, qui ont été définis par le Conseil européen.

Ces trois scenarios présupposent la création de *conditions favorables* (ce qui n'est pas le cas du *REF*). Ces conditions visent à faciliter la mise en œuvre concrète de changements structurels dans tous les secteurs de l'économie, grâce à une coordination efficace des différents changements et à leur acceptation par l'opinion publique. Des telles conditions favorables ne pourront être mises sur pied sans politiques additionnelles qu'elles soient sectorielles (visant, par exemple, la suppression des défaillances du marché et autres obstacles à l'amélioration de l'efficacité énergétique ou au développement des sources d'énergie renouvelables) ou publiques (par ex. le financement de la R&D et de l'innovation). En l'absence de conditions favorables, les agents économiques risquent (en raison des incertitudes liées au marché et aux politiques et mesures) de prendre des décisions qui, à long terme, pourraient se révéler sous-optimales, conduire à des verrouillages en termes de technologie et d'infrastructure et à un coût total plus élevé pour arriver à une économie bas carbone.

Les trois scénarios (*GHG40, GHG40EE* et *GHG40EERES30*) diffèrent quant au degré d'ambition affiché dans le domaine de l'efficacité énergétique et du déploiement des sources d'énergie renouvelables. Le premier scénario (*GHG40*) se concentre exclusivement sur les objectifs de réduction des émissions de gaz à effet de serre (GES) d'ici 2030 et 2050 et se fonde sur l'application de prix (ou de valeurs) du carbone. Le deuxième (*GHG40EE*) y ajoute des politiques et mesures ambitieuses en matière d'efficacité énergétique (EE). Et enfin, le troisième scénario (*GHG40EERES30*) complète le deuxième en fixant un objectif européen contraignant en matière d'énergies renouvelables (SER) de 30% en 2030. Les différents effets de ces trois scénarios sur le système énergétique belge sont décrits ci-après pour deux échéances précises : 2030 et 2050.

### Effets en 2030

Les émissions totales de GES diminuent de 27% dans le scénario *GHG40* et de quelque 30% dans les scénarios *GHG40EE* et *GHG40EERES30* par rapport au niveau de 1990 (contre 20% dans le *REF*). Comparativement à 2005, les trois scénarios alternatifs affichent des réductions similaires de GES dans les secteurs ETS et non-ETS. Elles sont de l'ordre de 27 à 31% dans les secteurs ETS et de 25 à 32% dans les secteurs non-ETS. Par rapport au *REF*, les réductions supplémentaires d'émissions en 2030 sont toutefois plus importantes dans les secteurs non-ETS que dans les secteurs ETS, surtout dans les deux scénarios alternatifs caractérisés par des mesures ambitieuses en matière d'efficacité énergétique (*GHG40EE* et *GHG40EERES30*). Les réductions supplémentaires de GES fluctuent entre 3 et 7 points de pourcentage dans les secteurs ETS et entre 9 et 17 points de pourcentage dans les secteurs non-ETS.

S'agissant des émissions de $CO_2$ liées à l'énergie, les réductions les plus importantes (les plus faibles), en termes relatifs, sont enregistrées dans le secteur tertiaire (le secteur du transport). Elles varient entre 31 et 55% (entre 10 et 18%) dans les scénarios alternatifs par rapport à 2010. En ce qui concerne les secteurs industriel et résidentiel, les fourchettes correspondantes sont respectivement de 20 à 32% et de 20 à 29%. Les limites supérieures de ces fourchettes correspondent aux scénarios alternatifs impliquant des mesures d'efficacité énergétique ambitieuses. Les réductions d'émissions dans le secteur électrique oscillent entre 25 et 35%.

La consommation finale d'énergie recule respectivement de 9 et 17% dans le *GHG40* et les *scénarios EE* (aussi bien le *GHG40EE* que le *GHG40EERES30*) par rapport à 2010 (36,4 Mtep). En termes absolus, les chiffres sont respectivement de 33,0 Mtep et de 30,2 Mtep, c'est-à-dire un niveau proche, voire en deçà, de l'objectif indicatif national d'efficacité énergétique fixé à 32,5 Mtep pour 2020. Par rapport au *REF*, on enregistre des économies d'énergie allant de 1,7 à 4,5 Mtep dans les scénarios alternatifs. Entre 2010 et 2030, les changements dans le mix énergétique sont comparables dans le *REF* et le *GHG40*, avec une diminution des parts des combustibles fossiles (charbon, pétrole et gaz naturel) et une hausse des parts de l'électricité, de la chaleur distribuée et des SER. En d'autres termes, la valeur du carbone dans les secteurs non-ETS, par laquelle le scénario *GHG40* se démarque du *REF*, conduit à une hausse des économies d'énergie plutôt qu'à une substitution des sources d'énergie. En revanche, les scénarios tablant sur des politiques ambitieuses en matière d'EE et de SER entraînent généralement un accroissement de la part de l'électricité (24% contre un peu plus de 21% dans le *REF* et le *GHG40*) au détriment du pétrole et du gaz naturel. Le *GHG40EERES30* présente également une part plus importante des SER (biomasse, géothermie et solaire thermique[2]) dans la consommation finale totale d'énergie.

Ce sont les secteurs résidentiel et tertiaire qui enregistrent les plus fortes diminutions de la consommation finale d'énergie dans tous les scénarios alternatifs. Dans le scénario basé essentiellement sur les prix (ou les valeurs) du carbone (*GHG40*), la consommation d'énergie recule de 13% (16%) dans le secteur résidentiel (tertiaire) par rapport à 2010. Dans les scénarios alternatifs misant sur des politiques d'efficacité énergétique ambitieuses en plus des signaux de prix (*GHG40EE* et *GHG40EERES30*), la consommation d'énergie diminue davantage avec une baisse de 21% (29%) dans le secteur résidentiel (tertiaire). En revanche, le secteur du transport affiche les plus faibles diminutions de la consommation finale d'énergie, à savoir respectivement 4% et 11% dans le *GHG40* et les *scénarios EE* par rapport à 2010.

La consommation d'électricité reprend après un creux en 2025, qui est l'année de la sortie du nucléaire. Alors qu'elle s'élevait à 90 TWh en 2010, l'énergie appelée atteint en 2030 le même niveau dans les *scénarios EE* que dans le *REF* (93 TWh), mais est légèrement moins élevée dans le *GHG40* (91 TWh). Le niveau des importations nettes varie fortement au cours de la période 2010-2030. En réalité, il prend la forme d'un U avec un creux en 2020 suivi d'une progression sensible pour atteindre 22 TWh en 2030. La production nette d'électricité enregistre une baisse considérable par rapport à 2010 (90 TWh); elle fluctue

[2] Le solaire photovoltaïque est comptabilisé dans le secteur électrique.

entre 70 (*GHG40*) et 72 TWh (*scénarios EE*), suivant ainsi la même évolution que celle décrite dans le *REF* (73 TWh). Trois facteurs (étroitement liés) sont à l'origine de cette chute dans la production domestique : 1) la sortie progressive du nucléaire, 2) la forte pénétration des SER dans le système électrique (entre 48% et 55% dans les scénarios alternatifs), et 3) les coûts de production relativement plus élevés de l'électricité produite dans notre pays par rapport à l'électricité importée de l'étranger, le coût moyen de la production domestique d'électricité passant de 64 €/MWh en 2010 à des niveaux situés entre 104 (*GHG40EE*) et 109 €/MWh (*GHG40*). Le coût de production moyen dans le *REF* penche vers la limite supérieure de cette fourchette (108 €/MWh), dès lors que les trois déterminants s'appliquent également au *REF*.

Ainsi, l'évolution de la production nette d'électricité n'est pas sensiblement affectée par la réalisation des objectifs climatiques (et SER) de l'UE pour 2030. Ce qui change, en revanche, est le mix énergétique. La production d'électricité à partir de gaz naturel est généralement moins élevée que dans le *REF* (36 TWh) et fluctue entre 30 (*GHG40EERES30*) et 35 TWh (*GHG40EE*), représentant ainsi entre 41% et 49% des mix de production respectifs. L'électricité produite à partir de SER vient compléter le mix : les niveaux de production d'électricité à partir de sources d'énergie renouvelables décollent suite à la détermination des objectifs climatiques (et SER) contraignants de l'UE, et également à la faveur de la baisse des courbes d'apprentissage et d'un certain nombre de conditions favorisant cette évolution (par ex., l'équilibrage transfrontalier). L'éolien devient la principale ressource avec des niveaux de production fluctuant entre 20 (*GHG40EE* et *REF*) et 24 TWh (*GHG40EERES30*).

Malgré la baisse de la production électrique, la capacité de production d'électricité s'accroît. Alors que la capacité installée totale était de 17 GW en 2010, elle s'étoffe d'environ 58% dans le *GHG40* et le *GHG40EE* (dans une mesure comparable au *REF* (+60%)) et de 65% dans *le GHG40EERES30* en dépit de la sortie du nucléaire. Les extensions de capacité se composent principalement de SER variables (à savoir l'éolien et le solaire) (+11 à 12 GW), et 5 à 6 GW supplémentaires de centrales au gaz naturel viennent compléter le système futur. On estime que les investissements monétaires sont semblables à ceux du *REF* dans le *GHG40* et le *GHG40EE*, mais ils sont nettement plus conséquents dans le *GHG40EERES30* en raison des investissements supplémentaires dans les éoliennes et, dans une moindre mesure, dans les centrales fonctionnant à partir de biomasse. Au cours de la période 2010-2030, les investissements s'élèvent à € 32 milliards dans le *GHG40*, € 31 milliards dans le *GHG40EE* et € 36 milliards dans le *GHG40EERES30* (par rapport aux € 31 milliards du *REF*). L'accroissement considérable de la capacité des SER variables donne (davantage) lieu à un *effet de compression* des centrales fonctionnant à partir de gaz naturel : les taux d'utilisation (60% en 2010) se réduisent à un niveau situé entre 32% (*GHG40* et *GHG40EERES30*) et 35% (*GHG40EE* et *REF*).

Les sources d'énergie renouvelables continuent à voir s'accroître leur part dans la consommation finale brute d'énergie. Alors que l'objectif national contraignant prévu dans le paquet Climat/Énergie 2020 (sur lequel se base le *REF*) était fixé à 13%, la part atteinte en 2030 s'élève à 18% dans le *GHG40* et le *GHG40EE* et même à 23% dans le *GHG40EERES30* (contre 17% dans le *REF* et seulement 5% en 2010). Les SER couvrent différents usages, à savoir le transport, le chauffage et le refroidissement et la production d'électricité. C'est essentiellement le développement de ce dernier usage qui fait grossir la part globale des SER. Cette tendance s'observait déjà dans le *REF*.

La consommation d'énergie primaire décline dans tous les scénarios alternatifs, mais de manière plus marquée dans les scénarios misant sur des politiques d'efficacité énergétique ambitieuses. La diminution par rapport à 2010 oscille entre 26 et 30%. Ce résultat conduit à 40,1 Mtep dans le *GHG40* et 37,6 Mtep dans les *scénarios EE* (contre 42,2 Mtep dans le *REF*). Ces niveaux de consommation se situent en dessous de l'objectif national indicatif d'efficacité énergétique de 43,7 Mtep en 2020. L'intensité énergétique de l'économie belge recule dans tous les scénarios alternatifs, mais surtout dans les *scénarios EE*. Cette baisse s'élève à 42% par rapport à 2010 dans le *GHG40* et à 45% dans les *scénarios EE* (contre 39% dans le *REF*).

La réalisation des objectifs climatiques de l'UE d'ici 2030 (combinés avec des politiques d'efficacité énergétique ambitieuses et un objectif SER) entraîne une diminution des importations d'énergie par rapport à 2010 et au niveau de 2030 dans le *REF*. Alors que les importations s'élèvent à environ 53 Mtep dans le *REF* (un niveau similaire à 2010), les scénarios alternatifs demandent seulement des niveaux d'importation situés entre 47 et 50 Mtep. Cette différence de 3 à 6 Mtep s'explique par une contraction du niveau des importations de combustibles fossiles (pétrole et gaz naturel), et ce malgré les importations plus élevées d'électricité et de biomasse.

Parmi les effets économiques, il convient de noter que le rapport entre le coût total du système énergétique (à savoir les dépenses d'investissement liées à la production d'énergie, à la consommation, au transport et à l'efficacité énergétique ainsi que les coûts d'achat d'énergie) et le PIB s'accroît en passant de 13,5% en 2010 à respectivement 16,2% et 17% dans le *GHG40* et les *scénarios EE*. Les chiffres susmentionnés dépassent ceux du *REF* de respectivement 0,3 et 1,1 point de pourcentage. Le déficit commercial des combustibles fossiles par rapport au PIB n'évolue guère comparativement à 2010 (environ 3,8% du PIB). Toutefois, le déficit observé dans les scénarios alternatifs est inférieur de 0,2 à 0,6 point de pourcentage à celui du *REF*.

La définition d'objectifs climatiques (et de SER) en 2030 (auxquels peuvent venir s'ajouter des mesures d'efficacité énergétique ambitieuses) a également un impact sur la création de nouveaux emplois. D'ici 2030, la création d'emplois supplémentaires dans les scénarios alternatifs par rapport au *REF* devrait se situer entre 26 000 et 28 000 équivalents temps plein (ETP) dans les *scénarios EE* et s'élever à approximativement 12 000 ETP dans le *GHG40*. Le principal levier de la création d'emplois est les efforts déployés en matière d'efficacité énergétique, qui créent généralement des emplois au niveau local (par ex. dans le secteur du bâtiment).

**Résumé des principaux résultats, dans le REF et les scénarios alternatifs, en 2030**

| | REF | GHG40 | GHG40EE | GHG40EERES30 |
|---|---|---|---|---|
| Consommation d'énergie primaire (en Mtep) | 42,2 | 40,1 | 37,6 | 37,6 |
| Consommation finale d'énergie (en Mtep) | 34,7 | 33,0 | 30,2 | 30,4 |
| Émissions GES non-ETS (% de différence par rapport à 2005) | -15,1 | -24,5 | -32,2 | -30,6 |
| Part des SER dans la CFBE (en %) | 16,8 | 18,0 | 18,4 | 23,4 |
| Dépendance énergétique (en %) | 88,2 | 87,7 | 87,6 | 85,7 |
| Coût total du système énergétique (en % du PIB) | 15,9 | 16,2 | 17,0 | 17,0 |
| Balance commerciale des combustibles fossiles (en % du PIB) | -4,1 | -3,9 | -3,7 | -3,5 |
| Émissions totales de GES (en Mt éq. $CO_2$) | 118,0 | 106,5 | 103,0 | 101,4 |
| Intensité en carbone du secteur électrique (en $tCO_2$/GWh) | 176 | 162 | 168 | 144 |
| Coût moyen de la production électrique (en €'10/MWh) | 108,0 | 108,5 | 104,2 | 105,4 |
| Part des SER dans la production nette d'électricité (en %) | 46,3 | 50,8 | 47,5 | 55,0 |
| Coût des investissements dans les centrales électriques (*) (en milliards €'10) | 31 | 32 | 31 | 36 |

Remarque : GES=Gaz à Effet de Serre; SER=Sources d'Énergie Renouvelables; CFBE=Consommation Finale Brute d'Énergie; ETS=Emission Trading Scheme.

(*) indique que les valeurs mentionnées ne représentent pas des chiffres annuels, mais le total des investissements nécessaires pour la période 2010-2030.

## Effets en 2050

Les émissions totales de GES se situent environ 65% en dessous du niveau de 1990, indépendamment du scénario politique (contre 17% dans le *REF*). Les émissions de GES continuent à reculer aussi bien dans les secteurs ETS que dans les secteurs non-ETS. Dans le scénario *GHG40,* où les émissions de GES dépendent principalement des prix du carbone dans les secteurs ETS et des valeurs du carbone dans les secteurs non-ETS, les réductions d'émissions de GES sont comparables dans les deux groupes et s'élèvent respectivement à 65 et 68% par rapport à 2005. En revanche, les réductions d'émissions de GES sont plus conséquentes dans les secteurs non-ETS que dans les secteurs ETS dans les *scénarios EE* : 71% contre 58% par rapport à 2005. En d'autres termes, les politiques ambitieuses en matière d'efficacité énergétique modèrent les réductions nécessaires dans les secteurs ETS. Par rapport au *REF*, les réductions supplémentaires de GES fluctuent entre 37 et 43 points de pourcentage dans les secteurs ETS alors qu'elles oscillent entre 55 et 58 points de pourcentage dans les secteurs non-ETS.

Les secteurs résidentiel et tertiaire sont les meilleurs élèves dans la transition vers une économie bas carbone en 2050 avec des réductions d'émissions variant entre 75 et 85% par rapport à 2010. Ces secteurs sont suivis par l'industrie et le transport dont les émissions de $CO_2$ liées à l'énergie sont inférieures de 50% à 65% à celles de 2010. Les réductions d'émissions dans le secteur électrique sont les plus faibles et varient dans une large mesure selon le scénario politique suivi : 55% dans le *GHG40*, 47% dans le *GHG40EERES30* et 34% dans le *GHG40EE*.

Les baisses de la consommation finale d'énergie s'accentuent : 17% (29%) dans le *GHG40* (les *scénarios EE*) par rapport à 2010 (36,4 Mtep). En termes absolus, la consommation finale totale d'énergie s'élève à 30,4 Mtep (26,0 Mtep). Par rapport au *REF*, on atteint des économies d'énergie allant de 7,5 à 11,9 Mtep dans les scénarios alternatifs. Ces derniers présentent des différences importantes en ce qui concerne le mix énergétique par rapport à 2010 (et également par rapport au *REF* en 2050). Ainsi, la part des combustibles fossiles (charbon, pétrole et gaz) chute lourdement à un niveau inférieur à 36% contre près de

75% en 2010; les combustibles fossiles sont principalement remplacés par l'électricité (33-34%) et les SER (22-25%), mais de nouvelles formes d'énergie comme l'hydrogène font également leur apparition. L'hydrogène, qui décolle littéralement après 2040, devient un substitut aux sources d'énergie conventionnelles dans tous les secteurs de la demande finale et dans tous les scénarios alternatifs. La consommation d'hydrogène en 2050 se répartit comme suit : 32% dans l'industrie, 18% dans le transport et 50% dans les secteurs résidentiel et tertiaire.

La baisse observée dans la consommation finale d'énergie se poursuit dans les secteurs résidentiel et tertiaire : la consommation d'énergie diminue de plus de 30% dans le *GHG40* et de près de 50% dans les *scénarios EE* par rapport à 2010. Quant à la consommation finale d'énergie dans l'industrie, elle évolue de manière divergente dans les différents scénarios alternatifs. Dans le *GHG40*, la consommation d'énergie retrouve le niveau de 2020, mais elle se situe encore 3% en dessous du niveau de 2010. Dans les *scénarios EE*, d'ambitieuses mesures supplémentaires d'efficacité énergétique permettent de soutenir la baisse à long terme jusqu'à atteindre 18% en dessous du niveau de 2010. Enfin, la consommation d'énergie dans le secteur du transport se stabilise à son niveau de 2030. L'effet le plus marquant des scénarios alternatifs sur le transport est l'accroissement considérable de la part des biocarburants et de l'électricité. La part des biocarburants (de l'électricité) varie entre 36% et 39% (entre 15% et 16%) selon le scénario suivi.

L'énergie appelée connaît une croissance spectaculaire dans tous les scénarios alternatifs. L'adoption d'objectifs climatiques à long terme a un impact très visible sur la consommation d'électricité. Celle-ci s'envole pour atteindre des niveaux d'environ 125 TWh dans les *scénarios EE* et culmine même à 145 TWh dans le *GHG40* (contre 115 TWh dans le *REF* et 90 TWh en 2010). Cette hausse considérable de la consommation d’électricité dans les scénarios alternatifs s'explique par trois facteurs : 1) une tendance à se tourner vers des formes d'énergie moins polluantes sous l'effet du niveau élevé des prix et valeurs du carbone, 2) la forte pénétration de l'électromobilité, surtout après 2030, 3) l'arrivée - couronnée de succès - de l'hydrogène produit à partir de l'électrolyse et utilisé dans plusieurs secteurs. Cette hausse de la consommation d'électricité est couverte aussi bien par le bond des importations nettes (32 TWh) que par la croissance de l'électricité produite en Belgique. La production nette dans les *scénarios EE* (environ 94 TWh) s'élève à des niveaux similaires à celui du *REF* (95 TWh), tandis que le niveau de production dans le *GHG40* est environ 20 TWh plus élevé et atteint 114 TWh.

Les niveaux de production diffèrent, mais également les mix énergétiques. Même s'il affiche des niveaux de production nettement plus élevés, le *GHG40* présente un mix très similaire à celui du *REF*, avec 46% de gaz naturel, 34% d'éolien, 10% de solaire et 8% de biomasse et de déchets. Bien que les deux *scénarios EE* présentent des niveaux de production similaires, leurs mix de production respectifs divergent (davantage). Le *GHG40EERES30* contient une part plus importante d'éolien (44%) et de biomasse et déchets (12%), mais moins de gaz naturel (35%) que le *GHG40EE* (respectivement 37%, 10% et 42%).

Les différences observées en ce qui concerne le niveau de production et le mix énergétique ont des répercussions sur les investissements requis et, partant, sur le coût moyen de la production électrique. Les investissements à consentir au cours de la période 2030-2050 s'élèvent à € 46 milliards dans le *GHG40*, € 31 milliards dans le *GHG40EE* et € 33 milliards dans le *GHG40EERES30* (contre € 31 milliards dans le

*REF*). Les sommes astronomiques à débourser dans le *GHG40* s'expliquent principalement par les investissements supplémentaires nécessaires pour couvrir l'accroissement de la consommation d'électricité qui n'est que très légèrement freiné par les initiatives prises en vue d'ajuster la demande, contrairement aux scénarios *GHG40EE* et *GHG40EERES30* où la maîtrise de la demande joue un rôle majeur. Les *scénarios EE* parviennent à infléchir la hausse du coût moyen de la production électrique qui commence en 2020 et qui devrait prendre fin en 2050 à un niveau de 95-96 €/MWh. Dans le *GHG40* en revanche, le coût moyen de production continue à grimper pour atteindre 119 €/MWh en 2050, soit près de 20% de plus que dans le *REF* où aucun objectif climatique (ou autre) ne doit être atteint au-delà de 2020.

Les sources d'énergie renouvelables continuent à progresser et atteignent des parts de 41% (*GHG40*), 39% (*GHG40EE*) et 45% (*GHG40EERES30*) dans la consommation finale brute d'énergie (contre 19% dans le *REF*). Les SER couvrent près de deux tiers de la consommation finale d'énergie pour le transport, entre 26% et 38% pour le chauffage et le refroidissement et entre 39% et 46% pour les usages électriques dans les scénarios alternatifs.

La consommation d'énergie primaire se contracte de 29% à 40% par rapport au niveau de 2010 (contre 15% dans le *REF*). Elle s'élève à 38,2 Mtep dans le *GHG40* et à 32,4 Mtep dans les *scénarios EE* (contre 45,2 Mtep dans le *REF*). L'intensité énergétique de l'économie belge continue à reculer avec une baisse de 60% par rapport à 2010 dans le *GHG40* et de 66% dans les *scénarios EE* (contre 54% dans le *REF*).

Les importations d'énergie restent en dessous du niveau de 2010 (53 Mtep) tandis que l'écart en termes d'importations d'énergie entre le *REF* et les scénarios alternatifs continue à se creuser : il s'élève à présent à un niveau situé entre 11 et 17 Mtep. Alors que les importations d'énergie se chiffrent à environ 56 Mtep dans le *REF*, elles diminuent dans les scénarios alternatifs pour atteindre des niveaux situés entre 39 et 45 Mtep. Les principales tendances se poursuivent : les importations de combustibles fossiles (pétrole et gaz naturel) diminuent sensiblement dans les scénarios alternatifs, tandis que les importations d'électricité et de biomasse explosent.

Après une quasi-stabilisation à 3,8% au cours de la période 2010-2030, le déficit commercial des combustibles fossiles par rapport au PIB est considérablement réduit en 2050. Il fluctue entre 1,6% et 2% du PIB en fonction du scénario politique retenu. La limite inférieure de la fourchette correspond au scénario *GHG40EERES30*. Par rapport au *REF*, le déficit commercial des combustibles fossiles se comprime de 1,4 à 1,8 points de pourcentage.

Tous les scénarios alternatifs mènent à une augmentation du coût du système énergétique par rapport au *REF*. Le coût total du système énergétique par rapport au PIB est respectivement estimé à 15,9% et environ 16,4% dans le *GHG40* et les *scénarios EE*. Ces pourcentages sont inférieurs à ceux enregistrés en 2030, ce qui signifie que le coût du système énergétique évolue moins rapidement que le PIB sur le long terme. Par rapport au *REF*, les chiffres susmentionnés sont respectivement 2,5 et 3 points de pourcentage plus élevés.

**Résumé des principaux résultats, dans le REF et les scénarios alternatifs, en 2050**

| | REF | GHG40 | GHG40EE | GHG40EERES30 |
|---|---|---|---|---|
| Consommation d'énergie primaire (en Mtep) | 45,6 | 38,2 | 32,4 | 32,2 |
| Consommation finale d'énergie (en Mtep) | 37,9 | 30,4 | 26,0 | 26,0 |
| Émissions GES non-ETS (% de différence par rapport à 2005) | -13,4 | -68,1 | -70,6 | -71,1 |
| Part des SER dans la CFBE (en %) | 19,2 | 40,6 | 38,8 | 45,2 |
| Dépendance énergétique (en %) | 85,7 | 80,5 | 81,1 | 79,0 |
| Coût total du système énergétique (en % du PIB) | 13,4 | 15,9 | 16,5 | 16,4 |
| Balance commerciale des combustibles fossiles (en % du PIB) | -3,4 | -2,0 | -1,7 | -1,6 |
| Émissions totales de GES (en Mt éq. $CO_2$) | 121,3 | 49,1 | 51,1 | 51,4 |
| Intensité en carbone du secteur électrique (en $tCO_2$/GWh) | 131 | 73 | 125 | 101 |
| Coût moyen de la production électrique (en €'10/MWh) | 100,2 | 119,0 | 96,3 | 95,3 |
| Part des SER dans la production nette d'électricité (en %) | 54,0 | 53,7 | 57,8 | 64,5 |
| Coût des investissements dans les centrales électriques (*) (en milliards €'10) | 31 | 46 | 31 | 33 |

Remarque : GES=Gaz à Effet de Serre; SER=Sources d'Énergie Renouvelables; CFBE=Consommation Finale Brute d'Énergie; ETS=Emission Trading Scheme.

(*) indique que les valeurs mentionnées ne représentent pas des chiffres annuels, mais le total des investissements nécessaires pour la période 2030-2050.

# Synthese

Het Federaal Planbureau heeft op 17 oktober 2014 de vijfde editie van zijn driejaarlijkse langetermijn-energievooruitzichten gepubliceerd (FPB, 2014). Het rapport beschrijft een *Referentiescenario* tot 2050 (afgekort REF) dat de evolutie van het Belgische energiesysteem simuleert in het licht van de huidige trends en de aangenomen beleidsmaatregelen op het vlak van klimaat, energie en transport, en de bindende doelstellingen van het 2020 Klimaat/Energiepakket integreert. Uit de analyse van de resultaten van dit scenario blijkt dat er grote verschillen bestaan tussen dit REF en de inspanningen die nodig zijn om op schema te blijven voor het Europese Klimaat- en Energiekader tegen 2030, alsook voor de overgang naar een koolstofarme economie tegen 2050. Dit is dan ook de reden waarom er nood is aan bijkomend beleid en maatregelen. Die vaststelling vormde de aanleiding voor het schrijven van deze paper waarin drie beleidsscenario's worden geanalyseerd die verenigbaar zijn met de uitdagingen aangestipt door de Europese Raad op het vlak van broeikasgasemissiereducties voor 2030 en 2050.

Deze drie scenario's gaan er allemaal van uit dat aan een aantal *noodzakelijke randvoorwaarden* is voldaan (en verschillen daarin van *REF*). Deze voorwaarden veronderstellen effectieve structurele veranderingen in alle sectoren van de economie waarbij aangenomen wordt dat de verschillende veranderingen tijdig en degelijk gecoördineerd gebeuren. Publieke aanvaarding is daarbij essentieel. De noodzakelijke voorwaarden dienen gecreëerd te worden door beleidsinspanningen en dit zowel op sectoraal (zoals de eliminatie van marktfalen en het wegwerken van hindernissen voor een efficiënt energieverbruik en voor de ontwikkeling van hernieuwbare energie) als op publiek vlak (zoals O&O en innovatiefinanciering). Het ontbreken van deze voorwaarden leidt ertoe dat economische agenten omwille van markt- en beleidsonzekerheden mogelijks beslissingen nemen die op lange termijn suboptimaal blijken te zijn. Deze kunnen dan uitmonden in technologie- en infrastructuurlock-ins die leiden tot hogere totale kosten voor de transformatie naar een lage-koolstofeconomie.

De drie scenario's (*GHG40*, *GHG40EE* en *GHG40EERES30*) hebben verschillende ambitieniveaus op het gebied van energie-efficiëntie en de inzet van hernieuwbare energie. Het eerste scenario (*GHG40*) spitst zich uitsluitend toe op de BKG-emissiereductiedoelstellingen voor 2030 en 2050 en is gestoeld op de toepassing van koolstofprijzen en koolstofwaarden. Het tweede scenario (*GHG40EE*) vormt een aanvulling op het vorige scenario door de toevoeging van ambitieuze beleidsmaatregelen inzake energie-efficiëntie (EE), terwijl het derde scenario (*GHG40EERES30*) het tweede scenario aanvult met een bindende hernieuwbare-energiedoelstelling (HEB) van 30% in 2030. Hieronder volgt een beschrijving van de verschillende effecten van deze drie scenario's op het Belgische energiesysteem voor twee tijdshorizonten: 2030 en 2050.

### Effecten in 2030

De totale broeikasgasemissies dalen met 27% in *GHG40* en met om en bij 30% in *GHG40EE* en *GHG40EERES30* ten opzichte van het niveau van 1990 (tegenover 20% in *REF*). In de drie beleidsscenario's worden gelijkaardige BKG-reducties opgetekend in de ETS- en niet-ETS-sectoren in vergelijking met 2005: van 27 tot 31% in de eerstgenoemde sector en van 25 tot 32% in de laatstgenoemde sector. In vergelijking met *REF* zijn de bijkomende emissiereducties in 2030 evenwel groter in de niet-ETS-sectoren dan in de ETS-sectoren, vooral in de twee beleidsscenario's die door ambitieuze energie-efficientiemaatregelen worden gekenmerkt (*GHG40EE* en *GHG40EERES30*). De bijkomende BKG-emissiereducties schommelen tussen 3 en 7 procentpunt in de ETS-sectoren, en tussen 9 en 17 procentpunt in de niet-ETS-sectoren.

De grootste (respectievelijk kleinste) energiegerelateerde $CO_2$-emissiereducties worden, relatief gezien, in de tertiaire sector (respectievelijk transport) verwezenlijkt. Zij variëren, in vergelijking met 2010, van 31 tot 55% (respectievelijk van 10 tot 18%) in de beleidsscenario's. Voor de industriële en residentiële sector liggen de desbetreffende cijfers respectievelijk tussen 20 en 32% en tussen 20 en 29%. De bovenste waarden van de intervallen stemmen overeen met de beleidsscenario's waarin ambitieuze energie-efficiëntiemaatregelen opgenomen zijn. In de elektriciteitssector schommelen de reducties tussen 25 en 35%.

De finale energievraag neemt in *GHG40* en de *EE-scenario's* (zowel *GHG40EE* als *GHG40EERES30*) met respectievelijk 9 en 17% af in vergelijking met het niveau in 2010 (36,4 Mtoe). De cijfers bedragen in absolute termen respectievelijk 33,0 Mtoe en 30,2 Mtoe, d.w.z. dichtbij of zelfs onder de indicatieve nationale efficiëntiedoelstelling van 32,5 Mtoe in 2020. In vergelijking met *REF* worden in de beleidsscenario's energiebesparingen gerealiseerd die tussen 1,7 en 4,5 Mtoe schommelen. De veranderingen in de energiemix zijn tussen 2010 en 2030 vergelijkbaar in *REF* en *GHG40*, d.w.z. een afname van de aandelen van fossiele brandstoffen (steenkool, olie en aardgas) en een toename van de aandelen van elektriciteit, gedistribueerde warmte en HEB. De koolstofwaarde in de niet-ETS (waarin het *GHG40*-scenario verschilt van *REF*) leidt met andere woorden tot meer energiebesparingen in plaats van fuel switching. De scenario's met een ambitieus EE- en HEB-beleid leiden daarentegen tot een groter aandeel van elektriciteit (24% tegenover iets meer dan 21% in *REF* en *GHG40*), ten nadele van olie en aardgas. *GHG40EERES30* toont eveneens een groter HEB-aandeel (biomassa, geothermie en zon thermisch[3]) in de totale finale energievraag.

In alle beleidsscenario's daalt het finale energieverbruik het sterkst in de residentiële en tertiaire sectoren. In het scenario dat voornamelijk op koolstofprijzen en koolstofwaarden is gestoeld (*GHG40*), daalt het energieverbruik met 13% (respectievelijk 16%) in de residentiële (respectievelijk tertiaire) sector in vergelijking met het niveau van 2010. In de beleidsscenario's die een ambitieus energie-efficiëntiebeleid voeren bovenop de prijssignalen (*GHG40EE* en *GHG40EERES30*) daalt de energievraag in de residentiële (respectievelijk tertiaire) sector nog meer, met 21% (respectievelijk 29%). Daar staat tegenover dat in de transportsector de finale energievraag het minst afneemt, namelijk met respectievelijk 4% en 11% in het *GHG40*-scenario en de *EE-scenario's* in vergelijking met het niveau in 2010.

De elektriciteitsvraag trekt aan na een dip in 2025, niet toevallig het jaar waarin alle kerncentrales zijn uitgedoofd. De opgevraagde energie die in 2010 90 TWh bedroeg, bereikt in 2030 in de *EE-scenario's* hetzelfde niveau als in *REF* (93 TWh), maar is ietwat lager in *GHG40* (91 TWh). Het niveau van de netto-invoer varieert aanzienlijk over de periode 2010-2030. Het doorloopt bovendien een U-vormige curve waarvan de bodem in 2020 wordt bereikt, gevolgd door een sterke stijging om in 2030 op 22 TWh uit te komen. De netto-elektriciteitsproductie daalt gevoelig in vergelijking met 2010 (90 TWh): zij schommelt

3 Fotovoltaïsche zonne-energie wordt in de elektriciteitssector ondergebracht.

tussen 70 (*GHG40*) en 72 TWh (*EE-scenario's*) en volgt hiermee dezelfde evolutie als *REF* (73 TWh). Deze terugval in de binnenlandse productie wordt veroorzaakt door drie (onderling verweven) factoren: 1) de uitstap uit nucleaire elektriciteitsproductie, 2) de sterke penetratie van HEB in het elektriciteitssysteem (tussen 48% en 55% in de beleidsscenario's), 3) de relatief hogere productiekosten van binnenlands geproduceerde elektriciteit in vergelijking met ingevoerde elektriciteit: de gemiddelde kostprijs van binnenlandse elektriciteitsproductie veert op van 64 €/MWh in 2010 naar 104 (*GHG40EE*) en 109 €/MWh (*GHG40*). De gemiddelde productiekost in *REF* leunt aan bij de bovengrens van het interval (108 €/MWh), aangezien de drie determinanten ook geldig zijn in het geval van *REF*.

De evolutie van de netto-elektriciteitsproductie lijkt daarom niet sterk beïnvloed door de implementatie van de Europese klimaat- (en HEB-) doelstellingen tegen 2030. Wat echter wel verandert, is de elektriciteitsmix. De elektriciteitsproductie op basis van aardgas is over het algemeen lager dan in *REF* (36 TWh) en bevindt zich tussen 30 (*GHG40EERES30*) en 35 TWh (*GHG40EE*). Hierdoor schommelt het aandeel in de energiemix voor de elektriciteitsproductie tussen 41% en 49%. De elektriciteitsproductie op basis van HEB vult dan de leemte: de niveaus van de hernieuwbare elektriciteitsproductie stijgen als gevolg van de bindende EU-klimaat-(en HEB-) doelstellingen in combinatie met dalende leercurven en een aantal gunstig veronderstelde voorwaarden (bv. grensoverschrijdende netevenwichtsdiensten). Wind wordt de belangrijkste energiebron met productieniveaus die tussen 20 (*GHG40EE* en *REF*) en 24 TWh (*GHG40EERES30*) schommelen.

Ondanks een daling van de elektriciteitsproductie neemt de elektriciteitsproductiecapaciteit toe. De totale geïnstalleerde capaciteit neemt met ongeveer 58% toe in *GHG40* en *GHG40EE* (vergelijkbaar met *REF* (+60%)) en met 65% in *GHG40EERES30*, en dit niettegenstaande de ontmanteling van de kerncentrales. De capaciteitsuitbreidingen bestaan voornamelijk uit variabele HEB (d.w.z. wind en zon) (+ 11 à 12 GW), terwijl een bijkomende 5 à 6 GW aardgas het toekomstige systeem vervolledigt. Verwacht wordt dat de benodigde investeringen in *GHG40* en *GHG40EE* gelijkaardig zijn aan deze becijferd in *REF*. In *GHG40EERES30* zijn de investeringskosten echter aanzienlijk hoger door bijkomende investeringen in windturbines en, in mindere mate, biomassacentrales. In de periode 2010-2030 belopen de investeringen € 32 miljard in *GHG40*, € 31 miljard in *GHG40EE* en € 36 miljard in *GHG40EERES30* (in vergelijking met € 31 miljard in *REF*). De spectaculaire stijging van de variabele HEB-capaciteit leidt tot een (verder) *compressie-effect* van de aardgasgestookte centrales: de gebruiksratio (nog 60% in 2010) slinkt daardoor en komt uit op ongeveer 32% (*GHG40* en *GHG40EERES30*) à 35% (*GHG40EE* en *REF*).

Hernieuwbare energiebronnen nemen een steeds groter aandeel in in het bruto finaal energieverbruik. Daar waar in het 2020 Klimaat/Energiepakket (en gesimuleerd in *REF*) een nationale bindende doelstelling werd vastgelegd van 13%, bereiken de aandelen in *GHG40* en *GHG40EE* 18% in 2030 en in *GHG40EERES30* zelfs 23% (tegenover 17% in *REF* en vertrekkend van 5% in 2010). Hernieuwbare energiebronnen kunnen ingezet worden voor verschillende toepassingen, d.w.z. transport, verwarming, koeling en elektriciteitsproductie. De ontwikkeling in de elektriciteitsproductie doet het HEB-aandeel het meest toenemen, een trend die reeds in *REF* merkbaar was.

Het primair energieverbruik daalt in alle beleidsscenario's, maar de daling is veel meer uitgesproken in de scenario's met een ambitieus energie-efficiëntiebeleid. De daling in vergelijking met 2010 schommelt tussen 26 en 30%. Dit resultaat vertaalt zich in 40,1 Mtoe in *GHG40* en 37,6 Mtoe in de *EE-scenario's* (tegenover 42,2 Mtoe in *REF*). Die verbruiksniveaus bevinden zich onder de nationale indicatieve energie-efficiëntiedoelstelling van 43,7 Mtoe in 2020. De energie-intensiteit van de Belgische economie neemt in alle beleidsscenario's af, maar het sterkst in de *EE-scenario's*: met 42% in vergelijking met 2010 in *GHG40* en met 45% in de *EE-scenario's* (in vergelijking met 39% in *REF*).

De tenuitvoerlegging van de EU-klimaatdoelstellingen voor 2030 en 2050 (in combinatie met een ambitieus energie-efficiëntiebeleid en HEB-doelstelling) leidt tot lagere energie-invoer in vergelijking met het niveau van 2010 (en het 2030-niveau van *REF*). Terwijl in *REF* ongeveer 53 Mtoe wordt ingevoerd (bijna hetzelfde niveau als in 2010), moet in de beleidsscenario's slechts 47 à 50 Mtoe worden ingevoerd. Dit verschil van 3 tot 6 Mtoe is te wijten aan een duidelijke daling van de invoer van fossiele brandstoffen (d.w.z. olie en aardgas) en dit niettegenstaande een hogere invoer van zowel elektriciteit als biomassa.

Een van de gevolgen op economisch vlak is het feit dat de verhouding tussen de totale energiesysteemkosten (d.w.z. de kapitaalkosten met betrekking tot productie, verbruik en transport van energie, efficiëntie-investeringen alsook aankoopkosten van energie) en het bbp stijgt van 13,5% in 2010 tot respectievelijk 16,2% en 17% in *GHG40* en de *EE-scenario's*. In vergelijking met *REF* liggen de bovenstaande kostencijfers respectievelijk 0,3 en 1,1 procentpunt hoger. Het handelstekort van de fossiele brandstoffen ten opzichte van het bbp evolueert nauwelijks in vergelijking met 2010 (ongeveer 3,8% van het bbp). Het ligt in de beleidsscenario's echter 0,2 à 0,6 procentpunt lager dan in *REF*.

Een bijkomend gevolg van de hernieuwing van de klimaat- (en HEB-) doelstellingen in 2030 (in combinatie met ambitieuze energie-efficiëntiemaatregelen) is de creatie van nieuwe banen. Geschat wordt dat in de beleidsscenario's tegen 2030 tussen 26 000 en 28 000 voltijdse equivalenten (VTE) worden gecreëerd in de *EE-scenario's* en ongeveer 12 000 VTE in *GHG40* en dit ten opzichte van *REF*. De voornaamste motor voor het scheppen van banen zijn de energie-efficiëntie-inspanningen die doorgaans voor lokale banen zorgen (bv. bouwsector).

**Samenvatting van de belangrijkste resultaten, REF en beleidsscenario's, 2030**

| | REF | GHG40 | GHG40EE | GHG40EERES30 |
|---|---|---|---|---|
| Primair energieverbruik (Mtoe) | 42,2 | 40,1 | 37,6 | 37,6 |
| Finale energievraag (Mtoe) | 34,7 | 33,0 | 30,2 | 30,4 |
| BKG-emissies niet-ETS (% verschil ten opzichte van 2005) | -15,1 | -24,5 | -32,2 | -30,6 |
| HEB-aandeel in BFEV (%) | 16,8 | 18,0 | 18,4 | 23,4 |
| Invoerafhankelijkheid (%) | 88,2 | 87,7 | 87,6 | 85,7 |
| Totale energiesysteemkost (% van het bbp) | 15,9 | 16,2 | 17,0 | 17,0 |
| Fossiele-brandstoffenhandelsbalans (% van het bbp) | -4,1 | -3,9 | -3,7 | -3,5 |
| Totale BKG-emissies (Mt $CO_2$-eq.) | 118,0 | 106,5 | 103,0 | 101,4 |
| Koolstofintensiteit van de elektriciteitssector ($tCO_2$/GWh) | 176 | 162 | 168 | 144 |
| Gemiddelde productiekost van elektriciteit (€'10/MWh) | 108,0 | 108,5 | 104,2 | 105,4 |
| HEB-aandeel in netto-elektriciteitsproductie (%) | 46,3 | 50,8 | 47,5 | 55,0 |
| Investeringsuitgaven in elektriciteitscentrales(*) (miljard €'10) | 31 | 32 | 31 | 36 |

Noot: BKG=broeikasgas; HEB=hernieuwbare energiebronnen; BFEV= Bruto Finaal Energieverbruik; ETS=emissiehandelssysteem.

(*) duidt op het feit dat de voorgestelde waarden geen jaarcijfers weergeven, maar de totale benodigde investeringen voor de periode 2010-2030.

## Effecten in 2050

Ongeacht het beleidsscenario liggen de totale BKG-emissies ongeveer 65% onder het niveau van 1990 (tegenover 17% in *REF*). Zowel in de ETS- als de niet-ETS blijven de BKG-emissies afnemen. In het *GHG40*-scenario waar de BKG-emissies hoofdzakelijk beïnvloed worden door koolstofprijzen in de ETS en koolstofwaarden in de niet-ETS, zijn de BKG-emissiereducties vergelijkbaar in beide sectoren: 65 en 68% ten opzichte van 2005. De BKG-emissiereducties zijn in de *EE-scenario's* evenwel hoger in de niet-ETS dan in de ETS: 71% en 58% ten opzichte van 2005. Het ambitieus energie-efficiëntiebeleid tempert met andere woorden de reducties die in de ETS nodig zijn. In vergelijking met *REF* variëren de bijkomende BKG-reducties van 37 tot 43 procentpunt in de ETS-sectoren, terwijl zij in de niet-ETS-sectoren tussen 55 en 58 procentpunt schommelen.

De residentiële en tertiaire sectoren lopen op kop in de race naar een koolstofarme economie in 2050 met emissiereducties die variëren van 75 tot 85% ten opzichte van 2010. Zij worden gevolgd door de industrie en de transportsector waar de energiegerelateerde $CO_2$-emissies naar verwachting 50 tot 65% onder het niveau van 2010 liggen. In de elektriciteitssector zijn de emissiereducties het kleinst en verschillen zij sterk per beleidsscenario: 55% in *GHG40*, 47% in *GHG40EERES30* en 34% in *GHG40EE.*

De daling van de finale energievraag neemt toe: 17% (respectievelijk 29%) in *GHG40* (respectievelijk de *EE-scenario's*) ten opzichte van 2010 (36,4 Mtoe). Verwacht wordt dat de totale finale energievraag in absolute zin 30,4 Mtoe (respectievelijk 26,0 Mtoe) bereikt. In vergelijking met *REF* worden in de beleidsscenario's energiebesparingen verwezenlijkt die tussen 7,5 en 11,9 Mtoe schommelen. In de beleidsscenario's zijn grote verschillen merkbaar in de energiemix in vergelijking met 2010 (en met *REF* in 2050). Het aandeel van de fossiele brandstoffen (steenkool, olie en gas) zakt bijvoorbeeld aanzienlijk tot onder de grens van 36%, in vergelijking met bijna 75% in 2010. Fossiele brandstoffen worden hoofdzakelijk vervangen door elektriciteit (33-34%) en HEB (22-25%), maar ook nieuwe energievormen zoals waterstof verschijnen op het toneel. Na 2040 kent waterstof in alle sectoren van de eindvraag en in alle beleidsscenario's succes als substituut van de conventionele energiebronnen. Het gebruik van waterstof gebeurt in 2050 als volgt: 32% voor de industrie, 18% voor het transport en 50% voor de residentiële en tertiaire sectoren.

De dalende trend in de finale energievraag zet zich door in de residentiële en tertiaire sectoren: in vergelijking met 2010 daalt het energieverbruik met meer dan 30% in *GHG40* en met bijna 50% in de *EE-scenario's*. De evolutie van de finale energievraag in de industrie verschilt in de beleidsscenario's. Het energieverbruik evenaart in *GHG40* het niveau van 2020, maar blijft nog steeds 3% onder het niveau van 2010. De ambitieuze aanvullende EE-maatregelen zorgen er in de *EE-scenario's* voor dat de dalende trend op lange termijn gevrijwaard blijft tot 18% onder het niveau van 2010. Ten slotte stabiliseert de energievraag in transport zich op het niveau van 2030. De belangrijkste impact van de beleidsscenario's op transport is te vinden in de aanzienlijke toename van het aandeel van biobrandstoffen en elektriciteit. Afhankelijk van het scenario schommelt het aandeel van biobrandstoffen (respectievelijk elektriciteit) tussen 36 en 39% (respectievelijk 15 en 16%).

In alle beleidsscenario's neemt de opgevraagde elektrische energie op spectaculaire wijze toe. Het aannemen van langetermijnklimaatdoelstellingen heeft een heel zichtbaar effect op de elektriciteitsvraag.

De elektriciteitsvraag klimt naar ongeveer 125 TWh in de *EE-scenario's* en bereikt een absoluut hoogtepunt van 145 TWh in *GHG40* (in vergelijking met 115 TWh in *REF* en 90 TWh in 2010). De spectaculaire stijging van de vraag in de beleidsscenario's is terug te brengen tot drie oorzaken: 1) een fuel switch naar minder vervuilende energievormen als gevolg van hogere koolstofprijzen en koolstofwaarden, 2) een sterke penetratie van elektromobiliteit, vooral na 2030, 3) de opkomst en het succes van waterstofproductie op basis van elektrolyse en het gebruik ervan in verschillende sectoren. De stijging van de elektriciteitsvraag wordt door zowel een stijging van de netto-invoer (32 TWh) als door een toename van de binnenlandse elektriciteitsproductie opgevangen. De nettoproductie komt in de *EE-scenario's* (ongeveer 94 TWh) op ongeveer hetzelfde niveau als in *REF* (95 TWh) te liggen, terwijl het productieniveau in *GHG40* ongeveer 20 TWh hoger ligt en 114 TWh bereikt (tegenover 90 TWh in 2010).

Niet alleen het productieniveau, maar ook de mix verschilt. Hoewel in *GHG40* aanzienlijk meer geproduceerd wordt, is de mix in *GHG40* zeer gelijkaardig aan de mix in *REF*: 46% aardgas, 34% wind, 10% zon en 8% biomassa en afval. Hoewel de twee *EE-scenario's* ongeveer evenveel produceren, hebben zij een verschillende energiemix voor de elektriciteitsproductie. *GHG40EERES30* omvat meer wind (44%) en biomassa en afval (12%), maar minder aardgas (35%) dan *GHG40EE* (respectievelijk 37%, 10% en 42%).

Het feit dat de elektriciteitsproductieniveaus en de mix verschillen, heeft een weerslag op de noodzakelijke investeringen en bijgevolg op de gemiddelde elektriciteitsproductiekost. In de periode 2030-2050 belopen de investeringen € 46 miljard in *GHG40*, € 31 miljard in *GHG40EE* en € 33 miljard in *GHG40EERES30* (in vergelijking met € 31 miljard in *REF*). De aanzienlijke investeringsuitgaven in *GHG40* zijn vooral te wijten aan de bijkomende investeringen die de stijging van de elektriciteitsvraag moeten dekken. Die stijging wordt maar in beperkte mate opgevangen door vraagsturingsinitiatieven, en dit in tegenstelling tot *GHG40EE* en *GHG40EERES30* waar vraagsturing een belangrijke rol inneemt. In de *EE-scenario's* wordt een halt toegeroepen aan de opwaartse trend van stijgende gemiddelde elektriciteitsproductiekost die in 2020 van start is gegaan en de gemiddelde elektriciteitsproductiekost strandt in 2050 op 95-96 €/MWh. Daar staat tegenover dat in *GHG40* de gemiddelde productiekost blijft oplopen om tegen 2050 op 119 €/MWh uit te komen. Dit is ongeveer 20% hoger dan de gemiddelde productiekost in *REF* waar na 2020 geen klimaat- (of andere) doelstellingen meer worden geïmplementeerd.

Hernieuwbare energiebronnen zetten hun opmars voort en bereiken aandelen van 41% (*GHG40*), 39% (*GHG40EE*) en 45% (*GHG40EERES30*) in het bruto finaal energieverbruik (tegenover 19% in *REF*). In de beleidsscenario's is HEB goed voor bijna twee derde van het finaal energieverbruik in transport, tussen 26% en 38% in verwarming en koeling, en tussen 39 en 46% in elektrische toepassingen.

Het primair energieverbruik daalt met 29 à 40% in vergelijking met het niveau van 2010 (tegenover 15% in *REF*). Het totaal primair energieverbruik bedraagt 38,2 Mtoe in *GHG40* en 32,4 Mtoe in de *EE-scenario's* (tegenover 45,2 Mtoe in *REF*). De energie-intensiteit van de Belgische economie daalt verder: met 60% ten opzichte van 2010 in *GHG40* en met 66% in de *EE-scenario's* (tegenover 54% in *REF*).

De energie-invoer blijft onder het niveau in 2010 (53 Mtoe,) terwijl het verschil in energie-invoer tussen *REF* en de beleidsscenario's steeds groter wordt: dit verschil loopt op tot 11 à 17 Mtoe in 2050. Terwijl in *REF* ongeveer 56 Mtoe wordt ingevoerd, wordt de energie-invoer in de beleidsscenario's tot 39 à 45

Mtoe teruggebracht. De belangrijkste trends houden stand: de invoer van fossiele brandstoffen (d.w.z. olie en aardgas) neemt aanzienlijk af in de beleidsscenario's, terwijl de invoer van elektriciteit en biomassa opveert.

Na een quasi-stabilisatie op 3,8% van het bbp in de periode 2010-2030 valt het handelstekort van de fossiele brandstoffen tegen 2050 aanzienlijk terug. Het schommelt tussen 1,6% en 2% van het bbp, naargelang van het beleidsscenario. De ondergrens van dat interval komt overeen met het *GHG40EERES30*-scenario. In vergelijking met *REF* komt het handelstekort van de fossiele brandstoffen uit op 1,4 à 1,8 procentpunt.

In vergelijking met *REF* leiden alle beleidsscenario's tot bijkomende energiesysteemkosten. De totale energiesysteemkosten ten opzichte van het bbp lopen in *GHG40* en de *EE-scenario's* op tot respectievelijk 15,9% en 16,4%. Die percentages zijn lager dan de percentages die in 2030 zijn opgetekend, wat betekent dat de evolutie van de energiesysteemkosten op lange termijn aan een langzamer tempo verloopt dan het bbp. In vergelijking met *REF* liggen de bovenstaande kostencijfers respectievelijk 2,5 en 3 procentpunt hoger.

**Samenvatting van de belangrijkste resultaten, REF en beleidsscenario's, 2050**

| | REF | GHG40 | GHG40EE | GHG40EERES30 |
|---|---|---|---|---|
| Primair energieverbruik (Mtoe) | 45,6 | 38,2 | 32,4 | 32,2 |
| Finale energievraag (Mtoe) | 37,9 | 30,4 | 26,0 | 26,0 |
| BKG-emissies niet-ETS (% verschil ten opzichte van 2005) | -13,4 | -68,1 | -70,6 | -71,1 |
| HEB-aandeel in BFEV (%) | 19,2 | 40,6 | 38,8 | 45,2 |
| Invoerafhankelijkheid (%) | 85,7 | 80,5 | 81,1 | 79,0 |
| Totale energiesysteemkost (% van het bbp) | 13,4 | 15,9 | 16,5 | 16,4 |
| Fossiele-brandstoffenhandelsbalans (% van het bbp) | -3,4 | -2,0 | -1,7 | -1,6 |
| Totale BKG-emissies (Mt $CO_2$-eq.) | 121,3 | 49,1 | 51,1 | 51,4 |
| Koolstofintensiteit van de elektriciteitssector ($tCO_2$/GWh) | 131 | 73 | 125 | 101 |
| Gemiddelde productiekost van elektriciteit (€'10/MWh) | 100,2 | 119,0 | 96,3 | 95,3 |
| HEB-aandeel in netto-elektriciteitsproductie (%) | 54,0 | 53,7 | 57,8 | 64,5 |
| Investeringskosten in elektriciteitscentrales(*) (miljard €'10) | 31 | 46 | 31 | 33 |

Noot: BKG=broeikasgas; HEB=hernieuwbare energiebronnen; BFEV= Bruto Finaal Energieverbruik; ETS=emissiehandelssysteem.

(*) duidt op het feit dat de voorgestelde waarden geen jaarcijfers weergeven, maar de totale benodigde investeringen voor de periode 2030-2050.

# Introduction

In 2011, the European Commission, in order to provide a long term perspective on climate, energy and transport, came forward with three initiatives based on a consistent analytical framework: the Roadmap for moving to a competitive low-carbon economy in 2050, the Energy Roadmap 2050, and the Roadmap to a Single European Transport Area. These publications provided fundamental elements for the transition to a low-carbon economy and a competitive, sustainable and secure energy system.

In reaction to these initiatives, the European Parliament stressed the necessity of clear climate and energy objectives for 2030, building on the Roadmaps. In March 2013, the Commission came forward with a consultative Green Paper on a 2030 framework for climate and energy policies. In May 2013, the European Council welcomed the Commission's Green Paper, recognised that significant investments in new and intelligent energy infrastructure are needed to secure the uninterrupted supply of energy at affordable prices, and that such investments are vital for jobs and sustainable growth and will help enhance competitiveness. The European Council also recognised the importance to have a well-functioning carbon market and a predictable climate and energy policy framework post-2020 which is conducive to mobilising private capital and to bringing down costs for energy investment. The European Council invited the Commission to step forward with more concrete proposals in time for the March 2014 European Council. On January 22, 2014, the Commission then unveiled its Communication accompanied by an Impact Assessment. This Impact Assessment, although highly valuable in terms of lessons to be learned as well as data and trends provided, does not allow to gain a thorough insight into national impacts of 2030 and 2050 target compatible scenarios.

This national view nonetheless is crucial, not only in order to discern the impact on our national energy system and, from there, define appropriate policies and measures, but also to prepare the national (and regional) position(s) in the run up to the climate discussions to be held in Paris at the end of this year (2015).

This national view then is exactly what this publication endeavours. This Working Paper, in combination with the October 2014 Outlook (FPB, 2014), has as main goal to evaluate the effects that the 2030 EU Framework and the 2050 long-term climate targets have on our national energy system. For this, three scenarios, all in line with the Commission's Impact Assessment, are defined:

– The first (*GHG40*) is a scenario in which the 40% and 80% greenhouse gas (GHG) emission reduction targets in respectively 2030 and 2050 are achieved at EU level. No additional energy efficiency (EE) policies compared to the *Reference scenario* and no pre-set renewable (RES) target are defined, not at European nor at national level.

– The second (*GHG40EE*) is mainly driven by explicit ambitious EE policies that ensure progress by addressing market imperfections and failures. Beyond concrete EE policies, carbon pricing incentivises fuel shifts, energy savings and non-energy related emission reductions. The 2030 as well as the 2050 GHG reduction target are achieved at EU level. Concerning RES, there is no pre-set target, but EE policies contribute to higher RES shares as they reduce total energy consumption (the denominator).

– The third scenario (*GHG40EERES30*) is driven by both explicit ambitious EE policies and a pre-set RES target of 30% at European level. Beyond concrete EE policies, carbon pricing continues to incentivise fuel shifts, energy savings and non-energy related emission reductions.

These scenarios[4] are comparable to the scenarios cited in the Commission's Impact Assessment, but, in line with the previously published *Reference* scenario for Belgium (FPB, 2014), diverge on a couple of elements, e.g. recent solar PV capacity, nuclear hypothesis, etc.

The main aim of this publication is to derive the differences (the "deltas") that exist between the already scrutinised *Reference* scenario (FPB, 2014) and the three policy scenarios, as well as to gain insight in the particularities of each of the scenarios. The former is meant to discern the need for policies and measures in order to change the current system towards a system compatible with the 2030 and 2050 pathway, the latter allows pinpointing the impact of adding an additional target (EE, RES) to the 2030 GHG target on the national energy system.

The focus of this publication will be on 2030 as the latest EU Framework was conceived and does provide guidance for that specific year. Results for the year 2050, nonetheless, will also be provided, specifically for those indicators demonstrating a rather (very) long-term impact.

The publication is subdivided into 4 chapters. Chapter 1 hinges on the applied methodology and describes (in certain cases: refreshes) the hypotheses used to fuel the model. Chapter 2, 3 and 4 are devoted to the results of the quantitative analysis and offer a description of a number of indicators simulated for the three *GHG40 scenarios*, often accompanied by their *Reference* equivalent. Chapter 2 describes the environmental impacts, chapter 3 the energy system impacts and chapter 4 distillates some economic and social impacts. For interested readers and number crunchers, the Annex provides additional data on the 3 (+1) scenarios in the form of supplementary figures and tables and gives a more extensive explanation of the so-called *enabling conditions*, conditions considered to be essential for a long-term energy system transformation and lacking in the *Reference* scenario.

4 In what follows, when reference is made to all three scenarios, the term "*GHG40 scenarios*" or *"policy scenarios"* is used.

# 1. Methodology and key assumptions

This publication aims at elaborating and analysing scenarios for Belgium that are compatible both with the stated 2030 (40%) and 2050 (between 80 and 95%) greenhouse gas emission reduction targets at EU level. The design of the target scenarios is inspired by the Impact Assessment issued by the European Commission on January 22, 2014 (COM(2014) 15 final).

The Impact Assessment (IA) of the European Commission describes seven scenarios that are all more ambitious in terms of GHG emission reductions than the *Reference* scenario, demonstrating GHG emission reductions between 35% and 45% in 2030 compared to 1990 at EU level (instead of 32.4% in the *Reference* scenario). These seven scenarios can be subdivided into two categories: scenarios achieving GHG emission reductions in line with the Roadmaps in a 2050 perspective (including so-called *enabling conditions*[5]) and others that are not (implementing so-called *Reference scenario conditions*, or not including *enabling conditions*).

In this publication, we chose to focus on only three scenarios[6]. Since the three *Reference scenario conditions* scenarios (GHG35EE®, GHG37® and GHG40®) do not add up to GHG emissions in line with the Roadmaps in a 2050 perspective, the choice was easy: neither of them were picked to be studied in this publication. Amongst the four that remained, it was decided, to not complicate the analysis and visualisations in the text, to pick three, preferably the three most interesting from the point of view of future readers of this paper. After a meeting with the Regions' and Federal State representatives, it was agreed to select the scenarios in which the EU GHG emission reductions in 2030 amount to 40% with respect to 1990 (and not the more/most ambitious one with EU GHG emission reductions of 45%). The three chosen scenarios then diverge in their specification of EE and RES targets[7].

## 1.1. Methodology

### 1.1.1. Scenario description

The present study scrutinizes this set of three EU defined scenarios. The analysis in this publication, nonetheless, focuses on Belgium, i.e. Belgium embedded in a wider, European context. The three scenarios under investigation are the *GHG40* scenario comprising a 40% EU GHG reduction, a 26.5% EU RES development in terms of gross final energy consumption and 25.1% energy savings with respect to the 2007 Baseline projections by 2030, the *GHG40EE* scenario assembling a 40% EU GHG reduction, a 26.4% EU RES development and 29.3% energy savings by 2030 and the *GHG40EERES30* scenario for a 40% EU GHG reduction, a 30% EU RES development and 30.1% energy savings by 2030[8]. In this paper, target scenarios are analysed up to the year 2050 with a specific focus on 2030.

5 An extensive description of these *enabling conditions* is provided in Annex.
6 This choice was made because of 1) time constraints, 2) the desire to present the main messages in synoptic graphs and tables.
7 Stricto sensu, EE is not implemented as a target (no *pre-set target*) but rather as the addition (on top of the *enabling conditions*) of EE policies leading to more significant energy savings by 2030 (difference of 4 to 5 percentage points with respect to the sole *GHG40* scenario on a European level).
8 A more elaborate description of the policy scenarios is provided in Annex.

In order to account for the EU context, carbon prices and values characterizing these three scenarios are taken from the analysis described in COM(2014) 15 final. They are reported in Table 1 below, next to the ones typifying the *Reference* scenario. It is worth mentioning that these carbon prices and values are based on cost-efficiency criteria, both on a Member State and sectoral (ETS and non-ETS) level. In model terms, this translates into an equalisation of the marginal abatement costs through the use of identical carbon prices in the ETS and identical carbon values in the non-ETS for all Member States as of 2025.

**Table 1 Evolution of carbon prices in the ETS and carbon values in the non-ETS, REF and policy scenarios, 2030-2050**
*€'10/t$CO_2$*

| | 2030 | 2040 | 2050 |
|---|---|---|---|
| REF | 35 | 78 | 100 |
| GHG40 | 40 | 109 | 264 |
| GHG40EE | 22 | 69 | 158 |
| GHG40EERES30 | 11 | 55 | 152 |

Source: PRIMES.

ETS prices are endogenously derived so as the cumulative ETS cap is met; the continuously decreasing number of available allowances combined with the significant allowance surplus which is only projected to decrease after 2020 suggest that the ETS price will follow only a slowly increasing trend until 2025. From 2030 on, the level of the ETS price is increasing significantly (see Table 1). This is the consequence of decreasing allowances supply following the implementation of the linear reduction factor[9] that reduces the cap substantially over time as well as the trends in international fuel prices.

### 1.1.2. Modelling approach

The evaluation of the *GHG40 scenarios* is based on a quantitative modelling approach. The focus is on the impact of both the 2030 Framework and the pathway towards 2050 on the Belgian GHG emissions, its energy system and energy costs using the PRIMES model developed by ICCS/NTUA (NTUA, 2013) and results from the GAINS model of IIASA (Höglund-Isaksonn, 2013) for non-$CO_2$ GHG.

Reducing GHG emissions and developing renewable energy sources have an impact on the evolution of the energy system, not only on the structure and quantity of energy needs but also on the technological choices for energy production and consumption. In order to evaluate such an impact, the energy model PRIMES is used. The PRIMES model covers the energy and process related $CO_2$ emissions.

Non-$CO_2$ GHG reduction possibilities are identified through the marginal abatement cost curves calculated with the GAINS model. These cost curves are defined per type of non-$CO_2$ GHG (i.e. $CH_4$, $NO_2$ and F-gases) and per country. These curves, along with $CO_2$ reduction possibilities quantified through the PRIMES model, are combined for constructing the *GHG40 scenarios*.

[9] In the *Reference* scenario, the annual linear reduction factor (LRF) was set at 1.74%. In the policy scenarios, the annual LRF is supposed to amount to 2.2% in *GHG40*, 2.1% in *GHG40EE* and 2.3% in *GHG40EERES30*.

## 1.2. Key assumptions

In order to elaborate long term energy and emission projections, it is indispensable to start with the stipulation of a number of hypotheses. The hypotheses used in this exercise relate to a number of variables, e.g. international fuel prices, economic activity and demography. They are for the most part identical to the ones already described in FPB (2014), pages 15-24. Some nevertheless diverge, they are summarised in the so-called *enabling conditions* assumed in the *GHG40 scenarios*. These conditions stem from the assumption of a strong policy commitment to deeply reduce GHG emissions in a 2050 perspective. How these policy efforts are translated into modelling material and which efforts in particular are aimed at, is documented in Annex.

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 *EU Energy, Transport and GHG emissions trends to 2050, Reference scenario 2013* (European Commission, DG ENER, DG CLIMA and DG MOVE) and in the Commission Staff Working Document COM(2014) 15 final of January 2014 accompanying the Communication *A policy framework for climate and energy in the period from 2020 up to 2030*.

### 1.2.1. Economic activity, demography and international energy prices

The assumptions adopted on economic activity, demography and international energy prices resort from the output of other models and are identical to the ones implemented in FPB (2014). They can be found in Table 2.

**Table 2 Some general indicators, 2010-2050**

| | Unit | 2010 | 2030 | 2050 | 10//30(*) | 30//50(*) |
|---|---|---|---|---|---|---|
| GDP | billion €'10 | 355 | 475 | 669 | 1.5 | 1.7 |
| Population | million | 10.8 | 12.2 | 13.1 | 0.6 | 0.4 |
| Households | million | 4.7 | 5.4 | 6.0 | 0.7 | 0.5 |
| Oil | $'10/boe | 80 | 121 | 143 | 2.1 | 0.8 |
| Natural gas | $'10/boe | 50 | 84 | 82 | 2.6 | -0.1 |
| Coal | $'10/boe | 21 | 31 | 40 | 1.9 | 1.3 |

Source: Federal Planning Bureau (2014).
(*): // stands for annual average growth rate (expressed in %).

GDP increases continuously towards 2050. Between 2010 and 2030, the annual average growth rate of GDP amounts to 1.5%, between 2030 and 2050 it further accelerates to 1.7%.

Population and the number of households also tend to rise. Between 2010 and 2050, the total number of Belgian inhabitants increases by approximately 2.3 million. In 2050, this leads to a total Belgian population of 13.1 million persons living in Belgium. Combined with a decreasing average size of a Belgian household, the population increase even leads to a relatively bigger increase in the number of households. By 2050, approximately 6 million households reside in Belgium, compared to 4.7 million in 2010.

The international energy prices are based on the stochastic PROMETHEUS world energy market model. Oil prices are expected to reach 121$ and 143$ (expressed in 2010 prices) per barrel of oil in 2030 and 2050 respectively. Gas prices become more and more decoupled from oil prices, mainly because of the large amount of undiscovered (conventional and unconventional) resources amongst which shale gas, while coal prices remain overall lower, although they are mounting gradually. These price assumptions have important consequences for the height of the carbon value required to meet the GHG emission reduction targets.

### 1.2.2. Policy context

For the exact policy context, the reader once again is referred to the FPB (2014) publication. It might nonetheless be useful to remind the policy adopted on the nuclear phase-out, specifically for the time period considered (up to 2030).

For nuclear energy, the legal policy framework as of 2013[10] is assumed. This law encompasses a.o. the confirmation of the phase-out calendar of nuclear power plants Doel 1 and 2 in 2015 next to the operational lifetime extension of Tihange 1 with another 10 years. The reason for this choice is that it is the currently ruling legal basis. The authors are nonetheless aware of the recent announcements of the current government to prolong the operational lifetime of both Doel 1 and 2, but since these do not, for the moment being, have an official (legitimate) character, they are not withheld for this analysis. Hence, all Belgian nuclear power generating facilities (about 6,000 MW) will be shut down between 2015 and 2025.

Next to that, it is also instructive to sketch the underlying conditions necessitating different policies and measures in the *GHG40 scenarios*. What makes the *GHG40 scenarios* different from the *Reference* scenario, is that the former include *enabling conditions*. These enabling conditions are modelled by altering modelling parameters with respect to those included in the *Reference* scenario. The enabling conditions are in fact presuppositions that act independently of carbon prices/values or economic or regulatory incentives for renewables and energy efficiency. They are extensively described in the Impact Assessment (pp.37-39 and Annex 7.2) and can be found pro memoria in Annex.

### 1.2.3. Some general assumptions

– The simulations are based on the last available statistics provided by Eurostat (year 2010) at the moment of modelling. Exception is made for solar PV for which the most recent evolution (2011, 2012) was taken into account.

– This also goes for the Belgian power generating facilities: the starting situation of the Belgian park is the one reported in 2010, meaning that the recent(ly announced) closures (because of economic motives) are not taken up in this outlook.

– Tax rates are kept constant in real terms.

– The PRIMES model is based on individual decision making of agents demanding or supplying energy and on price-driven interactions in markets. The modelling approach is not taking the perspective of a social planner and does not follow an overall least cost optimization of the entire energy system in the long term. Therefore, social discount rates play no role in determining model solutions. On the other hand discount rates pertaining to individual agents play an important role in their

10 Moniteur Belge/Belgisch Staatsblad (2013), *Wet houdende wijziging van de wet van 31 januari 2003 houdende de geleidelijke uitstap uit kernenergie voor industriële elektriciteitsproductie en houdende wijziging van de wet van 11 april 2003 betreffende de voorzieningen aangelegd voor de ontmanteling van de kerncentrales en voor het beheer van splijtstoffen bestraald in deze kerncentrales*, December 24.

decision making. Agents' economic decisions are usually based on the concept of cost of capital, which is, depending on the sector, either weighted average cost of capital (for larger firms) or subjective discount rate (for individuals or smaller firms). In both cases, the rate used to discount future costs and revenues involves a risk premium which reflects business practices, various risk factors or even the perceived cost of lending. The discount rate for individuals also reflects an element of risk averseness.

The discount rates vary across sectors. In the PRIMES modelling, the discount rates range from 8% (in real terms) applicable to public transport companies or regulated investments up to 17.5% applicable to individuals. Additional risk premium rates are applied for some new technologies at their early stages of development impacting on perceived costs of technologies. More specifically, for large power and steam generation companies the cost of capital is 9%. In industry, services and agriculture the discount rate amounts to 12%. Households have an even higher discount rate of 17.5%. For transport, the discount rate depends on the type of operator. Private passenger transport investments (e.g. for cars) are based on a discount rate of 17.5%, while for trucks and inland navigation ships, which are considered as investment goods the rate is 12%. Public transport investment is simulated with an assumed discount rate of 8% for the whole projection period reflecting the acceptance of longer pay-back periods than those required in industry or private households. All these rates are in real terms, i.e. after deducting inflation.

The decision making environment of businesses and households on energy consumption is expected to change because of the implementation of the Energy Efficiency directive (EED). The EED will bring about higher market penetration of Energy Service Companies (ESCOs) or similar institutions as well as the reduction of associated risks as perceived by potential clients through quality controls and certifications. This will entail lower perceived discount rates. The implementation of the EED and the widespread penetration of ESCOs is mirrored by the reduction of discount rates by up to 2 percentage points in services and up to 5.5 percentage points in households. Discount rates are assumed to decline linearly from their standard levels in 2010 to reach the policy driven values by 2020 and they remain at these levels throughout the remaining projection period. Thus the discount rates for households are reduced in the context of the Reference scenario to 14.75% in 2015 and 12% from 2020 onwards throughout the entire projection period. For services the discount rate was progressively decreased to 11% in 2015 and 10% from 2020 onwards.

– Degree days, reflecting climate conditions, are kept constant at the 2005 level, which is higher than the long term average without assuming any trend towards further warming. Such an approach facilitates comparison of statistics with the projection figures that are based on climate conditions at the beginning of this century. This simplification can also be justified by consistency reasons. A selective inclusion of global warming trends only for some modelling parts where this would be feasible (heating degree days) and not for others (e.g. impacts on agriculture) could provoke misleading results.

– All monetary values are expressed in constant prices of 2010 (without inflation). The dollar exchange rate for current money changes over time; it starts at the value of 1.39$/€ in 2009 and is assumed to decrease to 1.3 $/€ by 2012, at which level it is assumed to remain for the remaining period.

# 2. Environmental impacts

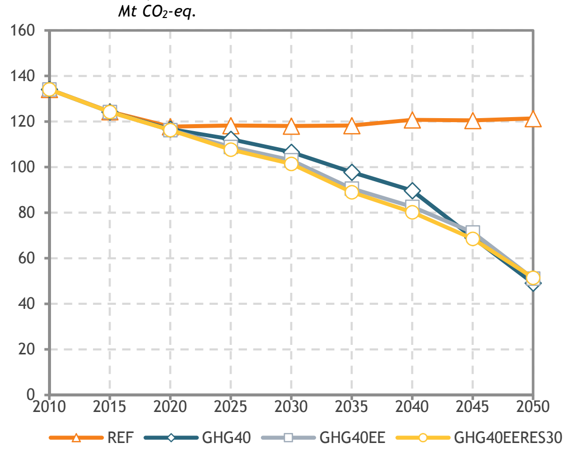
This and the next two chapters are devoted to the analysis of the impacts of the three *GHG40 scenarios* over the period 2010-2050. The assessment encompasses the environmental impacts (chapter 2), the energy system impacts (chapter 3) and the economic and social impacts (chapter 4). The focus is put on the year 2030 but the longer term effects of the policy choices for 2030 and enabling policies in line with the 2050 Roadmaps are also described.

The environmental impacts are split into the overall effect on greenhouse gas emissions, the differentiated effect in the ETS and non-ETS sectors and according to the type of pollutants and, finally, the sectoral contribution of energy-related $CO_2$ emission reductions.

## 2.1. Total GHG emission reductions

Graph 1 illustrates the evolution of total GHG emissions in the different scenarios. The *REF* and *GHG40 scenarios* show divergent GHG emission paths (only) from 2020 onwards as the same drivers influence the evolution of GHG emissions between 2010 and 2020 in each scenario (for instance the binding GHG and RES targets in 2020).

**Graph 1 Total GHG emissions, REF and policy scenarios, 2010-2050**
*Mt $CO_2$-eq.*




Source: PRIMES, E3M-Lab.

After 2020, GHG emissions continue to decrease in the three policy scenarios whereas they almost stabilize at 2020 level in *REF*.

In 2030, GHG emission reductions range from 27% (*GHG40*) to about 30% (*GHG40EE* and *GHG40EERES30*) compared to 1990.

In 2050, GHG emission reductions are comparable in the three policy scenarios: 65-66% with respect to 1990.

These percentages of GHG emission reductions are below the EU target of 40% in 2030 and 80% in 2050, indicating that Belgium belongs to the group of EU countries where it is comparatively more costly to achieve GHG emission reductions.

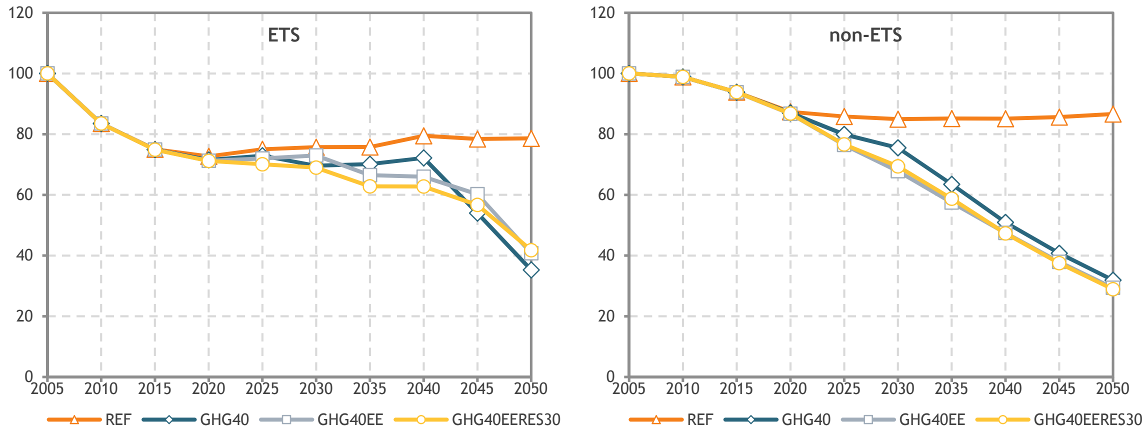
## 2.2. ETS vs. non-ETS emission reductions

Between 2005 and 2030, the three policy scenarios show rather similar GHG reductions in the ETS and non-ETS sectors: from 27 to 31% in the former and from 25 to 32% in the latter. Nevertheless, the additional emission reductions in 2030 compared to *REF* are more significant in the non-ETS than in the ETS sectors, and all the more so in the two policy scenarios characterized by ambitious additional energy efficiency measures (*GHG40EE* and *GHG40EERES30*). The additional reductions range from 3 to 7 percentage points in the ETS sectors while they lie between 9 and 17 percentage points in the non-ETS sectors.

The impact in the ETS sectors is relatively limited because the Reference already implements the continuation of the ETS linear reduction factor (equal to 1.74%) after 2020 according to the ETS Directive: emissions in the ETS are mainly driven by increasing carbon prices. The same mechanism applies in the policy scenarios though it involves a tightening of the linear reduction factor[11] (e.g. 2.2% in the *GHG40* scenario).

On the other hand, the impact in the non-ETS sectors is more significant because emissions are determined by carbon values and, in some policy scenarios, additional energy efficiency measures whereas no such mechanisms are implemented in *REF*.

**Graph 2 GHG emissions in the ETS and non-ETS sectors, REF and policy scenarios, 2005-2050**
*Index 100 = 2005*




Source: PRIMES, E3M-Lab.

The above impacts for Belgium are sometimes similar, sometimes different from those reported for the EU as a whole (EC, 2014). Among the similarities, we find the lowest additional GHG reductions in the ETS (3 percentage points) in the *GHG40EE* scenario where the implementation of ambitious energy efficiency measures brings additional pressure on the GHG emissions in the non-ETS and therefore reduces the required reduction effort in the ETS. These further reductions in the non-ETS also characterize the *GHG40EERES30* scenario but they are coupled to extra reductions in the ETS (and more specifically in the power sector) due to the implementation of a binding RES target.

Among the differences, the major one concerns the allocation of the 2030 GHG reduction target between the ETS and non-ETS sectors in the *GHG40* scenario. While the additional emission reductions in the non-ETS and ETS compared to *REF* are similar at EU level (13 and 11 percentage points respectively), they are much higher in the non-ETS at national (Belgian) level (9 percentage points against 6 percentage

11 The change in the linear reduction factor is required in order to achieve emission reductions in the ETS of 43% by 2030 compared to 2005. This cap on ETS emissions in 2030 results from the equalisation of marginal abatement cost of GHG emissions across the economy in order to meet the 40% GHG reduction target at EU level in 2030. The linear reduction factor depends on the policy scenario (see section 5.4.1 of EC, 2014).

points in the ETS). This divergence of impact results primarily from the narrow room for manoeuvre within the Belgian ETS and notably in the power sector where the fuel mix is already low carbon intensive in the Reference scenario (almost 50% natural gas and 50% renewables).

In the longer term (2050), GHG emissions continue to drop both in the ETS and non-ETS. In the *GHG40* scenario where GHG emissions are mainly driven by carbon prices in the ETS and carbon values in the non-ETS, GHG emission reductions are comparable in both sectors: 65 and 68% compared to 2005. By contrast, GHG emission reductions are higher in the non-ETS than in the ETS in the other two policy scenarios (*GHG40EE* and *GHG40EERES30*): 71% versus 58% compared to 2005. These results are coherent with the findings of the EC's impact assessment (EC, 2014): "*achieving emission reductions by focusing relatively more on energy efficiency policies […] reduces emissions in the non-ETS more and thus reduces the reductions needed in the ETS*".

Finally, it is worth noting that the assumption of equalisation of marginal GHG abatement cost across sectors and Member States (i.e. carbon prices and carbon values are set identical in the ETS and non-ETS and in every Member State) leads to lower GHG emission reductions in Belgium than in the EU28. In 2030, Belgium reduces its GHG emissions in the non-ETS by 24.5%[12] compared to 2005, against 30.5% for the EU as a whole. This conclusion holds when ambitious additional energy efficiency measures are included in the policy scenarios but the gap between Belgium and EU28 shrinks. For instance, in the *GHG40EE* scenario, GHG emission reductions of 32.2% are recorded in the Belgian non-ETS compared to 2005, against 34.7% for the EU as a whole.

## 2.3. Sectoral GHG emission reductions

First, Table 3 illustrates the development of GHG emissions by type of pollutants: energy related $CO_2$, non-energy related $CO_2$ and non-$CO_2$ (i.e. $CH_4$, $N_2O$ and F gases).

In 2030, the policy scenarios lead to decreasing energy related $CO_2$ and non-$CO_2$ emissions compared to both 2010 and the Reference scenario. On the other hand, non-energy related $CO_2$ emissions remain roughly stable in the period 2010-2030 and even grow by some 20% in the policy scenarios involving ambitious energy efficiency measures. The major part of non-energy related $CO_2$ emissions belongs to the ETS (around 90%) so that their evolution is driven notably by the carbon prices in the EU ETS. In 2030, the projected carbon prices are of the same order of magnitude in *REF* and *GHG40* (35 and 40 €/t $CO_2$ respectively) whereas they are much lower in *GHG40EE* and *GHG40EERES30* (22 and 11 €/t $CO_2$ respectively).

Non-$CO_2$ emissions decline more rapidly in the policy scenarios than in the Reference: emission reductions range from 28 to 34% in 2030 compared to 2010, against 14% in *REF*. The policy scenarios with ambitious energy efficiency policies record less reductions of non-$CO_2$ emissions compared to the *GHG40* scenario because these policies lead to more significant declines in energy related $CO_2$ emissions (according to the principle of communicating vessels). Indeed, between 2010 and 2030, the latter are reduced by 26% and 29% in *GHG40EE* and *GHG40EERES30* respectively compared to 20% in the *GHG40* scenario (and 14% in *REF*).

[12] It is also 10 percentage points above the current Belgian non-ETS objective for the year 2020 (i.e. 15%).

**Table 3 GHG emissions by type of pollutant, REF and policy scenarios, 2010, 2030 and 2050**
*Mt $CO_2$-eq.*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Energy related $CO_2$ | 105.4 | 90.5 | 84.5 | 78.2 | 74.9 | 92.2 | 41.1 | 42.9 | 38.9 |
| Non-energy related $CO_2$ | 11.8 | 11.8 | 11.3 | 13.8 | 14.4 | 11.8 | 0.9 | 0.9 | 5.3 |
| Non-$CO_2$ | 16.9 | 14.6 | 10.8 | 11.1 | 12.1 | 14.6 | 7.1 | 7.2 | 7.2 |
| Total GHG | 134.1 | 116.9 | 106.5 | 103.0 | 101.4 | 118.6 | 49.1 | 51.1 | 51.4 |

Source: PRIMES, E3M-Lab.

In a 2050 perspective, all categories of pollutants drop significantly in the policy scenarios compared to 2010 levels. The reductions in energy related $CO_2$ emissions range from 59 to 63%, the reduction interval is 55-92% for non-energy related $CO_2$ emissions and non-$CO_2$ emissions decrease by some 58% in all policy scenarios. The big reductions in non-energy related $CO_2$ emissions, specifically in *GHG40* and *GHG40EE*, concern the industrial process emissions which are to a large extent captured and stored at the end of the projection period when the carbon price is high enough to make this abatement option economically interesting.

Special attention is then devoted to the contribution of each sector in the reductions of energy related $CO_2$ emissions. As shown in Table 4, six sectors are identified: industry, the residential sector, the tertiary sector, transport, the power sector and the energy branch (including energy industries such as refineries and coke production).

**Table 4 Sectoral breakdown of energy related $CO_2$ emissions, REF and policy scenarios, 2010, 2030 and 2050**
*Mt $CO_2$-eq.*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Industry | 19.5 | 17.2 | 16.2 | 15.0 | 13.2 | 18.4 | 9.4 | 8.5 | 7.0 |
| Residential | 18.8 | 16.4 | 15.0 | 13.3 | 13.6 | 15.2 | 4.8 | 3.3 | 3.4 |
| Tertiary | 10.1 | 8.0 | 6.9 | 4.6 | 4.8 | 7.8 | 2.1 | 1.5 | 1.5 |
| Transport | 29.9 | 27.3 | 26.8 | 24.5 | 24.5 | 30.1 | 12.8 | 12.6 | 12.7 |
| Power generation | 20.3 | 15.8 | 14.0 | 15.3 | 13.3 | 14.5 | 9.2 | 13.4 | 10.7 |
| Energy branch | 6.9 | 5.8 | 5.6 | 5.4 | 5.4 | 6.1 | 2.8 | 3.6 | 3.6 |

Source: PRIMES, E3M-Lab.

By the year 2030, the biggest (resp. lowest) reductions, in relative terms, are experienced by the tertiary sector (resp. transport). They range from 31 to 55% (resp. from 10 to 18%) in the policy scenarios compared to 2010. Not surprisingly, the upper values of both intervals correspond to the policy scenarios involving ambitious energy efficiency measures (*GHG40EE* and *GHG40EERES30*).

$CO_2$ emission reductions in the power sector range from 25 to 35% in the policy scenarios. Emissions reduce the most in the scenario with a RES target (*GHG40EERES30*) as this induces a higher share of RES in electricity generation (see infra). They reduce the least in the scenario with striving energy efficiency policies (*GHG40EE*) because these policies favour the use of electricity and lead to more gas-based power generation compared to the other policy scenarios.

Industry and the residential sector show $CO_2$ emission reductions of approximately 20% in the *GHG40* scenario. Emission reductions of industry jump to 23% and 32% respectively in the *GHG40EE* and

*GHG40EERES30* scenarios. For the residential sector, the corresponding figures are 29% and 27%. Finally, the energy branch displays similar emission reductions around 20% in the three policy scenarios.

In the *GHG40 scenarios*, the additional emission reductions compared to the Reference are almost equally distributed among sectors. Three exceptions, however, to this general observation: the energy branch where the extra emission reductions are systematically lower than in the other sectors; the transport sector in *GHG40* scenario where the sole action of the carbon value has a more limited impact on the emissions than in other sectors; and the power sector in the *GHG40EE* scenario which displays the smallest additional reduction efforts among sectors as it records a comparatively higher level of electricity generation from natural gas.

Looking forward to 2050, $CO_2$ emission reductions rise significantly in all final and transformation sectors. The residential and tertiary sectors are number one in the race towards achieving a low-carbon economy in 2050 with emission reductions ranging from 75 to 85% compared to 2010. They are followed by industry, transport and the energy branch where energy related $CO_2$ emissions are projected to be 50 to 65% below the 2010 level. Emission reductions in the power sector are the lowest and vary widely according to the policy scenario: 55% in the *GHG40* scenario, 47% in *GHG40EERES30* and 34% in *GHG40EE*.

Compared to *REF* in 2050, emissions reductions in the power sector are also less outspoken than in the final demand sectors and energy branch. Given the already low carbon intensive energy mix of power generation in *REF* (based on natural gas and RES), additional emission reduction options are rather slim.

The main conclusion of this chapter is that a cost-effective allocation among Member States of the binding EU target of 40% domestic reduction in GHG emissions by 2030 compared to 1990, translates into total GHG emission reductions of some 30% for Belgium. Moreover, GHG emission reductions between 2005 and 2030 are comparable in the ETS and non-ETS sectors (around 30%). All sectors contribute to GHG emission reductions, with the residential and tertiary sectors decreasing the most (from 31 to 55% in 2030 compared to 2010 levels) and transport falling the least (between 10 and 18%).

Looking forward to 2050, Belgium's contribution to GHG emission reductions in line with the EU Roadmaps (i.e. 80% abatement at EU level compared to 1990) is a decrease in emissions of some 65%. Focusing relatively more on energy efficiency cuts emissions more in the non-ETS and therefore moderates the reduction effort needed in the ETS (70% in the former vs. 60% in the latter). The residential and tertiary sectors remain number one in the race towards achieving a low-carbon economy, whereas the power sector records the smallest emission decreases in the period 2030-2050.

# 3. Energy system impacts

The energy system impacts are scrutinized through five sets of indicators: final energy demand, power generation, RES development, primary energy consumption and energy imports.

## 3.1. Final energy demand

Graph 3 illustrates the projected evolution of total final energy demand in the three policy scenarios against the development in the Reference on the one hand, and the indicative energy efficiency target of Belgium in 2020 on the other hand.

Total final energy demand declines steadily in all policy scenarios in the period 2020-2050. However, the reduction is more significant in scenarios with ambitious additional energy efficiency measures while the tightening of the RES target in 2030 has almost no impact on the level of total final energy demand[13]. For that reason, the analysis below will focus on the following two policy scenarios: *GHG40* and *GHG40EE*.

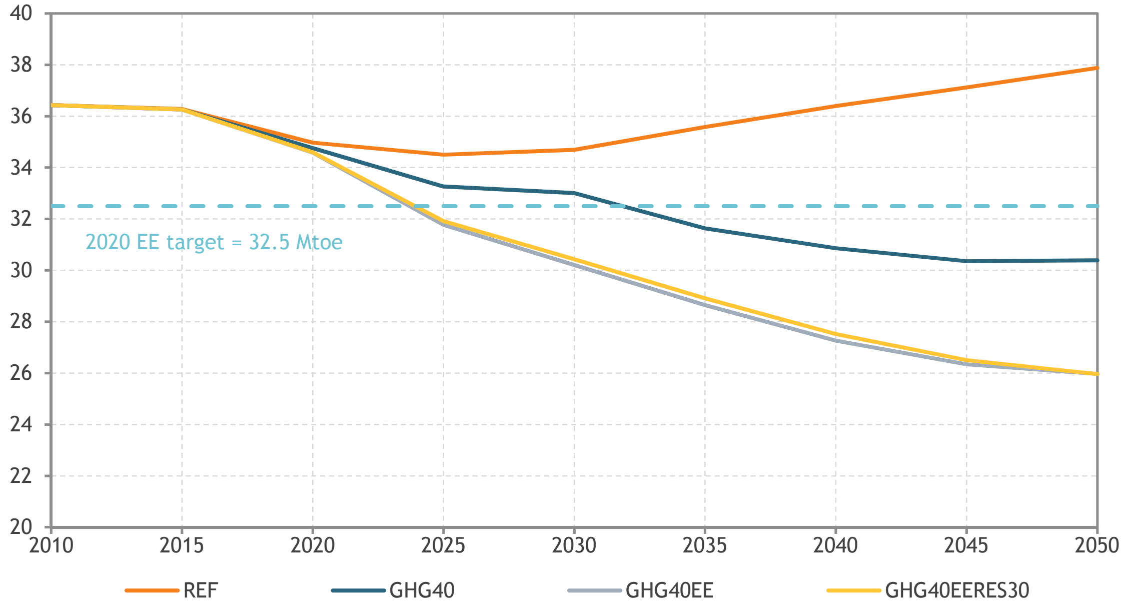
By the year 2030, final energy demand is reduced by 9 and 17% respectively in the *GHG40* and *GHG40EE* scenarios, compared to the level in 2010. In absolute terms, the figures are respectively 33.0 Mtoe and 30.2 Mtoe in 2030, against 36.4 Mtoe in 2010.

In comparison with *REF*, energy savings ranging from 1.7 to 4.5 Mtoe are achieved in the policy scenarios.

According to the requirements of the Energy Efficiency Directive 2012/27/EU (EED), Belgium notified an indicative national energy efficiency target in June 2013 (EC, 2013). In terms of final energy demand, the target was set at 32.5 Mtoe in 2020. Graph 3 demonstrates that current policies and measures and the binding GHG and RES targets in 2020 would not allow achieving the indicative target (see also FPB, 2014). Graph 3 shows however that the EE objective would be met some 10 years later if a sole 40% GHG reduction target is set for the EU as a whole in 2030 (*GHG40* scenario) and much earlier if the GHG target is coupled with ambitious EE policies.

13 More specifically, the development of total final energy demand is almost identical in *GHG40EE* and *GHG40EERES30*.

**Graph 3 Total final energy demand, REF and policy scenarios, 2010-2050**
*Mtoe*




Source: PRIMES.

By the year 2050, reductions in final energy demand intensify: 17% (resp. 29%) in 2050 compared to 2010 in the *GHG40* (resp. *GHG40EE*) scenario. The evolution between 2010 and 2050 translates into an annual average growth rate of the Belgian final energy demand of -0.5% (resp. -0.8%) in the *GHG40* (resp. *GHG40EE*) scenario, compared to +0.1% in *REF*. In absolute terms, total final energy demand is projected to reach 30.4 Mtoe (resp. 26.0 Mtoe) in 2050.

In comparison with *REF*, energy savings ranging from 7.5 to 11.9 Mtoe are achieved in the policy scenarios.

The scenarios simulating the 2030 Climate and Energy Framework and the 2050 Roadmaps exhibit differences in terms of energy mix in total final energy demand (see Table 5). The changes in the relative shares of energy forms are particularly significant near the end of the projection period.

**Table 5 Energy mix in total final energy demand, REF and policy scenarios, 2010, 2030 and 2050**
*%*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Solids | 3.2 | 2.5 | 2.5 | 2.5 | 2.6 | 2.1 | 1.2 | 0.8 | 0.9 |
| Oil | 41.0 | 36.9 | 37.0 | 36.0 | 36.0 | 35.1 | 14.8 | 16.2 | 16.3 |
| Gas | 30.4 | 29.1 | 28.2 | 26.8 | 24.9 | 28.6 | 18.9 | 19.5 | 16.9 |
| Electricity | 19.7 | 21.4 | 21.8 | 24.4 | 24.2 | 24.1 | 33.1 | 34.0 | 33.6 |
| Heat | 1.8 | 2.7 | 2.8 | 3.0 | 3.2 | 2.6 | 2.4 | 2.9 | 3.0 |
| RES | 3.9 | 7.3 | 7.6 | 7.2 | 9.0 | 7.4 | 24.9 | 21.9 | 24.8 |
| Others | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 4.8 | 4.6 | 4.6 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Source: PRIMES.
Note: 'Others' encompasses ethanol, methanol and hydrogen.

Between 2010 and 2030, the changes in the energy mix are comparable in *REF* and *GHG40*, i.e. a decrease in the shares of fossil fuels (coal, oil, and natural gas) and an increase in the shares of electricity, distributed heat and RES. In other words, the carbon price in the non-ETS, which differentiates the *GHG40* scenario from *REF*, leads to more energy savings rather than to fuel switching.

By contrast, scenarios with ambitious EE and RES policies typically result in a higher share of electricity (24% against slightly more than 21% in *REF* and *GHG40*) at the expense of oil and natural gas. Not surprisingly, the *GHG40EERES30* also shows a higher contribution of RES (biomass, geothermal and solar thermal[14]) in total final energy demand.

In 2050, the policy scenarios demonstrate major differences in the energy mix compared to 2010 and the Reference. For instance, the share of fossil fuels (coal, oil and gas) drops significantly at below 36% compared to almost 75% in 2010; fossil fuels are chiefly replaced by electricity and RES but new energy forms such as hydrogen also come into play. Among fossil fuels, oil products are particularly squeezed. Mainly used for transport, their share shrinks roughly by a factor 2 in comparison to *REF*, reflecting the development of transport electrification and biofuels (see infra). The share of solid fuels (mostly coal and coke consumed in the iron and steel industry) is also divided by 2 although their contribution to total final energy demand is much lower. Finally, the share of natural gas - the least carbon intensive fossil fuel - is also decreasing but to a lesser extent: it fluctuates between 17 and 20% in the policy scenarios against 29% in *REF*.

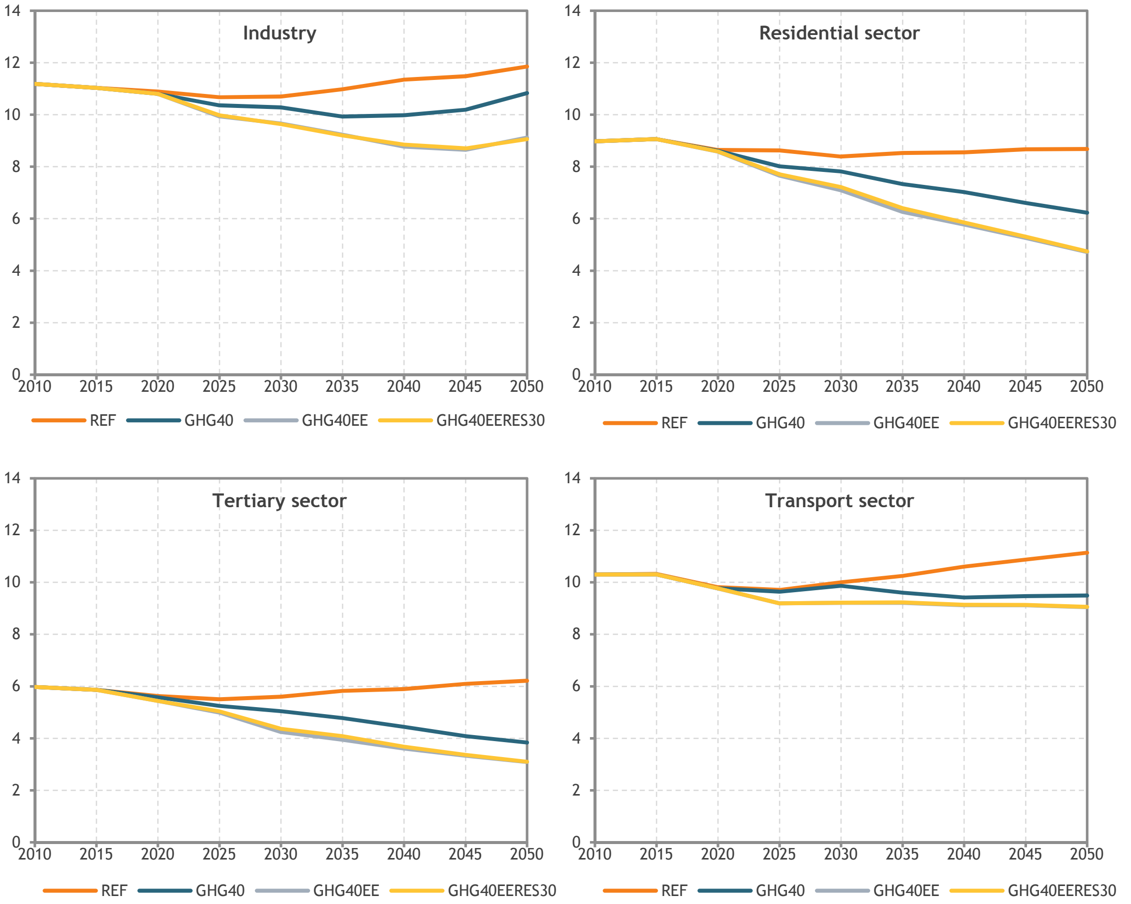
The winners in the move towards a low-carbon economy are electricity and renewables. Also, a newcomer appears in the energy mix: hydrogen. In 2050, the share of electricity jumps from 24% in *REF* to 33-34% in the policy scenarios. For renewables, the jump is even steeper: from 7.4% in *REF* to 22-25% in the policy scenarios. Biomass accounts for the lion share of the renewable energy sources with some 95% of total final RES consumption. The increasing carbon prices and carbon values make hydrogen a cost-efficient final energy form in the long term. Taking off after 2040, hydrogen becomes a substitute to conventional energy sources in all final demand sectors. In 2050, the consumption of hydrogen is allocated as follows: 32% in industry, 18% for transport and 50% in the residential and tertiary sectors.

In the transport sector, hydrogen is used in fuel cell cars or in internal combustion engines. In other final demand sectors, hydrogen feeds CHP installations (large or small scale depending on the sector). As regards the way hydrogen is produced, the technology selected in all policy scenarios is water electrolysis from (grid) electricity.

Next to the changes in energy mix, the evolution of final energy demand is also examined from a sectoral angle. Graph 4 depicts this evolution in the four final demand sectors. In order to visualize, at a glance, the relative energy savings in the different sectors with respect to both 2010 and the Reference, the same scale is used on the y-axis. Again, as the sectoral final energy demand follows the same pattern in *GHG40EE* and *GHG40RES30*, the analysis below will stick to the former.

[14] Solar PV is accounted for in the power generation sector.

**Graph 4 Final energy demand, by sector, REF and policy scenarios, 2010-2050**
*Mtoe*




Source: PRIMES.

By the year 2030, the *residential and tertiary* sectors experience the strongest reductions in final energy demand in all policy scenarios. In the scenario mainly driven by carbon prices and carbon values (*GHG40*), energy consumption falls by 13% (resp. 16%) in the residential (resp. tertiary) sector compared to the 2010 level. In the policy scenario where ambitious energy efficiency policies are implemented on top of the price signals (*GHG40EE*), energy demand decreases even further by 21% (resp. 29%) in the residential (resp. tertiary) sector. The absolute figures for the final energy demand in 2030 are: 7.8 Mtoe (resp. 5.0 Mtoe) in the *GHG40* scenario and 7.1 Mtoe (resp. 4.2 Mtoe) in the *GHG40EE* scenario, against 9.0 Mtoe (resp. 6.0 Mtoe) in 2010.

In comparison with *REF*, energy savings equal 0.6 Mtoe and 1.4 Mtoe according to the scenario. The absolute savings are comparable in both sectors. In the *GHG40* scenario, these energy savings come primarily from heating uses (better insulation, higher boiler efficiency, etc.), whereas the scenarios with ambitious EE policies also show additional (though limited) energy efficiency improvement of electric appliances compared to *REF*. On the other hand, there are no significant differences in energy mix among the various scenarios.

In the longer term (2050), the decreasing trend of the final energy demand continues in both sectors: energy consumption falls by more than 30% in the *GHG40* scenario and by almost 50% in the *GHG40EE* scenarios. The absolute end levels are 6.2 Mtoe and 4.7 Mtoe respectively in the residential sector, and

3.8 Mtoe and 3.1 Mtoe in the tertiary sector. Compared to *REF*, energy savings of between 2.4 and 4.0 Mtoe are realised in the former sector and between 2.4 and 3.1 Mtoe in the latter. Again, energy savings concentrate on heating uses. Concerning the energy mix, profound modifications are to be noticed. For instance, in the residential sector, the share of fossil fuel drops (to about 30% versus 78% in 2010) whereas the share of carbon-free energy forms takes off: 40% for electricity (compared to 19% in 2010), 15% for biomass (compared to 3% in 2010), 10% for hydrogen and 5% for solar thermal and geothermal heat.

As regards *industry*, the final energy demand follows a U-curve in the policy scenarios: it is first decreasing steadily up until 2035 (*GHG40*) or 2045 (*GHG40EE*), then increasing moderately to 2050.

In 2030, the final energy demand of industry is respectively 8% and 14% below the 2010 level in the *GHG40* and *GHG40EE* scenarios. In absolute terms, it amounts to 10.3 Mtoe and 9.7 Mtoe respectively, compared to 11.2 Mtoe in 2010. Energy savings with respect to *REF* total 0.4 Mtoe and 1.0 Mtoe respectively. These savings come primarily from technological improvements in industrial processes, they do not result from a decrease in value added (by assumption) nor from a change in the energy mix. The energy intensity of industry (i.e. the energy used per unit of value added) decreases by 4% and 10% respectively, compared to *REF*.

In a 2050 perspective, the evolution of final energy demand diverges in the policy scenarios. In the *GHG40* scenario, energy consumption by industry recovers to the level of 2020 (i.e. 10.8 Mtoe) but is still 3% below the 2010 level. Nevertheless, energy savings compared to *REF* are 2.5 times those projected in 2030 (1.0 Mtoe vs. 0.4 Mtoe). Furthermore, industry experiences significant transformations in its energy mix: electricity, biomass and hydrogen cover more than 60% of the energy needs, against 40% in *REF*. In a nutshell, technological improvements and fuel switching driven only by increasing carbon prices and carbon values do not suffice to compensate for the growth in value added (and production) of industry. In the *GHG40EE* scenario, ambitious additional EE measures allow (practically) safeguarding the decreasing trend in the long term. Final energy demand is projected to be 18% below the 2010 level (9.1 Mtoe). This figure translates into energy savings of some 2.7 Mtoe compared to *REF*. Extra EE improvement constitutes the major difference between the two policy scenarios: the changes in energy mix are very similar.

Finally, the *transport* sector shows the smallest reductions in energy demand over the projection period as well as the tiniest energy savings compared to *REF*. Different factors influence the evolution of energy consumption: the expected development of transport activity (for both passengers and goods) and modal shift, technological improvements, the electrification of the transport fleet and fuel prices. The first two factors (transport activity and modal choice) are first set exogenously at the Reference level but can afterwards adapt to changes in relative fuel prices (for instance through the introduction of carbon values). However, due to relatively low price elasticities, transport activity and modal choice are not that much modified in the policy scenarios. Moreover, the ambitious additional EE policies are more targeted to technological improvements and new transport fuels than to significant changes in mobility patterns. This restricted scope of action explains to a large extent the more modest effect of the policy scenarios on the final energy demand of transport than in the other final demand sectors.

By the year 2030, final energy demand is reduced by 4% and 11% respectively in the *GHG40* and *GHG40EE* scenarios compared to the level in 2010 (i.e. 9.9 Mtoe and 9.2 Mtoe respectively in 2030 versus 10.3 Mtoe in 2010). Energy savings compared to *REF* amounts to 0.1 Mtoe and 0.8 Mtoe respectively.

In addition to energy savings, the policy scenarios also lead to slight changes in the energy mix in 2030 (see Table 6), especially in the scenarios with ambitious EE and RES policies where the share of oil is (further) reduced by about 3 percentage points (with respect to REF) at the main benefit of natural gas (CNG) and electricity.

**Table 6 Energy mix in final energy demand for transport, REF and policy scenarios, 2010, 2030 and 2050**
%

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Oil | 95.1 | 88.9 | 88.6 | 85.3 | 85.3 | 87.4 | 42.5 | 42.7 | 42.8 |
| Biofuels | 3.5 | 7.8 | 7.7 | 7.3 | 7.3 | 7.6 | 39.2 | 35.8 | 35.9 |
| Natural gas | 0.0 | 0.2 | 0.2 | 2.1 | 2.1 | 0.9 | 2.4 | 4.3 | 4.3 |
| Ethanol/methanol | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| $H_2$ | 0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.5 | 0.9 | 1.4 | 1.3 |
| Electricity | 1.4 | 2.9 | 3.3 | 4.9 | 4.9 | 3.4 | 15.0 | 15.7 | 15.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Source: PRIMES.

By 2050, the modifications of the energy mix intensify in the policy scenarios whereas the level of energy demand stabilizes at 9.5 Mtoe and 9.0 Mtoe respectively in the *GHG40* and *GHG40EE* scenarios. These figures translate into energy saving of 1.7 Mtoe and 2.1 Mtoe respectively compared to *REF*. The most significant impact of the policy scenarios is the substantial increase in the share of biofuels and electricity. The share of biofuels (resp. electricity) ranges from 36 to 39% (resp. from 15 to 16%) according to the scenario. This trend is an outcome of the enabling conditions characterising the policy scenarios and including for instance accelerated innovation in biofuels and development of electric batteries for vehicles and recharging infrastructure (see Annex).

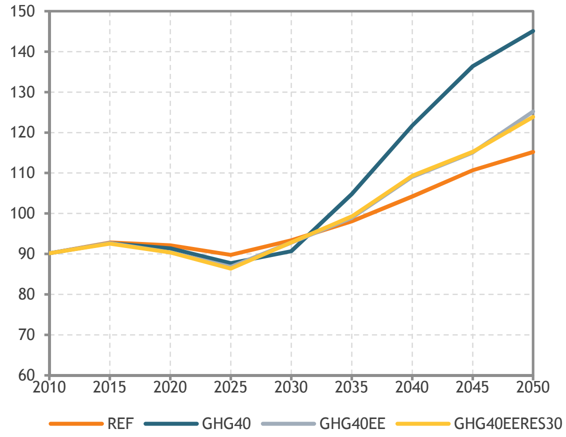
The main conclusion of this section is that final energy demand declines steadily in all policy scenarios. The drop is more significant in scenarios with ambitious additional energy efficiency measures while a higher RES share in 2030 has almost no influence on the trend. In 2030 (resp. 2050), final energy demand is 9 to 17% (resp. 17 to 29%) below the level in 2010. The changes in the energy mix are particularly significant near the end of the projection period. The share of fossil fuels (coal, oil and natural gas) drops significantly at below 36% (against nearly 75% in 2010); fossil fuels are chiefly replaced by electricity and RES, and by new energy forms such as hydrogen from 2040 on. The residential and tertiary sectors experience the strongest reductions in final energy demand as a majority of energy efficiency measures aim at improving the energy performance of buildings. On the other hand, the transport sector shows the smallest decreases.

## 3.2. Power generation

Turning to power generation, it is important to distinguish three components: demand, (net) imports and domestic production. In what follows, the impact of installing a climate (and energy) target on these different elements is scrutinised and described with respect to the evolution noted in the *Reference* scenario.

### 3.2.1. Electricity demand

**Graph 5 Called-up electrical power, REF and policy scenarios, 2010-2050**
*TWh*




Source: PRIMES.

First element to crunch is the electricity demand. The demand for electricity is reflected in an indicator called *called-up electrical power*. This indicator represents the sum of the electricity consumption of industry, transport, residential and tertiary sector, the energy branch as well as the losses on the transmission and distribution grids.

Up until 2030, a similar evolution in all scenarios (including *REF*) can be noticed: demand is relatively stable and oscillates between 87 and 93 TWh. All *GHG40 scenarios* display a very humble annual average growth rate: between 0.0% and 0.1% in the period 2010-2030. Main reason for this quasi stabilisation is the implementation of the Energy Efficiency Directive and the rather successful application of different energy efficiency measures. The sharp increase in the price of electricity (infra) further dampens consumption.

After 2030, a sharp increase in electricity demand can be observed. This surge is caused by, amongst others, a volume effect inflicted by the increasing number of households as well as the intensified growth in industrial activity (see Table 2), pulling demand upwards. But what is more interesting, is that demand levels start to diverge. Noteworthy is that the *GHG40 scenarios* all display (way) higher demand patterns than *REF*, with average annual growth rates in the 2030-2050 period reaching 1.5% (*GHG40EE* and *GHG40EERES30*) and 2.4% *(GHG40)* (compared to 1.1% in *REF*). Three phenomena cause this divergence: 1) a fuel switch prompted by the climate (and RES) target away from more expensive fossil fuels towards a.o. electricity, thereby boosting its demand, 2) the development of electromobility: although *REF* also accounted for some electric passenger transport, the penetration of electric vehicles (both plug-in hybrids and pure electric vehicles) in the *GHG40 scenarios* is considerably higher (see part 3.1), 3) the use of electricity in the production of hydrogen through electrolysis of water (see Table 5).

**Table 7 Called-up electrical power, REF and policy scenarios, 2010, 2030 and 2050**
*TWh*

| | 2010 | 2030 | 2050 | 10//30 | 30//50 | 10//50 |
|---|---|---|---|---|---|---|
| REF | 90.2 | 93.4 | 115 | 0.2% | 1.1% | 0.6% |
| GHG40 | 90.2 | 90.7 | 145 | 0.0% | 2.4% | 1.2% |
| GHG40EE | 90.2 | 92.8 | 125 | 0.1% | 1.5% | 0.8% |
| GHG40EERES30 | 90.2 | 92.8 | 124 | 0.1% | 1.5% | 0.8% |

Source: PRIMES.

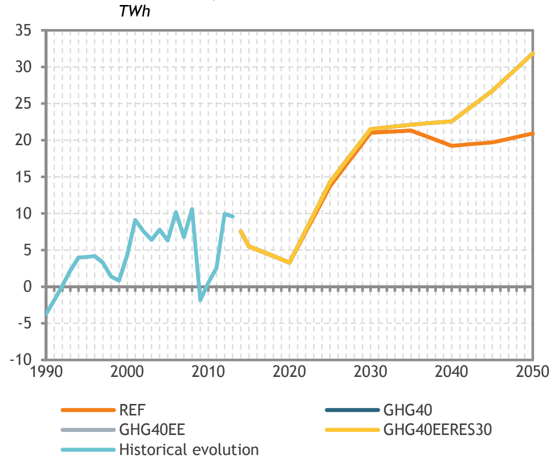
In 2050, highest demand is attained in *GHG40*, the scenario in which a sole GHG emission reduction target is implemented. By 2050, called-up electrical power reaches 145 TWh. *GHG40EE* and *GHG40EERES30* also exhibit higher demand levels than *REF* but strand at around 125 TWh (compared to 115 TWh in *REF*). The electricity consumption of the *EE scenarios* is somewhat mitigated through the application of rather ambitious energy efficiency initiatives, leading to the installation of more efficient, hence less consuming, electrical apparels and devices and the implementation of efficiency enhanced processes in the final demand sectors.

### 3.2.2. Net imports

As regards net electricity imports, it is essential to gain insight in how the PRIMES model goes about in calculating cross-border electricity exchanges. In fact, depending on the time period considered, two conceptually different methods are applied. For the period up to 2020, the Net Transfer Capacity or NTC method is employed: based on data provided by ENTSO-E, the future NTC is projected. After 2020, Flow-Based Market Coupling (FBMC) is assumed: this method supposes that the transmission of electricity within Europe will evolve in a context as if there was only one central TSO for all Member States or a framework of well-coordinated TSOs which do not apply reliability criteria from a national but from an EU-wide perspective, which is a key strategic goal for the future development of the internal electricity market (IEM) within Europe. The second phase of the target model to be applied after 2015 foresees flow-based allocation of interconnection capacities among Member States. In such an environment the concept of NTC has limited power, while that of load flows is more applicable.

In practical terms, the application of this method could result in electricity transmission beyond the projected NTC, eventually limited only by the installed capacity of the interconnectors between the Member States. As a result, such a system can be understood as a problem of optimizing electricity flows under the restriction of the overall capacity of the interconnectors, similarly to the problem that would be solved if the whole of Europe was a single country[15].

**Graph 6** **Net electricity imports, REF and policy scenarios, 1990-2050**
*TWh*




Source: Eurostat, PRIMES.

Next to a difference in methodology, there is also a difference in the assumed level of import capacity between *REF* and the *GHG40 scenarios*. In the *Reference* scenario, interconnection capacity is fixed at 4.5 GW as of 2020, whereas in the policy scenarios, the interconnection with Germany (1.25 GW) is added from 2020 on.

Graph 6 then demonstrates the level of net imports in both *Reference* and *GHG40 scenarios*[16]. Both show a remarkable increase after 2020, basically when the FBMC kicks in. This can be largely explained by three elements: 1) the nuclear phase-out, 2) the

[15] PRIMES therefore solves a DC linear power flow optimization model which means that when determining the flows, the model respects the 1st and 2nd Kirchhoff laws.

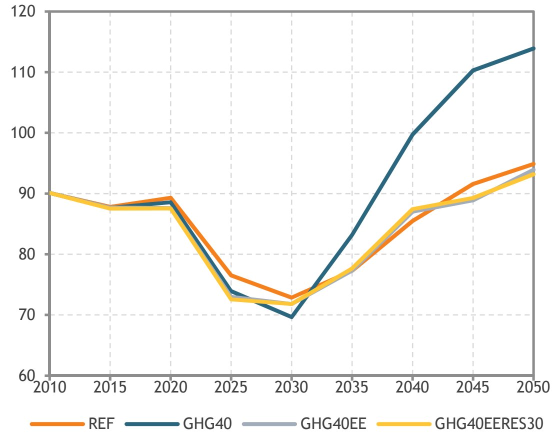
[16] The level of net imports is assumed to be identical in the *GHG40 scenarios*.

significant penetration of renewables in the power system, 3) the relatively higher production cost of domestically produced electricity compared to imported electricity. The level of net imports reaches 22 TWh in 2030 and, contrary to *REF* where net imports more or less stabilise at around 20 TWh, further increases in the policy scenarios towards 32 TWh in 2050. The divergence between the *GHG40 scenarios* and *REF* can be understood by 1) the higher import capacity in the policy scenarios (+1.25 GW), 2) more renewables in the policy scenarios' power system which pose a higher need for additional balancing. More renewables can be uptaken in these systems because of assumed market improvements and the supposed EU-wide market coupling which allows for rather low balancing costs for RES on a European scale (see Annex).

### 3.2.3. Power generation

**Graph 7 Net power generation, REF and policy scenarios, 2010-2050**

*TWh*




Source: PRIMES.

Demand can be met through domestically produced power on the one hand, net imports on the other (see 3.2.2). Domestically produced power shows a relatively stable trend up to 2020, followed by a sharp decrease between 2020 and 2030, to afterwards resume and peak in 2050.

In 2030, bottom production levels are attained. This seemingly temporary dip in domestic generation can be explained by three (interrelated) factors: 1) the nuclear phase-out, 2) the change in the mix towards a *bipolar* structure, being natural gas and RES (see Table 8), 3) higher imports from neighbouring countries (see Graph 6). All scenarios note low production levels (around 72-73 TWh), but the lowest level is achieved in *GHG40* (i.e. 70 TWh). This is due to the somewhat lower called-up electrical power in the latter in the medium term.

In 2050, things drastically change. The once lowest electricity producer *GHG40* notes record production levels: 114 TWh of electricity is being produced, compared to 93 (*GHG40EERES30*) and 94 TWh (*GHG40EE*) in the *EE scenarios*. Net power production in *REF* stands at 95 TWh. This remarkable increase in power production can be brought back to the surge in demand after 2030.

Next to the level attained in electricity production, it is also instructive to have a look at the mix. Table 8 gives an insight in the composition of net power production.

**Table 8 Energy mix in net power generation, REF and policy scenarios, 2010, 2030 and 2050**
*%*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Nuclear energy | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydro | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Wind | 1 | 27 | 31 | 28 | 34 | 34 | 34 | 37 | 44 |
| Solar | 1 | 7 | 7 | 7 | 7 | 11 | 10 | 9 | 8 |
| Biomass & waste | 6 | 11 | 12 | 11 | 13 | 9 | 8 | 10 | 12 |
| Geothermal heat | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| Coal | 4 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 0 |
| Natural gas | 34 | 49 | 45 | 49 | 41 | 45 | 46 | 42 | 35 |
| Other | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Source: PRIMES.
Note: 'Other' stands for petroleum products and derived gases.

Three things attract attention.

First, all scenarios undergo a transformation from a relatively diversified portfolio in 2010 with nuclear, gas(es), biomass, coal and some (other) renewable energy sources towards a bipolar power system in 2050, exclusively made up of natural gas on the one hand and (a variety of) renewable energy sources on the other.

In 2030, a marginal amount of coal, petroleum and derived gases (together accounting for some 4%) can still be spotted in the mix, but natural gas is the dominant energy source with a share between 41% (*GHG40EERES30*) and 49% (*GHG40EE*). Wind follows with a share between 28% (*GHG40EE*) and 34% (*GHG40EERES30*).

By 2050, the transformation is complete. The share of natural gas has decreased in the *EE scenarios* to 35% (*GHG40EERES30*) and 42% (*GHG40EE*) at the benefit of RES (wind in particular), but stays roughly the same in *GHG40* at 46%.

Second, *REF* shows remarkable similarities with *GHG40* in the long term (2050).

Third, although the *EE scenarios* display similar levels of production, their mix is rather different, both in 2030 and 2050. It appears that the additional renewable energy target in *GHG40EERES30* changes the mix, but not the level (nor the demand), towards more wind and slightly more biomass and waste, and this at the expense of natural gas.

This leads us to conclude that 1) installing a sole GHG emission reduction target (without accompanying energy efficiency measures) does not have a major impact in the long term on the composition of power generation, but it does on the level of production, 2) installing an additional RES target (on top of the GHG objective and EE measures) does not have a significant impact on the level of production, but it influences the mix.

**Hydrogen in power generation**

Although it does not highlight in Table 8, hydrogen makes its appearance onto the power generation system as of 2040. Although the option to deploy hydrogen is available in all scenarios (and is taken up in the final demand sectors, see section 3.1), only *GHG40EERES30* exploits the possibility for the round-trip cycle power-hydrogen-power.

In fact, hydrogen is derived from a surplus production of renewable energy and therefore serves a storage purpose. This storage option is endogenous in the model and consists, next to hydrogen, of technologies like hydro-based pumped storage (PSH), air compression and even (car) batteries. Depending on the economics, storage simultaneously levels out load and accommodates the transfer of renewable energy from times when RES availability exceeds load to times when RES is insufficiently available. The model represents the possibility for producing hydrogen from electrolysis and blending it with natural gas (up to a maximum share of 30-40%). In case of high RES development, hydrogen production, assumed to take place at off peak hours, helps smoothing out the load curve, relaxing reserve power constraints and hence allowing for more variable RES capacities which comes in handy in a scenario that has an ambitious RES deployment like *GHG40EERES30*.

### a. Renewable energy sources

Because of the increasing importance of RES in power generation and their impact, specifically from the variable RES, on the system, particular attention is paid to this type of energy source.

First, a distinction should be made between variable (intermittent or weather-dependent like wind and sun) and non-variable (like hydro, biomass and geothermal) renewable energy technologies. Both increase, but given their potential impact on the electricity system, the former is looked at with more attention. Its share in net power generation increases swiftly (see Table 8): in 2030, it represents between 35% (*GHG40EE*) and 41% (*GHG40EERES30*), in 2050 between 44% (*GHG40*) and 51% (*GHG40EERES30*).

In 2030, the level of RES production increases considerably: from 8 TWh in 2010 to an interval between 34 TWh (*GHG40EE*) and 39 TWh (*GHG40EERES30*). Not surprisingly, the level is highest in *GHG40EERES30*, a fact that is attributable to the binding RES target. When looking at the mixes in the different scenarios, we notice that they differ only slightly, with a minor trade-off between on- and offshore wind: more offshore is produced in *GHG40EERES30* whilst more onshore is developed in both *GHG40* and *GHG40EE*. Biomass and waste stay an important energy source, and although their relative contribution dwindles (basically because the other RES types gain ground), their absolute production grows from 5.6 TWh in 2010 to around 8 TWh in *GHG40* and *GHG40EE* and 9 TWh in *GHG40EERES30*.

By 2050, things are different. RES production levels are significantly higher in both *GHG40EERES30* and *GHG40* in comparison with *REF* and *GHG40EE*: the former reach 60 and 61 TWh respectively, the latter 52 and 54 TWh respectively. The high levels can be explained by the elevated demand and the towering carbon prices in *GHG40* and the high renewable value in *GHG40EERES30*. This nonetheless does not constitute the only difference: energy mixes are no longer comparable. Although producing approximately the same amount of renewable electricity, major differences between *GHG40* and *GHG40EERES30* are that the former utilises more solar (11 TWh in *GHG40* versus 7 TWh in *GHG40EERES30*) whilst the latter deploys more offshore wind (27 TWh in *GHG40EERES30* versus 25

TWh in *GHG40*) and biomass and waste (11 TWh versus 9 TWh respectively). Same goes for the discrepancy between *REF* and *GHG40EE*: although they generate comparable amounts of renewable electricity, the former delivers more solar produced power (10 TWh in *REF* versus 9 TWh in *GHG40EE*) and less offshore wind (19 TWh versus 21 TWh respectively) and biomass and waste (8 TWh versus 10 TWh respectively) than the latter.

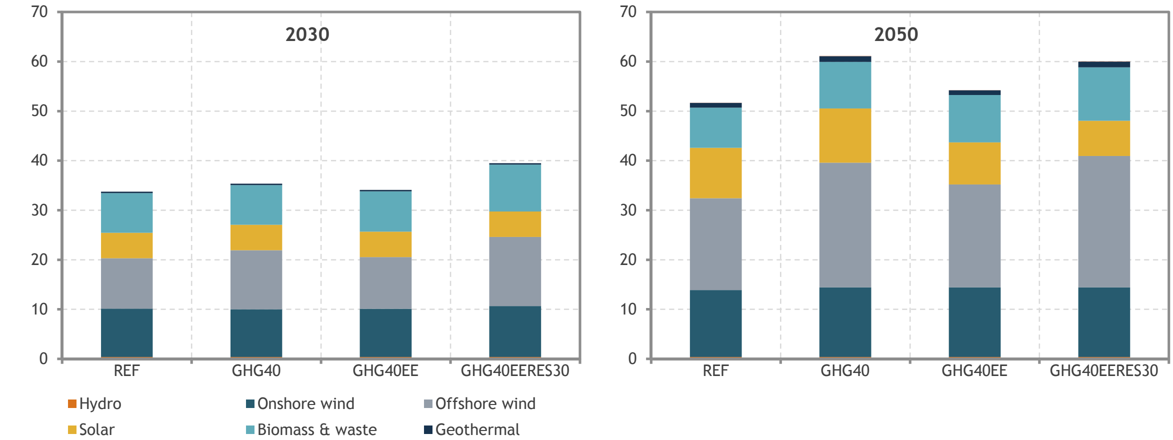
**Table 9 Composition of renewable energy sources for electricity generation, REF and policy scenarios, 2010, 2030 and 2050**
*%*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Hydro | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Onshore wind | 8 | 29 | 27 | 28 | 26 | 26 | 23 | 26 | 23 |
| Offshore wind | 8 | 30 | 34 | 31 | 35 | 36 | 41 | 38 | 44 |
| Solar | 7 | 15 | 15 | 15 | 13 | 20 | 18 | 16 | 12 |
| Biomass & waste | 72 | 24 | 23 | 24 | 24 | 16 | 15 | 18 | 18 |
| Geothermal | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Source: PRIMES.

Before passing to gas-fired generation, a quick note on geothermal. Geothermal energy slowly gains ground from 0 TWh in 2010 to 1 (*REF* and *GHG40EE*) and 1.2 TWh (*GHG40* and *GHG40EERES30*) in 2050. It is not really the absolute amount of geothermal that strikes, it is rather its contribution to the system: since geothermal is a non-variable energy source, it can be used as baseload, a quality it shares with biomass and waste power plants.

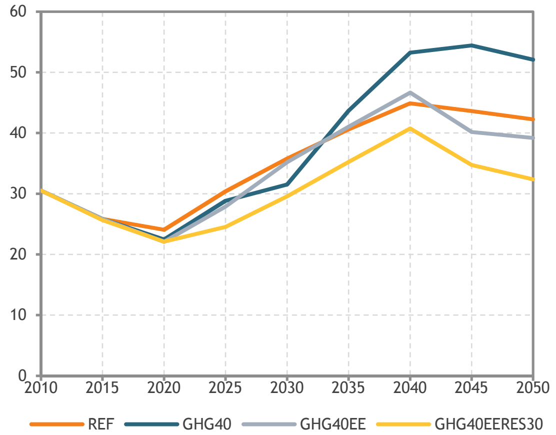
**Graph 8 Net power generation by RES, REF and policy scenarios, 2030 (left) and 2050 (right)**
*TWh*




Source: PRIMES.

### b. Gas-fired power plants

**Graph 9** **Net power generation by natural gas, REF and policy scenarios, 2010-2050**
*TWh*

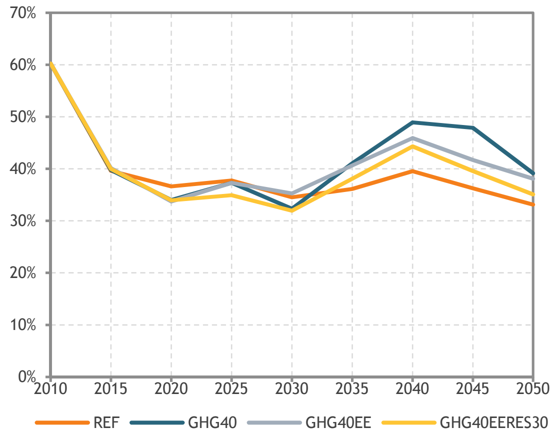



Source: PRIMES.

Complementing the renewable energy sources in the bipolar power system of the future is natural gas. Although natural gas plays a key role in each and every scenario, its contribution differs across the scenarios.

Lowest levels of natural gas based electricity are reached in 2020, the year in which the legislative Climate/Energy package induces high amounts of renewable based electricity in the system. Starting from 31 TWh in 2010, the net power generation by natural gas fired power plants decreases to 22 TWh in 2020 in the policy scenarios (compared to 24 TWh in *REF*). After 2020, the natural gas based electricity uniformly grows until 2040[17] when it reaches a level between 41 TWh (*GHG40EERES30*) and 53 TWh (*GHG40*). Intermediate 2030 levels oscillate between 30 (*GHG40EERES30*) and 35 TWh (*GHG40EE*). In the run up towards 2050, production levels (slightly) level off and strand between 32 TWh (*GHG40EERES30*) and 52 TWh (*GHG40*).

**Graph 10** **Utilisation rate of natural gas fired power plants, REF and policy scenarios, 2010-2050**
*%*




Source: PRIMES.

The evolution of the production, in conjunction with the net installed capacity (see 3.2.4), allows us to calculate the average utilisation rate of the entire park of natural gas fired power plants (see Graph 10).

In the first decade (2010-2020), utilisation rates dwindle: from a level of 60% in 2010, they tumble down to somewhere between 34 and 37% by 2020. Between 2020 and 2030, they hover around this percentage and even reach their lowest level (32%) in two scenarios (*GHG40* and *GHG40EERES30*). After 2030, the utilisation rate in the *GHG40 scenarios* picks up again and starts to outpace the *REF*'s. The rate even reaches 50% in *GHG40* in 2040 to afterwards decline to somewhere between 35% (*GHG40EERES30*) and 39% (*GHG40*) by 2050.

Reason for these rather modest average utilisation rates[18] is the *merit order effect* triggered by the increased variable renewable energy deployment in combination with the electricity demand patterns calculated in 3.2.1.

17 Even 2045 in *GHG40*.

18 This is also known as the *compression effect* and represents the reduction of the utilisation rates of dispatchable power generators as low-marginal cost renewables have priority over dispatchable supply (OECD, 2012).

### 3.2.4. Production capacity

These levels of production have to be generated in different (types of) power plants. This section covers the capacity that has to be installed in order to produce the amounts of power described above. Table 10 displays the evolution of the total installed capacity split per energy source.

Total installed capacity significantly increases in the *GHG40 scenarios*. Where it stood at 17 GW in 2010, it largely exceeds this level by 2030 when it amounts to 27 GW (*GHG40* and *GHG40EE*) and 28 GW (*GHG40EERES30*). The rhythm at which total capacity expands occurs way faster than the rhythm at which production increases. For the period 2010-2030, the former even increases at an annual average growth rate between 2.3% (*GHG40* and *GHG40EE*) and 2.5% (*GHG40EERES30*) whilst the latter decreases at an annual average rate between 1.3% (*GHG40*) and 1.1% (*GHG40EE* and *GHG40EERES30*). Notwithstanding this general increase in capacity, some energy forms are being phased out: nuclear loses 6 GW over the 2010-2030 period, coal 1 GW. Other energy forms then have to (more than) make up for these losses, so large capacity extensions of RES and natural gas are taking place at the same time. Compared to 2010, *GHG40* and *GHG40EE* add around 11 GW RES and 5 GW natural gas during the 20 years period, whilst *GHG40EERES30* adds more renewables (+13 GW), but slightly less natural gas.

By 2050, capacity has continued on its growth path: it now reaches levels between 37 GW (*GHG40EE* and *GHG40EERES30*) and 44 GW (*GHG40*). Capacity expansions are majorly provided by RES since the installed natural gas capacity keeps a status quo with respect to 2030. Sole exception is provided by *GHG40* where an additional 4 GW natural gas capacity is installed. RES additions in the policy scenarios comprise mostly variable RES, i.e. wind and sun. Compared to 2030, an additional 12 GW of variable RES is installed in *GHG40* (of which +7 GW wind, +5 GW solar), 9 GW in *GHG40EE* (of which +6 GW wind, + 3 GW solar) and 8 GW in *GHG40EERES30* (of which +6 GW wind, +2 GW solar). Next to the variable RES, the installed amount of biomass and waste power plants doubles in all *GHG40 scenarios* and boils down to 3 GW by 2050.

**Table 10 Installed capacity, REF and policy scenarios, 2010, 2030 and 2050**
*GW*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Nuclear | 5.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Hydro | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Wind | 0.9 | 7.6 | 8.2 | 7.6 | 9.2 | 12.5 | 14.9 | 13.7 | 15.3 |
| Solar | 0.9 | 4.8 | 4.8 | 4.8 | 4.8 | 9.2 | 10.0 | 7.7 | 6.4 |
| Biomass & waste | 1.1 | 1.5 | 1.5 | 1.5 | 2.0 | 2.4 | 3.0 | 2.9 | 3.5 |
| Geothermal | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 |
| Coal | 1.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Natural gas | 5.8 | 11.8 | 11.1 | 11.4 | 10.6 | 14.6 | 15.2 | 11.7 | 10.6 |
| Other | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 | 0.6 | 0.5 | 0.5 | 0.5 |
| Total | 17.0 | 27.2 | 27.0 | 26.8 | 28.1 | 39.5 | 43.9 | 36.7 | 36.6 |

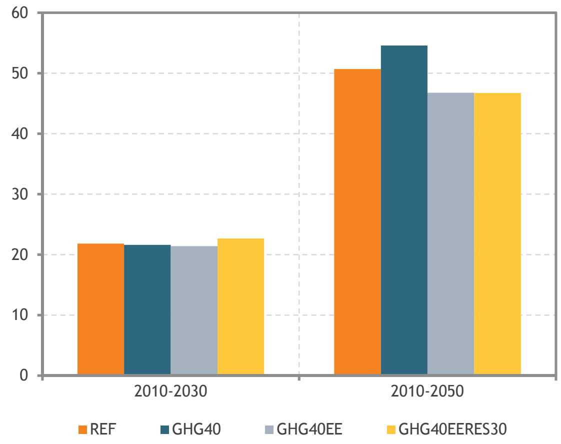
Source: PRIMES.
Note: 'Other' stands for petroleum products and derived gases.

It is interesting to see that, when a sole GHG target is installed, capacity reaches its highest level (44 GW) in the long term. This can be subscribed to (the combination of) three elements: 1) the high amount of variable renewable energy sources necessitating back-up capacity, 2) the fact that this scenario, beyond 2030, demonstrates the highest electricity demand levels and 3) the fact that no ambitious demand response programme (EE) accompanies these high demand levels (hence, could dampen both demand and capacity requirements). This last observation is corroborated when looking at *GHG40EE* and *GHG40EERES30*: in the long term (2050), these scenarios succeed in keeping a lid on installed capacity. Their generating facilities amount to 37 GW, a level even below *REF*'s (40 GW).

### 3.2.5. Investments

In order to install the capacity calculated in 3.2.4, investments have to be undertaken. In this section, we look into the capacity additions required to cope with 1) increasing demand (mostly after 2030), 2) replacing end-of-technical-lifetime and decommissioned units, 3) guaranteeing back-up for variable renewable technologies.

**Graph 11 Investments in production capacity split up per period, REF and policy scenarios, 2010-2030 and 2010-2050**
*GW*




Source: PRIMES.

Graph 11 displays the height of the necessary investments in all discussed scenarios in two (partly overlapping) periods: the first between 2010 and 2030 and the second between 2010 and 2050.

Differences in investments in the first period (2010-2030) are rather minor: total investments hover around 22 GW in all scenarios (including *REF*) and can basically be attributed to the large replacements of the nuclear capacity together with RES investments necessary to a.o. honour the 2020 Climate/Energy package. Investments in *GHG40EERES30* are slightly higher (23 GW) because of the implementation of the additional RES target in 2030, hence the higher investments in RES based capacity.

It is not until the second period that variances between scenarios can be observed. By 2050, total investments cover a range between 47 and 55 GW, the lower end represented by the *EE scenarios*, the higher end corresponding to *GHG40*. The high investments in the latter have to do with a.o. the large increase in electricity demand (see also Graph 5).

More surprisingly is that total investments in the *EE scenarios* (amounting to 47 GW) are lower than *REF* (51 GW), and this notwithstanding their higher electricity demand levels. This is where demand response comes into play: the presumed demand response programmes in the *EE scenarios* tend to induce smoother load curves. Smoother load curves improve the economics of capital intensive power technologies, thereby facilitating carbon-free and low-carbon power generation investments.

For an assessment of the monetary costs that go along with these investments, the reader is referred to part 4.4.1.

### 3.2.6. Generation adequacy

This part zooms in on the question whether the capacity expansion resulting from the model will suffice to, at all times, cover peak load. The applied methodology is taken from both Gusbin (2013) and FPB (2014) and is inspired by the deterministic approach adopted by ENTSO-E, the European network of transmission system operators (ENTSO-E, 2013, ENTSO-E, 2014).

Two things are necessary in order to diagnose whether the future power system[19] will be up for the adequacy task (under normal conditions): the evolution of Peak Load (PL) and an insight in Reliable Available Capacity (RAC).

The Reliable Available Capacity (RAC) is in fact the Net Generating Capacity (NGC) minus the Unavailable Capacity (UC). The Unavailable Capacity is the part of the Net Generating Capacity that is not reliably available to power plant operators due to limitations of the output power of power plants. Although a power station can theoretically generate electricity from its total installed power, this is not actually the case in real life for several reasons like 1) (un)intentional (temporary) limitations of the production level under normal circumstances (Non-Usable Capacity), 2) scheduled unavailability of generating capacity for regular inspection and maintenance (Overhauls), 3) forced (not scheduled) unavailability of generating capacity (Outages), 4) the fact that capacity is required to maintain the security of supply according to the operating rules of each TSO (System Services Reserve).

The Unavailable Capacity (UC) is not a number that is commonly published, it is in fact the result of a calculation. This calculation is performed based on figures provided by the national TSO and ENTSO-E, the European network of TSO's, together with an assumption on the system services of the national TSO.

The proper diagnosis whether the projected Belgian capacity will (not) be adequate in the future, can be made after an analysis that applies ENTSO-E's deterministic approach. In this paper, we focus on the analysis under normal conditions. In that case, the Reliable Available Capacity (RAC) is being compared to Peak Load (PL). The difference between these two indicators gives the Remaining Capacity. The Remaining Capacity (RC) is the part of Net Generating Capacity left on the power system to cover any unexpected load variation and unplanned outages in normal (average) conditions. If this difference has a positive sign, demand can be covered by domestic capacity and there is no structural need for imports (besides commercial purposes). When negative, this indicates that the generation park is not adequately equipped to absorb demand in normal situations without having to structurally depend on import. This in fact can be interpreted as a signal. The signal points to a potential capacity deficit, hence an investment need in new generation capacity. When this happens, the absolute value of the RC has to be compared to the nation's import capacity.

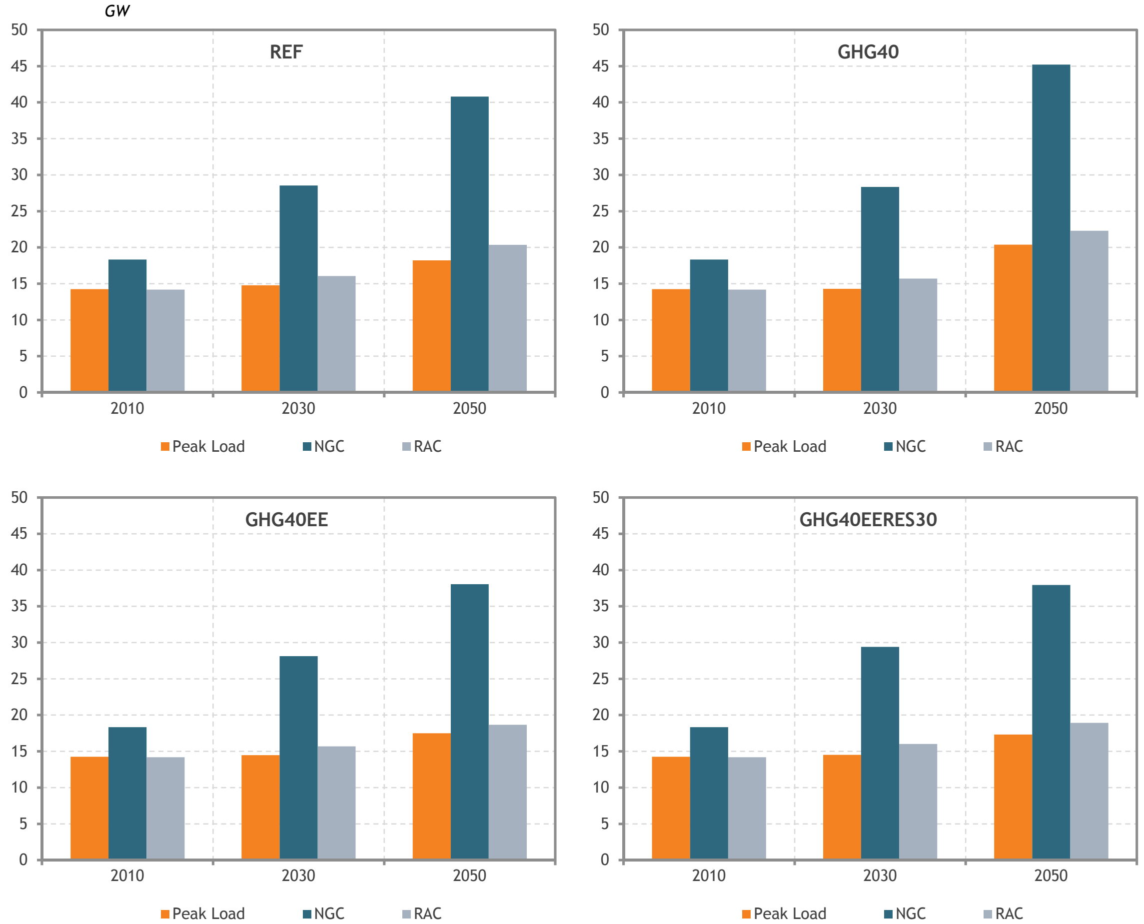
Graph 12 depicts the NGC next to the RAC and Peak Load. The difference between NGC and RAC is the UC, the difference between RAC and Peak Load is the RC. All scenarios show the same trend: although the NGC largely outperforms Peak Load, the RAC does not grow at the same rhythm as the NGC[20] and in some cases, even exhibits only a marginal buffer of less than 1 GW to cover demand at all

[19] This analysis focuses on the medium term (starting from 2020) since the Federal Public Service Economy is in charge of evaluating the short term adequacy of the Belgian electricity system (FPS Economy, 2012).

[20] Over the period 2010-2050, the annual average growth rate of NGC in *GHG40* (the *EE scenarios*) amounts to 2.3% (1.8%) whilst the rhythm at which the RAC grows on average is only 1.1% (0.7% respectively).

times. Nonetheless, we can conclude that 1) under normal conditions, adequacy is safeguarded since the RC is higher than zero throughout the projection period, 2) although demonstrating an identical trend, the level of RC differs (substantially) between scenarios, certainly in the longer term (after 2035), 3) RC reaches its lowest level in *GHG40* in the year 2045, i.e. 0.3 GW.

**Graph 12 Peak Load, Net Generating Capacity and Reliable Available Capacity, REF and policy scenarios, 2010, 2030 and 2050**
*GW*




Source: PRIMES.
Note: NGC=Net Generating Capacity; RAC=Reliable Available Capacity.

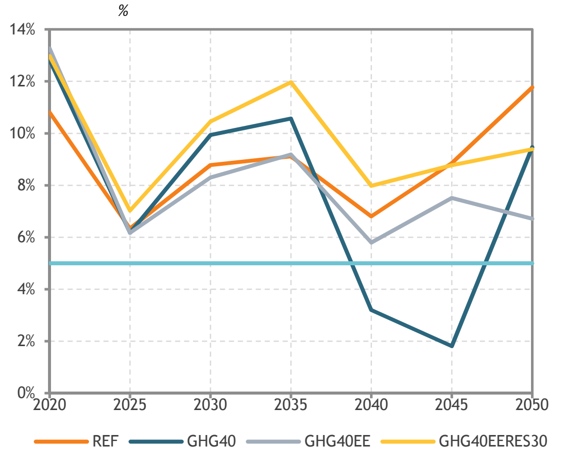
This last finding can be further examined through the calculation of the inherent security (or System Reserve) Margin (SRM) through

$$RAC = (1+SRM)xPL \qquad (1)$$
$$SRM = (RAC-PL)/PL \qquad (2)$$

What we then observe (Graph 13) is that the *GHG40* scenario seems to be in a pickle during the period after 2035 and before 2050 with an ultimate low in terms of SRM (i.e. 1.8%) being reached in the year 2045. An SRM level below 5% is generally accepted to be worrisome (ENTSO-E, 2013, Albrecht, 2014). In fact, a paradox seems to emerge in *GHG40*: on the one hand, its generation capacity expansion is the highest of all scenarios (see 3.2.5), on the other hand, its SRM reaches the lowest level observed. Two elements are at play: 1) a higher peak demand given a.o. the higher carbon price due to the sole GHG reduction target inducing a fuel switch towards more electricity consumption (see 3.2.1) combined with the absence of elaborate demand response instruments (lack of ambitious energy efficiency initiatives to smoothen the load curve), 2) the capacity additions comprise, because of the climate target, chiefly variable RES (i.e. wind) which tend to be capital intensive but, because of their rather low capacity credit factor, do not add significantly to the RAC.

**Graph 13 Evolution of the System Reserve Margin, REF and policy scenarios, 2020-2050**

%




Source: PRIMES.

*GHG40EE* and *GHG40EERES30*, then, do include more ambitious demand response instruments through which the load curve (hence, the peak load) can be smoothened. This causes total capacity additions to be lower (but not less capital intensive because of the (combination of both a) climate (ánd a renewable) target).

To put this low SRM into perspective, it is important to stress that after 2020, a different approach as to security of electricity supply was assumed (see also part 3.2.2). After 2020, reliability criteria are supposed to no longer be applied from a purely national but rather from an EU-wide perspective (in line with the envisaged development and constituting one of the key objectives of the IEM), meaning that if in the future it turns out to be more cost effective to (to a certain extent) rely on neighbouring countries, part of our generation adequacy will be imported. This is observable in *GHG40* in the period after 2035 and before 2050, but the other scenarios can also count on (or contribute to) this "adequacy exchange". Cross-border electricity exchanges will therefore gain an even bigger importance, not only in terms of commercial trade and arbitrage opportunities, but also in terms of flexibility and reliability, certainly in scenarios with high amounts of installed RES.

The main conclusion of this section is that the policy scenarios, from 2030 onwards, demonstrate significantly higher electricity demand levels than the *Reference* scenario. By 2030, demand picks up after a quasi-stabilisation and the policy scenario with a sole GHG target (*GHG40*) displays the highest demand levels. From 2030 on, more net imports of electricity are envisaged in the policy scenarios compared to *REF*. It seems that these higher net import levels suffice to cover the additional demand (wrt *REF*) in the *EE scenarios*, but this is not the case in *GHG40.* The latter exhibits, in 2050, higher production levels. Compared to *REF*, *GHG40* differs in the level of production, but not so much in the mix, whilst the *EE scenarios* have different mixes than *REF*, but exhibit rather similar levels of production. The mix of the *EE scenarios* is characterised by less natural gas and more renewables.

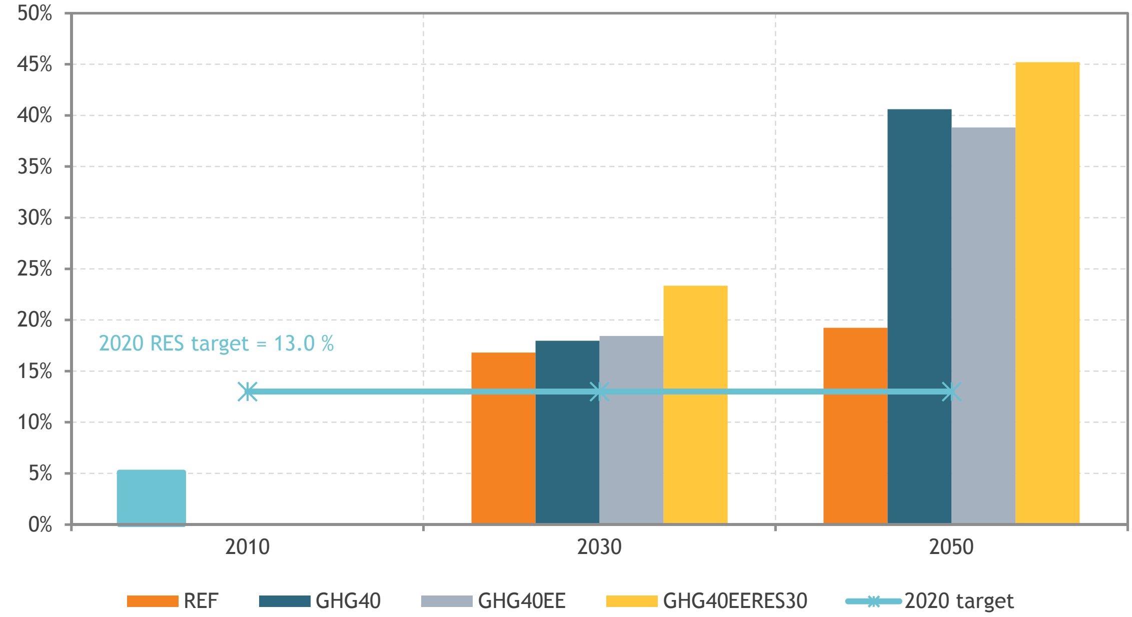
Installed capacity increases sharply in all scenarios. Already by 2030 and notwithstanding the nuclear phase-out, more power plants are integrated in the system. In 2050, the highest installed capacity is observed in *GHG40*, whilst the *EE scenarios*, thanks to ambitious demand response programmes, manage to keep their total capacity below the level observed in *REF*. Investment needs are enormous but guarantee generation adequacy (under normal conditions), all the more so because cross-border electricity exchanges are supposed to relieve national reliability concerns within a framework of European-wide enhanced TSO coordination.

## 3.3. Renewable energy sources

After the spotlight on different aspects of electricity (generation), this part zooms in on renewable energy sources in general. Although part 3.2.3 already discussed renewable energy sources in power generation, this section will broaden the scope and will treat all potential uses of renewables, i.e. transport, heating and cooling and power generation.

Graph 14 demonstrates that, expressed in terms of the target definition of RES in Directive 2009/28/EC, RES in the policy scenarios continue to grow after 2020[21] to increase their relative importance. In 2030, the policy scenarios are on a sustained growth path. The highest share of RES is, without surprises, reached in the *GHG40EERES30* scenario: 23.4% of Gross Final Energy Consumption (GFEC) is covered by renewable energy. *GHG40* and *GHG40EE* pursue with shares of 18.0% and 18.4% respectively (compared to 16.8% in *REF*).

**Graph 14 Share of RES in Gross Final Energy Consumption, REF and policy scenarios, 2010, 2030 and 2050**
%




Source: PRIMES.

By 2050, shares have not stopped mounting. *GHG40EERES30* maintains pole position and levels off at 45.2%, whereas *GHG40* and *GHG40EE* record shares of 40.6% and 38.8% respectively.

Table 11 further dissects the global RES share and splits it up into its different uses: RES-H for heating and cooling, RES-E for electricity production and RES-T for transport purposes.

21 By assumption, the share in 2020 in all scenarios (incl. *REF*) is consistent with the RES target set in the 2020 legislative Climate/Energy package.

**Table 11 Share of RES by type of use, REF and policy scenarios, 2010, 2030 and 2050**
*% in Gross Final Energy Consumption*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| RES-H | 5.2 | 12.9 | 13.8 | 14.8 | 22.1 | 12.5 | 32.4 | 26.2 | 38.4 |
| RES-E | 6.9 | 35.2 | 38.0 | 35.8 | 41.8 | 42.9 | 39.1 | 40.9 | 46.0 |
| RES-T | 4.2 | 11.4 | 11.9 | 13.3 | 13.9 | 12.5 | 65.0 | 63.8 | 65.2 |

Source: PRIMES.

In 2030, all policy scenarios tend to have higher RES shares (both with respect to *REF* and 2010) for all uses, but large divergences can be noted between the policy scenarios. Without surprises, the implementation of a binding RES target in *GHG40EERES30* induces the record renewable percentages of 22% in RES-H, 42% in RES-E and 14% in RES-T. This is caused by two elements:

– a higher numerator: the absolute amount of total RES in this scenario far outweighs the RES quantities employed in the other scenarios,

– a lower denominator: through energy efficiency measures, lower amounts of final energy are consumed.

The latter observation is also visible in *GHG40EE* where the energy efficiency measures, more specifically in the final demand sectors buildings (heating and cooling) and transport, cause the denominators to be lower, in its turn impacting the height of RES-H and RES-T which stand at 15% and 13% respectively.

In 2050, things change. *GHG40EERES30* still leads in relative terms for all uses because of the two cited reasons and shares surge to 38% for RES-H, 46% for RES-E and 65% for RES-T. Nonetheless, through the effect of a much higher carbon price (hence inducing massive fuel switching), absolute amounts of renewables are superior in *GHG40*. *GHG40* therefore becomes second in line for all (relative) indicators, exception made by RES-E. In electricity, the highest absolute amount of renewables is being used in *GHG40* but due to a relatively high denominator the RES-E share only reaches 39%.

The main conclusion of this section is that the contribution of renewable energy sources in the energy system of the future keeps growing. The share of RES in Gross Final Energy Consumption increases dramatically throughout the projection period and, compared to *REF*, is twice as high in the policy scenarios by 2050. RES cover different uses, i.e. transport, heating and cooling and electricity production. By 2050, RES cover almost two thirds of final energy consumption in transport in the policy scenarios, between 26% and 38% in heating and cooling and between 39 and 46% for electricity uses.

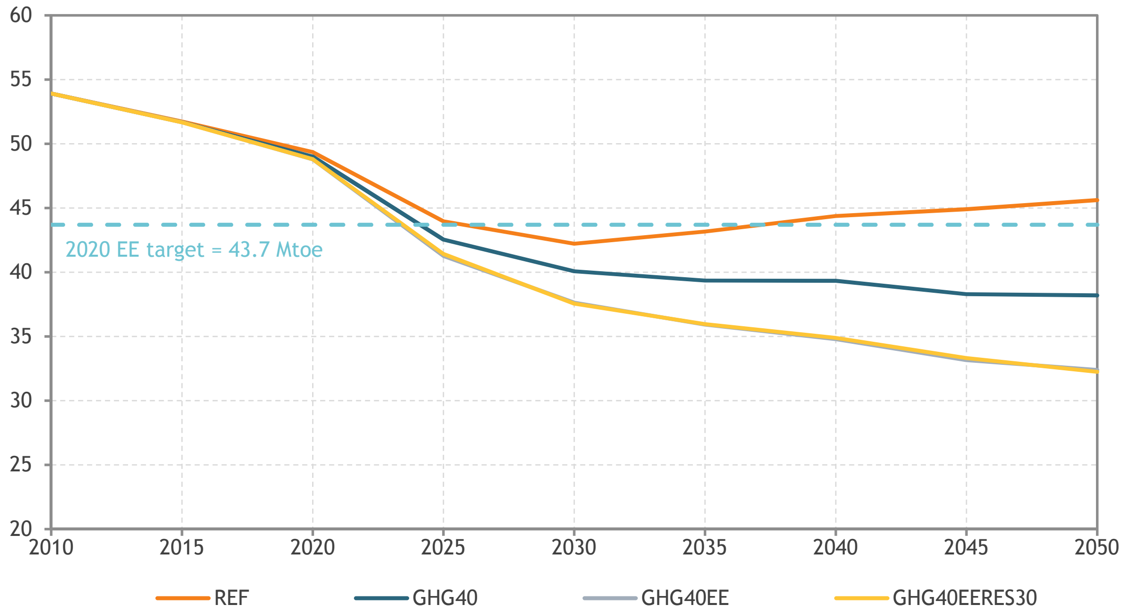
### 3.4. Primary energy consumption

The impact of the policy scenarios on final energy demand and power generation described above translates into changes in our total energy needs and mix. Total energy needs are represented by the primary energy consumption. This indicator combines energy produced in Belgium (mainly RES) and energy imported from abroad (primarily fossil fuels) but excludes energy used as feedstock[22] (for instance in the petrochemical industry). Primary energy consumption is also an indicator used in the Energy Efficiency Directive.

Primary energy consumption follows a decreasing trend in all policy scenarios (see Graph 15) but, as can be expected, the decline is much more outspoken in the scenarios with ambitious EE policies. While a binding RES target (*GHG40EERES30*) alters the relative importance of each energy source in the energy system (see infra), it only has a negligible impact on the development of primary energy consumption.

For the sake of comparison, Graph 15 also shows the evolution of primary energy consumption in the *Reference*. Moreover, it plots the level Belgium has specified to reach in 2020 according to the indicative EE target reported to the European Commission in June 2013 (EC, 2013)[23].

**Graph 15 Primary energy consumption, REF and policy scenarios, 2010-2050**
*Mtoe*




Source: PRIMES.

In 2030, consumption reductions with respect to 2010 range from 26 to 30% in the policy scenarios (compared to 22% in *REF*). This result converts into 40.1 Mtoe in the *GHG40* scenario and 37.6 Mtoe in the "*EE*" policy scenarios, against 53.9 Mtoe in 2010 (and 42.2 Mtoe in *REF* in 2030). Although primary energy savings in all scenarios fall short of the indicative EE target in 2020, the 2030 Climate and Energy Framework would allow bringing forward its achievement by 1 to 2 years compared to the Reference.

22 The sum of primary energy consumption and non-energy uses is equal to the gross inland consumption.

23 Next to a target in terms of final energy demand, Belgium also indicated an objective in terms of primary energy consumption following the guidelines of Directive 2012/27/EE.

In 2050, primary energy consumption is reduced by between 29 and 40% compared to the level in 2010 (versus 15% in *REF*). It totals 38.2 Mtoe in the *GHG40* scenario and 32.4 Mtoe in the other two policy scenarios (compared to 45.2 Mtoe in *REF*).

The policy scenarios exhibit significant modifications in terms of energy mix (see Table 12), especially in the long term.

**Table 12 Energy mix in primary energy consumption, REF and policy scenarios, 2010, 2030 and 2050**
*%*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Solids | 5.9 | 4.5 | 4.5 | 4.4 | 4.5 | 2.7 | 1.3 | 1.0 | 1.0 |
| Oil | 35.1 | 37.5 | 37.6 | 36.2 | 36.5 | 35.8 | 15.5 | 18.4 | 18.5 |
| Natural gas | 29.9 | 37.4 | 35.7 | 36.6 | 32.6 | 37.6 | 36.9 | 33.8 | 28.5 |
| Nuclear | 22.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Electricity | 0.1 | 4.3 | 4.6 | 4.9 | 4.9 | 3.9 | 7.2 | 8.5 | 8.5 |
| RES | 6.1 | 16.4 | 17.6 | 17.9 | 21.5 | 19.9 | 39.1 | 38.4 | 43.5 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Source: PRIMES.

Further to the changes in final energy demand and power generation (and supply) described in the previous sections, the share of fossil fuels first grows in the medium term (74 to 78% in 2030 versus 71% in 2010) reflecting the increased use of natural gas in the power sector to i.a. compensate for the decommissioning of the nuclear plants, but then decreases in the long term (46 to 53% in 2050) due to the sharp decline in oil consumption in the transport sector. On the other hand, the share of electricity goes up to around 5% in 2030 and 7 to 9% in 2050; this development follows the trend of net electricity imports. Finally, the contribution of RES to primary energy consumption intensifies over the projection period: from 6% in 2010, it jumps to around 20% in 2030 and reaches 40 to 45% in 2050. The share of RES is the highest in the scenario with a 30% RES target at EU level in 2030 (*GHG40EERES30*) where it is even the top energy source in 2050.

As a result of reduced primary energy consumption, the energy intensity of the Belgian economy[24] is decreasing in all scenarios but most significantly in the *EE scenarios*: by 42% in 2030 and by 60% in 2050 compared to 2010 in the *GHG40* scenario and by 45% and 66% in the *EE scenarios* (compared to 39% and 54% respectively in *REF*).

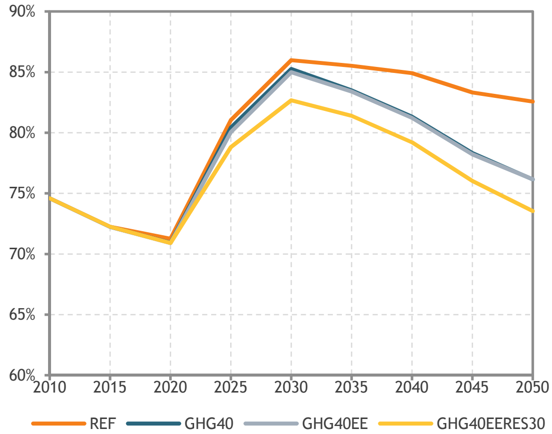
As underlined at the beginning of this section, primary energy consumption encompasses energy produced in Belgium and energy imported from abroad. The evolution and relative contribution of net energy imports provide valuable information to assess Belgium’s energy dependence in the future and, more importantly, the security of its energy supply. That is why a special focus is devoted to this component of the primary energy consumption in the following section.

[24] Measured by the ratio of gross inland consumption to GDP.

## 3.5. Energy imports

All tendencies described above do reflect in the (net) amount of energy that has to be imported from abroad. As commonly known, Belgium does not possess indigenous fossil fuel resources, so all use of these fuels rests on imports from other countries and continents. This explains the rather high energy import dependency indicator of 77% in 2010.

**Graph 16 Energy import dependency, REF and policy scenarios, 2010-2050**
*%*




Source: PRIMES.

Between 2010 and 2020, a decrease can be noted: as a consequence of the implementation of the 2020 legislative Climate/Energy package, the indicator falls to 75%. Main reason for the decrease is the joint action on both energy consumption (through a.o. the implementation of the Energy Efficiency Directive) and enhanced use of (mostly) domestic RES.

In 2030, energy dependencies reach their maximum level, being 88%. That is basically caused by the fast decrease in the denominator (see supra) that overtakes the reduction in net imports. One scenario nonetheless exhibits a lower dependency of 86%: *GHG40EERES30*. This result can be attributed to the fact that *GHG40EERES30* further promotes both the use of RES and energy efficiency/savings.

Between 2030 and 2050, dependencies contract, but they never fall back to their original 2010 level. *GHG40* and *GHG40EE* end with energy import dependencies of 80% and 81% respectively (3 to 4 percentage points higher than 2010), *GHG40EERES30* again demonstrates a lower dependency of 79% (only 2 percentage points difference with 2010). Although the energy import dependency levels are not that far apart, explanations behind the 2050 shares differ: whilst *GHG40* specifically benefits from the carbon price effect inducing fuel switching away from fossil fuels and towards renewable energy sources and electricity, *GHG40EE* mostly leans on fossil energy conservation to provoke the downward trend. *GHG40EERES30* then profits from the combination of the two effects.

Next to the more general overview, it is also instructive to dig a bit deeper and dissect the absolute level and composition of the energy imports.

**Table 13 Net imports of energy, REF and policy scenarios, 2010, 2030 and 2050**
*Mtoe*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Oil | 32.6 | 30.3 | 29.4 | 27.8 | 27.9 | 31.8 | 15.3 | 15.2 | 15.2 |
| Natural gas | 16.8 | 17.6 | 16.1 | 15.6 | 14.1 | 20.5 | 21.4 | 17.7 | 16.0 |
| Coal | 3.1 | 1.9 | 1.8 | 1.7 | 1.7 | 1.3 | 0.5 | 0.3 | 0.3 |
| Electricity | 0.1 | 1.8 | 1.9 | 1.9 | 1.9 | 1.8 | 2.7 | 2.7 | 2.7 |
| RES | 0.6 | 1.1 | 1.2 | 1.2 | 1.5 | 0.9 | 5.2 | 4.3 | 4.9 |
| Total | 53.1 | 52.7 | 50.4 | 48.0 | 46.9 | 56.3 | 45.2 | 40.2 | 39.1 |

Source: PRIMES.

Between 2010 and 2030, all policy scenarios see their net imports dwindle: from 53 Mtoe in 2010 to an interval between 47 Mtoe (*GHG40EERES30*) and 50 Mtoe (*GHG40*) in 2030. This in fact hides a contrasted movement: whilst fossil fuel imports (oil, natural gas and coal) decrease by somewhere between 5 (*GHG40*) and 9 Mtoe (*GHG40EERES30*), imports of electricity and biomass tend to augment by 2 Mtoe and a bit less than 1 Mtoe respectively, the latter however not by measure to curb the net decrease in imports.

Between 2030 and 2050, net imports shrink further and in 2050, occupy an interval between 39 and 45 Mtoe. The lower end of the range is taken by *GHG40EERES30*, the higher end by *GHG40*. *GHG40EE* is situated within the interval and displays net energy import levels of around 40 Mtoe. Compared to *REF*, the reduction in *GHG40* is already noteworthy (-24%), but the addition of energy efficiency measures in *GHG40EE* and *GHG40EERES30* is able to restrain net imports to a level that is between 40 and 44% lower. What distinguishes *GHG40* from the *EE scenarios* is the significantly higher imports of natural gas (and, to a lesser extent, biomass), chiefly used in power generation.

# 4. Economic and social impacts

This chapter deals with economic and social consequences for Belgium of implementing the EU policy Framework for Climate and Energy in 2030 and moving towards a low-carbon economy by 2050. Among the large variety of impacts, the analysis focuses on the total energy system cost, the fuel trade balance, the unit energy cost in final demand sectors, the cost of electricity generation and job creation.

## 4.1. Total energy system cost

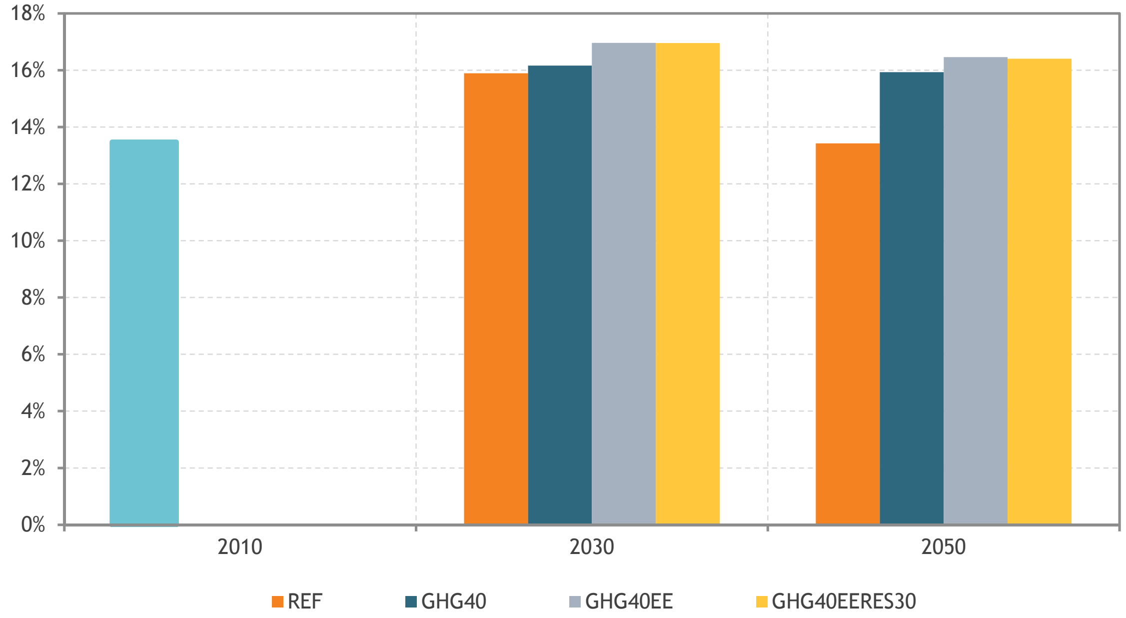
Total energy system cost[25] encompasses capital costs[26] (related to energy producing installations, energy consuming equipment and energy infrastructure), energy purchase costs (fossil and RES fuels, electricity and heat) and direct efficiency investments costs (such as expenditures for insulation).

Graph 17 presents the evolution of total energy system cost as share of GDP in the policy scenarios as well as in the *Reference*. It concentrates on the years 2010, 2030 and 2050. The ratio of total energy system cost to GDP increases from 13.5% in 2010 to respectively 16.2% and 17% in 2030 in the *GHG40* and *EE scenarios* (*GHG40EE* and *GHG40EERES30*). In other words, total energy system cost grows faster than GDP between 2010 and 2030. This evolution also characterises the *Reference* as it mainly reflects rising international fuel prices, the need to replace a significant portion of the power generation capacity and the investments required to comply with the 2020 Climate/Energy package. Compared to *REF*, the cost figures for the policy scenarios are respectively 0.3 and 1.1 percentage points higher.

After 2030, the ratio of total energy system cost to GDP starts decreasing to respectively 15.9% and 16.4 % (or 16.5%) in 2050, meaning that the energy cost progresses at a slower pace than GDP in the long run. It is worth noting that, in the period 2030-2050, gas import prices are projected to stabilize and the impact of EE and RES investments on energy purchases becomes more tangible. Nevertheless, the gap with respect to *REF* rises, ranging from 2.5 to 3 percentage points according to the policy scenario, and the total energy system cost expressed in terms of GDP stays above the 2010 figure in all policy scenarios.

25 For a more extensive definition of total energy system cost, see pp.74-76 of (EC, 2014).
26 Capital costs are expressed in annuity payments.

**Graph 17 Total energy system cost, REF and policy scenarios, 2010, 2030 and 2050**
*In % of GDP*




Source: PRIMES.

Regarding the comparison of the *GHG40* scenario only driven by carbon prices and carbon values with the scenarios involving more ambitious EE policies and RES, it is important to highlight the caveat described extensively in (EC, 2014) and summarized as follows: "*the different modelling approaches implemented reduce the comparability (of energy cost) among policy scenarios…The long term costs and cost-efficiencies of the various scenarios are challenging to assess with any precision*".

The structure of total energy system cost changes substantially over time reflecting the increasing capital intensiveness of the energy system. This trend was already observed in *REF* but intensifies in the policy scenarios. By the year 2030, the capital costs and direct efficiency investments (CAPEX) at final demand level[27] represent about one third of total energy system cost in the *GHG40* scenario and even rise to 40% in the *EE scenarios* (against 20% in 2010). In 2050, these percentages are still higher: 50% and 60% respectively. For the sake of comparison, the share of CAPEX is projected to be 32% in 2030 and 37% in 2050 in *REF*.

Table 14 focuses on the evolution of total energy purchases (OPEX) to 2050. It illustrates the differences across the scenarios on the one hand and between fuel (fossil and RES) and electricity & steam on the other hand[28]. Over time, total energy purchases steadily increase in the *GHG40* scenario while they first rise by the year 2030 and then slightly reduce to 2050 in the *EE scenarios*. Regarding the structure of energy purchases, the overall trend is a growing share of the component 'electricity & heat'.

[27] The split of total energy system cost into CAPEX and OPEX is made according to a final demand perspective. This means that the capital cost borne by the transformation sectors (e.g. investments in new power plants by electric utilities) is not reported in CAPEX but (implicitly) in OPEX. For instance, the electricity purchase cost which is part of OPEX is calculated from the price of electricity which in turn reflects investment costs (power plants, grid) at the power sector level.

[28] This component also includes the purchase of hydrogen where relevant.

Between 2010 and 2030, energy purchases increase by 29 to 33% in the policy scenarios, compared to 38% in *REF*. The bulk of the escalation comes from electricity & heat (+52 to 55%), while the growth of fuel purchases ranges from 17 to 22%.

**Table 14 Energy purchase costs, REF and policy scenarios, 2010, 2030 and 2050**
*Billion €'10*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Fuel | 24.8 | 31.5 | 30.3 | 28.9 | 29.2 | 35.1 | 26.9 | 24.4 | 24.6 |
| Electricity & heat | 12.6 | 20.0 | 19.5 | 19.1 | 19.2 | 22.7 | 26.6 | 21.1 | 20.9 |
| Total energy | 37.4 | 51.6 | 49.8 | 48.1 | 48.4 | 57.8 | 53.5 | 45.4 | 45.5 |

Source: PRIMES.

The period 2030-2050 is characterised by a slowing down of the increase in energy purchases in the *GHG40* scenario and by a small drop in the *EE scenarios*. In 2050, energy purchases stand respectively 43% and 22% above the 2010 level. The intensification of the use of electricity and substantial fuel savings, in particular in scenarios with ambitious EE and RES policies, result in an almost equal allocation of total energy purchases between fuel and electricity & heat at the end of the projection period.

## 4.2. External fuel bill and fossil fuel trade balance

The reduction in fossil fuel imports recorded in the policy scenarios (see section 3.5) and noticeable in the previous section (4.1) translates into external fuel bill effects.

In 2030, the gains in monetary terms due to the reduced purchase of fossil fuels (with respect to *REF*) are rather limited in the *GHG40* scenario: a gain of 0.5 billion € for oil and 0.7 billion € for natural gas. In *GHG40EE* and *GHG40EERES30*, on the other hand, great bargains can be achieved: in the former, 1.6 billion € for oil and 0.4 billion € for natural gas, whilst in *GHG40EERES30*, 1.5 billion € for oil and up to 1.6 billion € for natural gas can be saved due to the significantly lower imports of fossil fuels.

By 2050, benefits increase notably. In *GHG40*, 0.2 billion € less has to be spent on the purchase of coal, 11.8 billion € less on oil, but an additional 0.5 billion € has to be paid for the increased use of natural gas. In *GHG40EE* and *GHG40EERES30*, figures are similar: 0.2 billion € less spent on coal, 11.8 billion € less on oil but these scenarios, through their diminished use of natural gas, can save respectively up to 1.2 billion and 2.0 billion € on natural gas.

The above results obviously have an impact on the fuel trade balance: reduced (resp. higher) fuel costs improve (resp. deteriorate) the fuel trade balance of Belgium. This effect is all the more important since Belgium does not possess any fossil fuel[29] resources and largely relies on non-EU fuel supply[30].

[29] Today, fossil fuels represent the bulk of our energy imports. Moreover, among the fossil fuels, oil and natural gas dominate the scene as they represent around 95% of Belgium's energy trade balance in 2010.

[30] This constitutes a major difference with the electricity trade balance which concerns intra-EU power exchanges in the context of the EU internal electricity market.

Table 15 shows the evolution of the (net) fossil fuel trade balance as % of GDP. Belgium had a fossil fuel trade deficit of 3.8% of GDP in 2010[31]. Looking forward, the evolution pattern is similar in all policy scenarios: in 2030, the fossil fuel trade deficit does not evolve much compared to 2010 (the difference does not exceed 0.3 percentage point) whereas it reduces markedly by the year 2050 (the difference ranges between 1.8 and 2.2 percentage points).

**Table 15 Fossil fuel trade balance, REF and policy scenarios, 2010, 2030 and 2050**
*In % of GDP*

| | 2010 | 2030 | 2050 |
|---|---|---|---|
| REF | -3.8 | -4.1 | -3.4 |
| GHG40 | -3.8 | -3.9 | -2.0 |
| GHG40EE | -3.8 | -3.7 | -1.7 |
| GHG40EERES30 | -3.8 | -3.5 | -1.6 |

Source: PRIMES, FPB calculation.
Note: A negative trade balance means a trade deficit.

Between 2010 and 2030, the projected significant increase in oil and natural gas prices[32] is not counter-balanced by the decrease in the volume of imports (see 3.5). Nevertheless, the resulting value of imports grows (almost) in parallel with the GDP. The fossil fuel trade deficit as part of GDP is 0.2 to 0.6 percent-age point smaller in the policy scenarios than in the Reference.

Beyond 2030, the story is different. First, the price effect is softened: while the oil price is still projected to increase between 2030 and 2050 (but at a slower pace than in the previous period), the price of natural gas nearly stabilises. Then, oil consumption drops in all policy scenarios (and consequently oil import) and the demand for natural gas increases only moderately, at least in the scenarios with ambitious EE and RES policies. All in all, these evolutions translate into a decline of the value of imports overtime and consequently into a reduction of Belgium’s fossil fuel trade deficit. The latter varies from 1.6% to 2.0% of GDP in 2050, according to the policy scenario. Not surprisingly, the lower end of the range corresponds to the scenario *GHG40EERES30*. Compared to *REF*, the fossil fuel trade deficit as % of GDP boils down to between 1.4 and 1.8 percentage points in 2050.

The main conclusion of the above two sections is threefold. First, the total energy system cost as share of GDP rises in all policy scenarios by 2030 compared to *REF*: the gap ranges from 0.3 and 1.1 percentage points by 2030, and from 2.5 to 3 percentage points by 2050. Second, the structure of the total system cost changes substantially over time: the share of energy purchase costs decreases steadily reflecting the increasing capital intensiveness of the energy system. Third, the decrease in fossil fuel imports translates into external fuel bill effects which in turn influence the evolution of the (net) fossil fuel trade balance as % of GDP: in 2030, the fossil fuel trade deficit does not deteriorate compared to 2010 (it totals some 4% of GDP in both years), whereas it reduces markedly by the year 2050 (less than 2% of GDP).

[31] Since 2000 the deficit has deteriorated substantially from 2.9% of GDP. This can mainly be attributed to the trade in oil (and petroleum products) and natural gas: the value of oil and gas (net) imports almost doubled between 2000 and 2010. This trend mostly results from increasing oil and gas prices.

[32] The evolution of oil and natural gas prices is assumed to be the same in all scenarios.

## 4.3. Energy costs in final demand sectors

The energy costs supported by industry and the tertiary and residential sectors include the capital costs related to energy using equipment (e.g. boiler, oven, appliances) and building insulation, energy purchase costs with energy encompassing fuels, electricity, heat and hydrogen, and auction payments where relevant (i.e. in the ETS sector). The effect of the 2030 Climate and Energy Framework and 2050 Roadmaps on these energy costs is analysed below per sector.

Two cost indicators are scrutinized: (1) the energy cost and how it is allocated between the different cost components and (2) the (real) unit energy cost. The unit energy cost (see also EC, 2014) focuses on the energy purchase cost; it measures the energy input cost per unit of value added (industry and tertiary sector) or the share of households' energy expenses[33] in private consumption (residential sector).

### 4.3.1. Industry

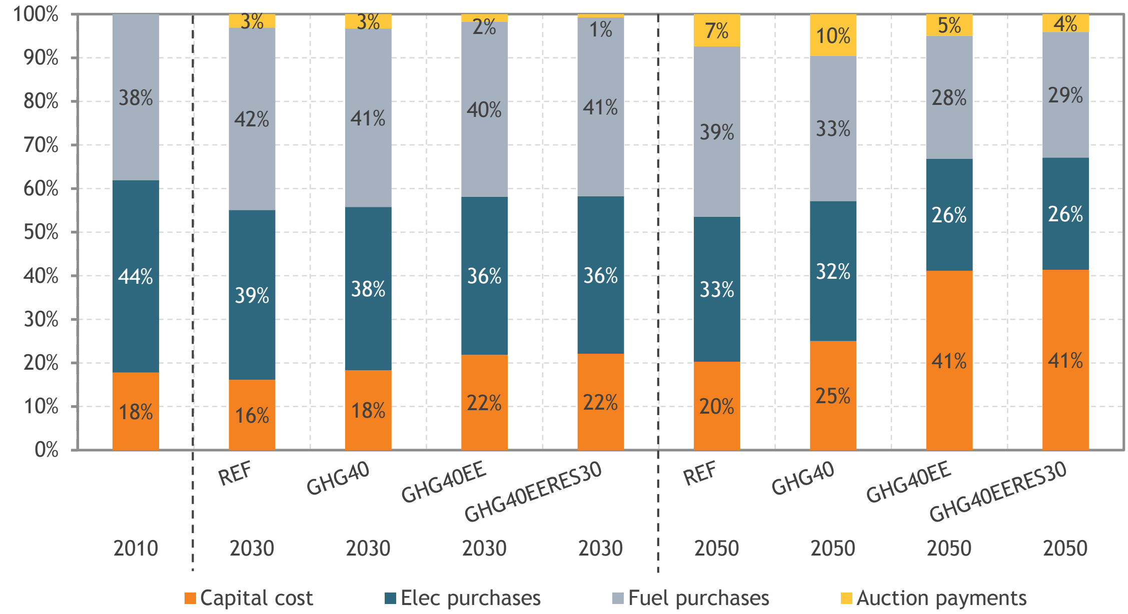
The energy cost in industry is expected to steadily increase over the projection period in all scenarios but at a higher pace in the *GHG40 scenarios* (by 2% per year on average) compared to *REF* (1.6%). A similar growth rate in the policy scenarios hides, however, differences in the way each component of the energy cost evolves over time (see Graph 18).

In 2030, the overall structure of the energy cost does not differ much between the scenarios and with respect to 2010: energy expenses represent the bulk of the energy cost supported by industry (they range between 76 and 82%), capital cost fluctuates around 20% and the share of auction payments does not exceed 3%. Compared to 2010, the major changes in 2030 concern the presence of auction payments and a lower (resp. higher) contribution of fuel (resp. electricity) expenses to total energy cost.

The changes and differences between scenarios are much more important in the longer term (2050). Compared to 2010, the share of energy purchases drops markedly in the policy scenarios (from 82% in 2010 to less than 65% in 2050) at the "benefit" of capital cost and auction payments. The fall is even dramatic in the *EE scenarios* (*GHG40EE* and *GHG40EERES30*) where the energy purchases represent less than 55%. By contrast, capital cost extends to reach 41% in these two scenarios. This evolution is due to higher levels of investments in energy efficient and RES technologies whose aim is to reduce energy (electricity and/or fuel) consumption and hence the energy bill. The effect on the share of energy purchases applies to fuels and electricity taken separately. Auction payments and their contribution to the energy cost are influenced by two elements: the carbon price and the gap with respect to the GHG emission cap in the ETS. In the policy scenarios, the share (and level) of auction payments rank according to the carbon price in the ETS: the lower the carbon price the lower the share.

33 Excluding those for transport purposes.

**Graph 18 Components of the energy cost in industry, REF and policy scenarios, 2010, 2030 and 2050**
%




Source: PRIMES.
Note: The component "Elec purchases" includes electricity, heat and hydrogen where relevant.

Table 16 shows the evolution of the unit energy cost in industry in the different scenarios. This indicator brings together two components of industry competitiveness: the energy price and the energy intensity. The energy price is calculated by dividing the energy purchases by the final energy consumption of industry. The energy intensity is the ratio between the final energy consumption and the value added of industry.

**Table 16 Decomposition of the unit energy cost in industry, REF and policy scenarios, 2010, 2030 and 2050**
*In % of value added*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Unit energy cost | 16.2% | 17.2% | 16.5% | 15.8% | 15.1% | 13.8% | 13.3% | 10.9% | 10.5% |
| Energy intensity(*) | 0.274 | 0.197 | 0.189 | 0.178 | 0.177 | 0.160 | 0.146 | 0.123 | 0.122 |
| Energy price(**) | 590 | 874 | 876 | 888 | 854 | 861 | 912 | 884 | 857 |

Source: PRIMES.
(*): expressed in toe per thousand €'10 of value added.
(**): expressed in €'10 per toe.

In 2030, the policy scenarios display unit energy costs close to the figure in 2010 (in the range of 15.1 to 16.5%). In other words, the sharp increase in energy price is counterbalanced by a decrease in energy intensity. The growing energy price results from a rise in fuel and electricity prices and changes in the energy mix. Declining energy intensity is due to real energy efficiency improvements sometimes combined with slight restructuring effects[34]. As expected, the *EE scenarios* show the lowest energy intensities.

By 2050, the unit energy cost shows a declining trend. It amounts to 13.3% in the *GHG40* scenario and to around 11% in *GHG40EE* and *GHG40EERES30*. The extra decrease in energy intensity is worth noting,

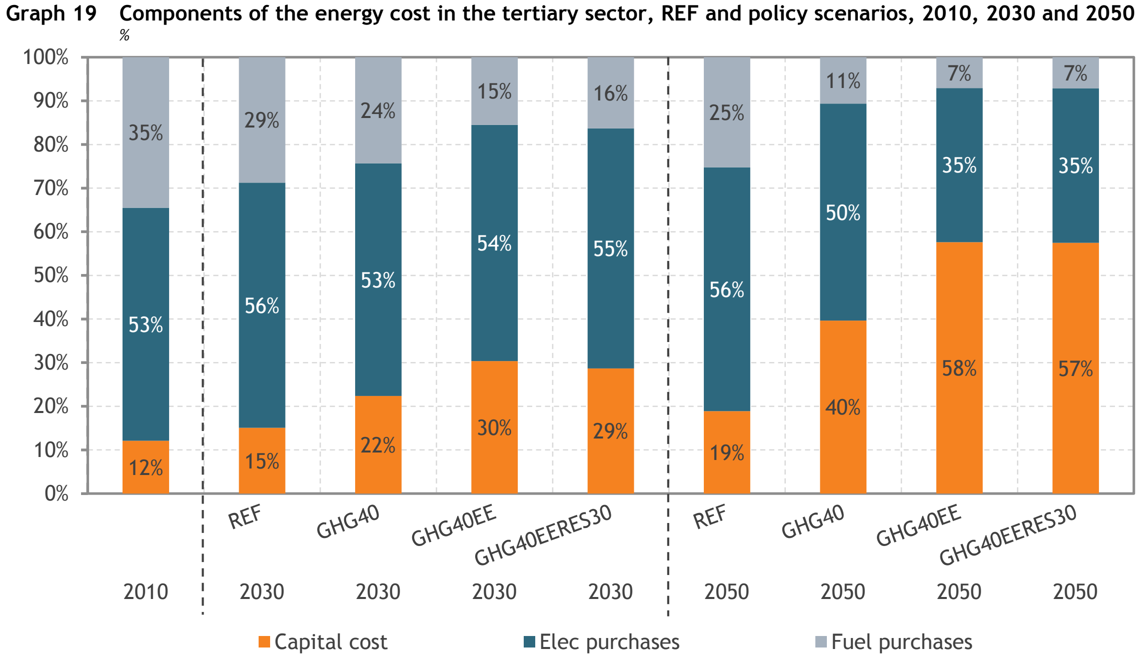
[34] By assumption, the evolution of value added of industries (i.e. those identified in the Eurostat energy balances) is similar in all scenarios. Nevertheless, some restructuring is possible within each industry.

in particular in the *EE scenarios* where energy intensity is divided approximately by a factor 2 compared to the situation in 2010. It will be a real challenge for industry to achieve such reductions in energy intensity. On the other hand, the energy price is stabilising in the period 2030-2050.

### 4.3.2. Tertiary sector

The same energy cost indicators are analysed for the tertiary sector. Graph 19 shows, for all scenarios, the changes in the structure of the energy cost in 2030 and 2050, compared to 2010. Table 17 presents the evolution of the unit energy cost and its components.

**Graph 19 Components of the energy cost in the tertiary sector, REF and policy scenarios, 2010, 2030 and 2050**




Source: PRIMES.
Note: The component "Elec purchases" includes electricity, heat and hydrogen where relevant.

The energy cost in the tertiary sector in the period 2010-2050 is projected to rise by some 2% per year on average in all *GHG40 scenarios*, compared to 1.4% in *REF*.

As regards the structure[35] of the energy cost, significant modifications can already be noticed in 2030 contrary to what happens in industry (see supra). The share of capital cost in the policy scenarios gains 10 to 18 percentage points with respect to 2010, primarily at the expense of fuel purchases. It even becomes higher than the part of the energy cost devoted to the fuel bill in *GHG40EE* and *GHG40EERES30*. On the other hand, the share of the "electricity" component remains stable at around 53%. The increase in the (share of) capital cost originates in higher investments in energy efficient equipment stimulated by the carbon value, the enabling conditions and, for the *EE scenarios*, EE policies that go beyond enabling conditions. A significant part of these investments concerns buildings insulation and hence mostly influences fuel consumption (rather than electricity consumption). Indeed, natural gas and gasoil still dominate the fuel mix for space heating in 2030.

[35] There is no auction payment in the tertiary sector, as it belongs to the non-ETS.

Beyond 2030, the impact of the enabling conditions and EE policies intensifies leading to an even higher share of capital cost in 2050: 40% in the policy scenario mainly driven by carbon values (*GHG40*) and 57 to 58% in the scenarios with ambitious EE policies (*GHG40EE* and *GHG40EERES30*). This evolution again has a direct effect on fuel purchases whose share collapses to reach less than 11% in the policy scenarios in 2050. Although the purchase costs related to electricity, heat and hydrogen do not evolve much (in relative terms) in the *GHG40* scenario (around 50%), they shrink between 2030 and 2050 in the *EE scenarios*. In 2050, they represent slightly more than one third of the energy cost in the tertiary sector.

The unit energy cost in the tertiary sector is much lower than in industry. This is mainly due to the relative energy intensiveness of both sectors despite the fact that the tertiary sector experiences, on average, higher energy prices than industry (see Table 16 and Table 17).

**Table 17 Decomposition of the unit energy cost in the tertiary sector, REF and policy scenarios, 2010, 2030 and 2050**
*In % of value added*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Unit energy cost | 2.4% | 2.7% | 2.5% | 2.3% | 2.4% | 2.1% | 1.8% | 1.3% | 1.3% |
| Energy intensity(*) | 0.024 | 0.017 | 0.015 | 0.013 | 0.013 | 0.013 | 0.008 | 0.007 | 0.007 |
| Energy price(**) | 1002 | 1606 | 1662 | 1810 | 1810 | 1582 | 2184 | 2008 | 1999 |

Source: PRIMES.
(*): expressed in toe per thousand €'10 of value added.
(**): expressed in €'10 per toe.

Notwithstanding a substantial escalation of the energy price (+66% in *GHGH40* and +81% in *GHG40EE* and *GHG40EERES30*), the unit energy cost remains roughly stable in 2010-2030 thanks to a simultaneous decrease in the energy intensity of the sector. This effect can primarily be attributed to the reduction in fossil fuel consumption for heating uses (see supra).

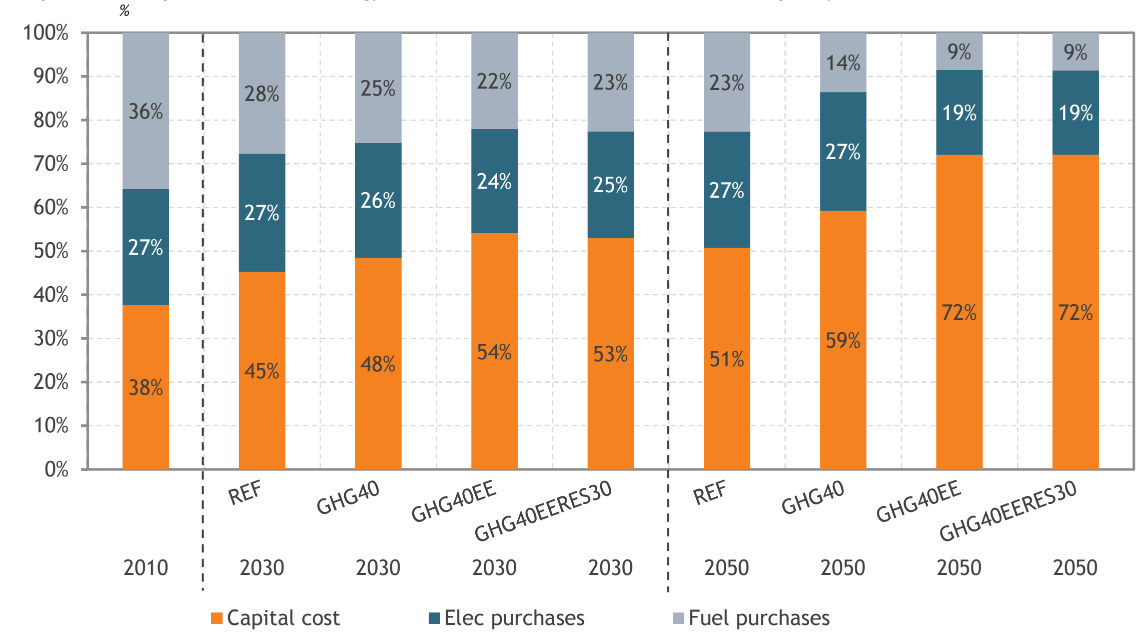
In 2050, the unit energy cost is below the 2010 level: it lies between 1.3 and 1.8%. The lowest percentage applies to the *EE scenarios*. In the long term, the impact of the policy scenarios on energy intensity dominates the energy price effect.

### 4.3.3. Residential sector

Even though the residential sector has a different energy cost structure than the tertiary sector, it shows similar evolutions: a steady increase in the share of capital cost, all the more significant when more ambitious EE policies (i.e. in *GHG40EE* and *GHG40EERES30*) are implemented, a constant share of electricity purchases except at the end of the projection period in the *EE scenarios* when it diminishes considerably and a constant decrease in the part taken by energy purchases (see Graph 20). The drivers of the changes are also identical in both sectors: a progressive removal of barriers to energy efficiency in buildings, the uptake of more efficient heating equipment and electric appliances, a speeding up of the renovation rate of buildings.

In quantitative terms, the share of capital cost in 2030 fluctuates around 50% in the policy scenarios (against 38% in 2010) and the remaining 50% are almost equally allocated between fuels and other energy carriers (electricity and heat). In 2050, the share of capital cost represents almost 60% in the *GHG40* scenario and slightly less than three quarters in the *EE scenarios*. Fuel (resp. electricity) expenses range from 9 to 14% (resp. 19 to 27%). At the end of the projection period, the "electricity" component also includes hydrogen.

**Graph 20 Components of the energy cost in the residential sector, REF and policy scenarios, 2010, 2030 and 2050**




Source: PRIMES.
Note: The component "Elec purchases" includes electricity, heat and hydrogen where relevant.

The evolution and decomposition of the unit energy cost in the residential sector are presented in Table 18. In 2030, the unit energy cost is slightly above the 2010 level in the *GHG40* scenario (5.5% vs. 5% in 2010) whereas it is comparable to the 2010 level in *GHG40EE* and *GHG40EERES30*. In the former scenario, the decrease in energy intensity does not fully compensate for the increase in energy price. On the other hand, the more ambitious energy efficiency policies in the *EE scenarios* do allow for such a compensation.

**Table 18 Decomposition of the unit energy cost in the residential sector, REF and policy scenarios, 2010, 2030 and 2050**

*In % of private consumption*

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Unit energy cost | 5.0% | 5.7% | 5.5% | 4.9% | 5.0% | 4.3% | 4.2% | 3.0% | 3.0% |
| Energy intensity(*) | 0.048 | 0.034 | 0.032 | 0.029 | 0.029 | 0.024 | 0.017 | 0.013 | 0.013 |
| Energy price(**) | 1045 | 1695 | 1731 | 1726 | 1732 | 1771 | 2376 | 2292 | 2270 |

Source: PRIMES.
(*): in toe per thousand €'10 of private consumption.
(**): in €'10 per toe.

In 2050, the fall in energy intensity results in a reduction of the unit energy cost by 1 to 2 percentage points compared to 2010. This fall more than offsets the doubling of the energy price between 2010 and 2050.

## 4.4. Cost of electricity generation

This part deals with the power production cost. The cost of power generation is composed of different elements. One of these elements is the fixed costs of which the annual cost of capital, constituted by investments, represents a large chunk (next to fixed operation and maintenance costs). Part 4.4.1 describes these investment costs, whilst part 4.4.2 depicts the (composition of the) average cost of power production.

### 4.4.1. Investments

This section translates the investments estimated in section 3.2.5 into monetary terms.

Between 2010 and 2030, investments in the power system amount to 32 billion € in *GHG40*, 31 billion € in *GHG40EE* and 36 billion € in *GHG40EERES30* (compared to 31 billion € in *REF*).

Between 2030 and 2050, 46 billion € in *GHG40*, 31 billion € in *GHG40EE* and 33 billion € in *GHG40EERES30* (compared to 31 billion € in *REF*) are required to 1) cover increasing load, 2) replace end-of-technical-lifetime and decommissioned units, 3) guarantee back-up for variable renewable technologies. Investments over the 40 year period (2010-2050) then boil down to 78 billion € in *GHG40*, 62 billion € in *GHG40EE* and 70 billion € in *GHG40EERES30* (compared to 62 billion € in *REF*).

These amounts are enormous and seem counterfactual to what we observe today in the Belgian electricity markets, where a complete lack of investments and even a wave of disinvestments can be detected. What these results then convey, is that the amount of investments and the ensuing capacity calculated by the model are deemed necessary to 1) be able to answer demand at all times, 2) achieve the nationally induced targets (set at European level) in terms of greenhouse gas emission reductions in the *GHG40 scenarios* both in 2030 and 2050 (and renewable energy sources in *GHG40EERES30*), 3) secure electricity supply, both in terms of production and capacity (see 3.2.6). These results nonetheless do not give information on how the capacity additions will be triggered or who will undertake them. In order for these investments to prevail, it is crucial to straighten out the current investment climate and to assess the market failures explaining the potential investment deficit, e.g. market interventions, market functioning, market failures in other markets, etc. These topics nonetheless are out of the scope of this paper.

### 4.4.2. Average cost of power generation

These investments have an undeniable effect on the total costs that the power sector has to commit to in the future. In this, the choice of technology applied to cover demand is crucial since this technology not only influences the height of the equity that has to be reimbursed, but also determines whether and how much fuel costs have to be paid and whether and how much emission rights have to be bought on the Emission Trading System market.

Table 19 presents an overview of the average cost of electricity generation for all scenarios in the years 2010, 2030 and 2050. Similar evolutions can be noted in *REF* and the *EE scenarios*, but *GHG40* seems to digress. Whereas the former do reach a peak in costs around 2030 of 104-105 €/MWh (108 €/MWh) in the *EE scenarios* (*REF*) followed by a declining trend towards 95-96 €/MWh (100 €/MWh) in the *EE scenarios* (*REF*), average costs in *GHG40* continue to mount to an absolute maximum level of 119 €/MWh in 2050.

**Table 19 Decomposition of average electricity generation costs, REF and policy scenarios, 2010, 2030 and 2050**
***€'10/MWh***

| | 2010 | 2030 | | | | 2050 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | REF | GHG40 | GHG40EE | GHG40EERES30 | REF | GHG40 | GHG40EE | GHG40EERES30 |
| Fixed | 31.9 | 56.7 | 60.1 | 56.9 | 64.8 | 50.1 | 53.0 | 47.0 | 52.7 |
| Variable | 31.7 | 44.6 | 41.4 | 43.2 | 38.9 | 36.4 | 48.2 | 31.6 | 28.7 |
| Other | 0.2 | 6.7 | 7.0 | 4.1 | 1.8 | 13.7 | 17.8 | 17.8 | 13.9 |
| Total | 63.8 | 108.0 | 108.5 | 104.2 | 105.4 | 100.2 | 119.0 | 96.3 | 95.3 |

Source: PRIMES.

The table also demonstrates the decomposition in cost elements: fixed (capital costs), variable (fuel and operational costs) and other costs (auctioning costs for the purchase of emission rights).

In 2030, all scenarios tend to become more capital intensive (compared to the situation in 2010), meaning that the fixed cost part represents more than 50% of the total average cost. The share of the fixed in total costs in the *GHG40EERES30* scenario even reaches a high of 61% because of the outspoken capital intensity of renewable energy sources.

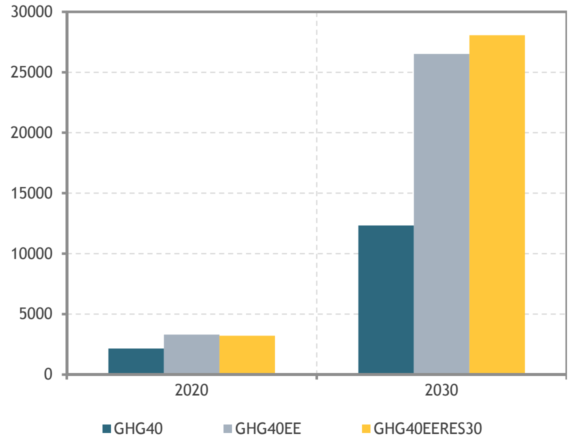
In 2050, things change. The other costs start to gain a bigger weight. This has to do with the fact that a significant part of the power produced is generated through the burning of natural gas (see 3.2.3). Burning of fossil fuels emits carbon and since carbon prices increase dramatically during the projection period (see Table 1), the other costs surge. In 2050, they occupy a share between 15% (*GHG40* and *GHG40EERES30*) and 18% (*GHG40EE*) compared to 14% in *REF*. Lowest average costs are noted in *GHG40EERES30*: they arrive at 95 €/MWh. This is also the only scenario that (still) exhibits a ratio fixed (capital) on total costs above 50%. The capital intensity of RES is at the source of this effect.

The main conclusion of this section is that a huge amount of investments characterises the future power generation sector. Investments for the period 2010-2050 in the policy scenarios reach heights between 62 and 78 billion €, undeniably impacting the average cost of power generation. The latter increases dramatically by 2030 in the policy scenarios. By 2050, the *EE scenarios* nevertheless manage to curb the growth in average costs, whilst costs in *GHG40* keep on mounting to levels that are on average 20% higher than *REF's*.

## 4.5. Job creation

In addition to the different cost indicators, a dedicated employment analysis of some selected sectors (amongst which the power generation sector) was conducted. For this purpose, the multiplicator methodology described in Wei, Patadia and Kammen (2010) and used in Devogelaer (2013) was applied. It focuses more specifically on the employment impacts of additional investments in the power sector (covering coal, natural gas, nuclear, wind, solar, biomass, geothermal and hydro) and retrofitting of energy efficiency equipment in buildings (e.g. residential houses) and non-industrial buildings (e.g. offices). Basically, it attempts to estimate how many additional jobs would be created by undertaking these investments.

**Graph 21 Additional annual job-years, policy scenarios, 2020 and 2030**
*Total FTE's wrt REF*




Source: FPB calculations.
Note: FTE=full-time equivalent.

Graph 21 provides estimates of the relative employment effects in terms of number of full-time equivalents generated by, on the one hand, differences in the energy mix in the power generation sector, on the other, energy efficiency endeavours. Two years are looked upon: 2020 and 2030[36].

In 2020, incremental employment (with respect to *REF*) in the three policy scenarios represents between 2,200 and 3,300 full-time equivalents (FTE's). Major job creation trigger are the changes in energy efficiency requirements in the residential and tertiary sector as the electricity mixes in the different policy scenarios do not digress much. The latter is due to the fact that all scenarios implement the same nuclear phase-out calendar, simulate the same legislative 2020 Climate/Energy package and have the same no-go investment policy on coal-fired power stations.

In 2030, additional FTE's shoot to levels above 25,000 in the *EE scenarios* (26,500 in *GHG40EE* and 28,100 in *GHG40EERES30*), whereas they are estimated to be at 12,300 in *GHG40*. The situation has changed somewhat with more marked divergences between scenarios as regards their power mix (e.g. relatively more offshore wind and biomass in *GHG40EERES30*). Still, the energy efficiency component is preponderant, so it should come as no surprise that the *EE scenarios* are to gain the most in terms of employment impact (see also Meijer et al., 2012). It should also be pointed out that energy efficiency jobs (construction, renovation, glazing, etc.) are largely locally anchored jobs, hence creating a significant number of non-outsourceable domestic jobs.

Two considerations have to be made, both with a conceivable impact on the estimated job creation potential in the policy scenarios. First, it has to be pointed out that this analysis focuses on both power generation and energy efficiency investments, hence it does not include the employment impact of other *filières* like for instance low-carbon transport (e.g. biofuels' value chain). It is nevertheless to be expected

36 Basically because in the long term, other mechanisms are at play (see Devogelaer, 2013).

that these chains also create additional employment. This is particularly relevant for *GHG40* as this scenario contains a lot of (advanced) biofuels in transport.

Second, since energy costs are bound to increase (see section 4.3), negative employment effects, most notably in energy-intensive sectors, may moderate this optimistic picture. Although these negative effects (or potential job losses) can be substantial and above all, real, they can be contained and even reverted depending on the approach that is taken on carbon pricing. The auctioning of EU ETS permits indeed provides new public revenues and additional receipts may be captured in the non-ETS sectors if the government succeeds in implementing revenue-generating instruments, such as a carbon tax. Bossier et al. (2011) demonstrate that if these revenues can be recycled into reductions of social contributions paid by employers, a beneficial impact on employment may follow.

The overall positive job effect is being confirmed in other studies (Fraunhofer et al., 2009, European Commission, 2014). They all suggest that on the aggregate level, there may be a positive contribution from policies aiming at restraining climate change, more specifically through energy efficiency ventures and renewable energy deployment. Reduction of labour taxes compensated by increasing revenues from carbon pricing can be beneficial for job creation. Energy efficiency measures and renewable energy targets in particular may help in this quest.

The main conclusion of this section is that overall net employment impacts can be positive compared to *REF* on the aggregate level. Reduction of labour taxation compensated by increasing revenues from carbon pricing could be beneficial for employment. In 2030, the scenario with the highest increase in employment is the one in which an ambitious EE programme and a RES target are combined. Main job creation impact originates from EE endeavours, which typically generate local jobs (e.g. building sector).

# Annex

This Annex provides a more elaborate description of the enabling conditions as well as of the policy scenarios integrating these enabling conditions. It is taken from the Commission Staff Working Document 2014 (15) final.

## The enabling conditions

In what follows, the *enabling conditions* differentiating the policy context in the *Reference* scenario from the one presumed in the policy scenarios are listed per sector: first power generation, then transport and finally buildings and industry.

For enabling a near complete decarbonisation of the *power sector*, a combination of appropriate improvement of infrastructures, fostered technological innovation and social acceptance for key technologies is modelled, and this including:

*Intelligent grids and metering*: intelligent IT systems in power distribution and in metering, as well as for managing recharging of car batteries are assumed to develop at large scale so as to become common practice before 2030; they help demand response in power markets, thus inducing further energy efficiency; they support better integration into network operations and wider diffusion of decentralised RES; they support micro-CHP and they ensure management of battery recharging/discharging bringing significant benefits for smoother load curves and higher system stability while providing even the possibility to have the electricity stored in car batteries function as a (limited) buffer. Smoother load curves also improve the economics of capital intensive power technologies, facilitating carbon-free and low-carbon power generation investments. Although the effects of the developments regarding intelligent grids and metering can only be observed in the time period after 2030, it is essential for the developments to occur already in the time period 2020-2030, as only such a development can lead to a large scale and quick uptake of the above mentioned technologies in the time period after 2030. The commitments for 2030 and 2050 must be firm in order to incite/oblige infrastructure developments before these are justified by demand. A strong market coordination is necessary as well as strong commitments by regulated bodies such as DSOs, as it is difficult to assume that these developments would occur entirely based on initiatives of privately owned institutions. Safety and security of supply must be broadly tested and be operational in order for the large scale transformations after 2030 to occur.

*Infrastructure to harvest decentralised as well as remote RES for power generation*: higher RES potentials and earlier availability of this potential is assumed, especially for decentralised RES and remote areas offering big potential for wind and maritime RES; this is enabled by a portfolio of synergetic developments involving streamlining of permitting procedures, higher investment in and timely availability of grids (both high voltage, incl. DC lines for e.g. remote wind areas, and smart grids supporting management of decentralised RES, storage of RES generated electricity in form of hydrogen as well as electricity demand response to high RES availability through appropriate price signal by smart and net metering (that also accounts for RES/CHP electricity flowing from consumers to the grid); these policies, despite not including financial support to RES, imply higher potential at equal cost levels, hence higher uptake of RES technologies, compared to Reference, in the period after 2020. The enabling conditions imply that the total potential of RES increases between 4 and 6% by 2030 compared to the Reference scenario for wind–onshore, wind-offshore and solar PV. The additional potential is mainly in highly decentralised RES (which depend on distribution grid infrastructure, discussed above) and in large scale offshore wind in remote areas (which depends on long distance DC systems to be also developed). The developments and the supporting infrastructure are assumed to develop before 2030 and to accelerate after 2030. The higher RES potential by 2030 allows approx. 3 p.p. higher RES-E share in 2030 compared to a scenario without enabling setting with equal emission reduction target in 2030.

*Gas and hydrogen*: technological progress enabling mix of hydrogen and bio-gas in gas supply and possibility to use hydrogen-based storage for balancing RES power and so exploiting variable RES at larger scale; these options develop after 2035, although testing for safety and security of supply must occur already in the previous decade anticipating the strong commitments for emission reductions. The analysis of enabling conditions does not deal with the institutional and regulatory issues to bring about such conditions, but it clearly highlights the need for such outcomes.

Also for the decarbonisation and electrification of the *transport sector*, enabling conditions are presupposed. In the transport sector thanks to the anticipation of strong commitments towards emission reductions and successful market coordination electrification is enabled by a combination of the development of battery recharging infrastructure, and R&D to improve the performance and costs of batteries for vehicles. This allows specific policy instruments, such as regulatory measures on $CO_2$ standards to be more effective in bringing about market acceptance and uptake of electric vehicles as key means to achieve decarbonisation of transport. Similarly strengthened R&D being up to the challenge of deep decarbonisation objectives supports innovation in biofuel supply, which facilitates decarbonisation in transport uses without electrification option.

*Battery technology development*: Substantial R&D is assumed to take place in the decade 2020-2030 allowing for the cost of batteries to decrease compared to the Reference already in 2030; costs for batteries are assumed to be around 15% lower than in the Reference scenario already in 2030. Lacking this development even if infrastructure were available, the penetration of electric vehicles in the transport sector would remain limited, due to the high costs of the vehicles. At the basis of the R&D developments is the assumption of successful market coordination policies to build confidence so as battery technology providers and car manufacturers record great progress in battery costs and performance so as to make EV cars competitive, together with the assumption about the development of recharging infrastructure.

*Transport sector-recharging infrastructure*: Battery recharging infrastructure is assumed to develop in a timely manner, achieving shortly after 2030 a sufficient coverage to allow customer confidence about recharging not only in houses or city centres but also in public areas in wider metropolitan areas and on highways. The enabling environment, driven by the anticipation of strong emission reductions, pushes toward stronger market coordination, which leads to the development of transport recharging infrastructure (and the necessary changes in the grid infrastructure-see below) as well as R&D for vehicle batteries. The development of infrastructure particularly regarding safety, large scale demonstrations, etc. are all assumed to occur in the decade 2020-2030; if such developments triggered by strong coordination would not occur, the large scale development of infrastructure and the large scale penetration of electric vehicles beyond 2030 could not materialise. The cost of achieving the same emission reduction in transport in a scenario which fails to deliver such an infrastructure and a similar scenario including enabling and subsequent development of recharging infrastructure for transport would be approx. five times higher.

*Market acceptance*: Beyond 2030, $CO_2$ regulations for vehicles are assumed to become sufficiently strict so as to enable transport electrification developing, the more significantly, the more stronger the enabling conditions are to support specific policy instruments such as $CO_2$ standards. The availability of both recharging infrastructure and mature battery vehicles at affordable prices leads to higher market acceptance of the new technology and therefore high market penetration beyond 2030, which is possible thanks to the coordinated activity pursued by diverse actors in the decade 2020-2030.

*Innovation in biofuels*: In particular in order to enable strong emission reduction in transport activities for which electrification is not possible, such as long distance truck haulage, ships and aviation, biomass related innovation policies and agriculture policies are assumed to develop appropriately so as to allow the development of new generation bio-energy feedstock (basically lignocellulosic crops) at large scale already in early years of the 2020-2030 decade. In all decarbonisation scenarios with enabling conditions therefore in the modelling the same post 2030 values for $CO_2$ standards for cars (60 $gCO_2$/km in 2035; 35g in 2040 and 25g in 2050) and LDVs (90 $gCO_2$/km in 2035, 70 g in 2040 and 60 g in 2050) are applied. The developments in agriculture are assumed to take place at the same time as large scale improvements in advanced biofuel production, initially targeted at the road transport sectors; the earlier developments of the road transport sector already around 2025 allow for a significantly larger scale deployment of fungible bio-fuels mainly after 2030. The share of advanced biofuels in total biofuels increases typically by 10 percentage points in a scenario with enabling settings in 2030 compared to a scenario without the enabling setting. A new industry would emerge with vertical integration ranging from agriculture, industrial-scale collection and pre-treatment, bio-refineries with new conversion technologies, product standardization and commercialisation.

*Overcoming some market barriers to Energy Efficiency in Buildings*: In anticipation of strong emission reduction commitment until 2050, the energy efficiency effort regarding thermal integrity of houses and buildings is assumed to continue after 2020 at a moderate pace, contrasting deceleration of such efforts after 2020 as assumed under Reference scenario conditions given that related ambition levels in the Energy Efficiency Directive and Effort Sharing Decision are only defined until 2020. The enabling environment is driven by the fact that renovations continue to be undertaken in an energy efficient manner even if no specific regulatory obligations were implemented at EU level because actors believe that e.g. energy efficient renovated buildings will continue to have a significantly higher value on the real estate market, in view of strong emission reductions to 2050. It is important that such building modernisation action continues and is not delayed beyond 2030 as it would otherwise not be possible for the building stock to achieve high enough renovation rates to compensate for the previous inactivity. Given the longevity of the building stock and the low renovation rates, the enabling setting mainly ensures that ongoing renovations post 2020 are used to also improve thermal integrity even if direct policies or economic incentives are not strong in the decade 2020-2030 at an EU level. The intensity of the assumed effort in the context of the enabling settings is however lower than the existing potential and it includes only highly cost-effective energy saving cases. Specific energy efficiency policies at both EU and MS level have to come in addition for actually exploiting the building renovation opportunities for decarbonisation up to its economic potential. Enabling conditions encompass just the highly cost-effective decarbonisation within a deliberate long term GHG reduction strategy. Enabling conditions imply higher investment in thermal integrity of houses/buildings after 2020, facilitating efficiency improvements compared to a scenario without the enabling policies. The efficiency effort is assumed to accelerate at a faster pace after 2030 compared to the decade 2020-2030. This continued action after being also encouraged by the recently adopted EE Directive creates an enabling environment which partly overcomes some of the market barriers which are particularly strong in the building sector. A more substantial removal of market barriers can only occur through relentless and ambitious targeted action/EE policies as mirrored in some of the scenarios which include policies going beyond the enabling settings.

*Heating equipment and appliances technology uptake in the domestic sector*: more accelerated uptake of efficient technologies in the households and tertiary demand sectors reflecting increased acceptance and stronger innovation is enabled by lowering perceived cost parameters and by assuming higher learning rates of demand side technologies as a result of a stable long term EU commitment on deep decarbonisation leading to better anticipation of future emission reduction commitments. Enabling policies ensure better acquaintance of customers with advanced technologies, including heat pumps which allow for higher use of electricity in heating/cooling applications, higher efficiency and thus lower emissions. This is particularly the case for heating/cooling equipment where the stronger renovations also lead to a faster renewal of equipment. Faster renewal and higher uptake of advanced technologies bring benefits in terms of unit costs as the learning potential is exploited earlier than in the absence of the enabling policy. Yet the assumptions for the enabling settings leave significant potential untapped regarding efficiency progress for energy equipment and appliances, which are additionally developed in the context of ambitious emission reduction scenarios, in particular and to a greater extent in those that include ambitious and very ambitious energy efficiency policies.

*Energy efficiency innovation diffusion in Industry*: the acceptance and adoption of best available techniques in industry and in combustion applications is assumed to accelerate after 2020 at a pace above the Reference scenario due to the anticipation of strong commitments for emission reductions; the assumed enabling environment would be mainly based on a better innovation and technology policy framework and also through hedging against future emission costs by the industry as result of higher predictability about strong emission reduction commitments in the future. Best available techniques uptake in industry is assumed to become common practice and to accelerating mainly after 2030; the effects of the industrial BAT enabling setting are assumed to be limited until 2030, compared to potential. The enabling context is modelled by assuming higher market acceptance of advanced technologies earlier in the period after 2020, compared to the Reference scenario, notably in the domain of heat recovery techniques, cogeneration, low enthalpy heat processing and horizontal systems controlling and managing energy in industry. Thanks to lower perceived costs, the industry accelerate the uptake of advanced technologies which implies that learning potential is tapped on earlier, bringing benefits in terms of cost reductions. Only very cost-effective BAT in industrial applications are assumed in the context of the enabling conditions; obviously additional drivers such as carbon prices and direct policy measures would lead to further uptake of BAT in industry.

*Interactions*: Obviously there are synergies between the above mentioned enabling conditions. For example the conditions allowing power generation to further reduce emissions also facilitate energy efficiency and emission reductions in final demand through substitutions of fossil fuels for electricity. Similarly, conditions better managing RES in power sector through hydrogen storage also reduce emissions in gas supply when some of the excess hydrogen with respect to storage capacity is fed into the natural gas grid easing thereby emission cuts at final demand level. The system-wide synergies have significant effects even in the absence of high carbon prices/values or specific RES or energy efficiency incentives.

## The policy scenarios

### a. GHG40

This scenario is set in enabling conditions – it does achieve GHG emission reductions in line with the Roadmaps in a 2050 perspective. This implies a tightening of the linear reduction factor in the ETS (see footnote 9).

#### General description

This scenario presents a medium ambition in terms of GHG emission reduction that meets in 2030 a 40% GHG reduction, and in 2050 a 80% GHG reduction compared to 1990 levels. It is based on the assumption of equalisation of marginal abatement cost of GHG emissions across the economy driven by increasing carbon prices and simulated carbon values. This represents a least cost approach to reduce GHG emissions economy-wide without yet defining the additional policies through which this would be achieved (in the non-ETS sector).

In addition, as of 2035, more stringent $CO_2$ standards for passenger cars apply to simulate electrification.

Carbon pricing incentivises fuel shifts and GHG emission reductions, it also has a pull effect on RES penetration and increase of energy efficiency.

#### GHG policies

GHG policies lead to the achievement of the 40% and 80% reduction targets in respectively 2030 and 2050 through equalisation of increasing carbon prices and values.

#### EE policies

There are no additional EE policies compared to the *Reference* scenario. In the long term, the EEVs are higher than in the *Reference* scenario to reflect the energy efficiency effect of the carbon value. Stringent $CO_2$ standards for passenger cars are implemented: 95 $gCO_2$/km in 2030 and 25 $gCO_2$/km in 2050.

#### RES policies

There is no pre-set RES target and consequently no dedicated policy in support of RES (in addition to the *Reference* scenario). The increased EU RES share of 26.5% is mostly achieved in the ETS sectors.

### b. GHG40EE

This scenario is set in enabling conditions – it does achieve GHG emission reductions in line with the Roadmaps in a 2050 perspective.

#### General description

This scenario presents a medium ambition in terms of GHG emission reduction and is mainly driven by explicit ambitious energy efficiency policies that ensure progress by addressing market imperfections and failures. Beyond concrete EE policies, carbon pricing continues to incentivise fuel shifts, energy savings and non-energy related emission reductions.

#### GHG policies

The achievement of the 40% reduction target in 2030 is realised. There is an equalisation of the overall cumulative GHG emissions up to 2050 to projections of the *GHG40* scenario with overall ETS emissions approximating cumulative ETS emissions of *GHG40*. This implies a tightening of the linear reduction factor to -2.4% applied to all ETS sectors from 2021 on.

#### EE policies

These policies are ambitious and go beyond the enabling conditions. An exhaustive list is provided in COM(2014) 15 final, some key elements are:

- Measures speeding up the buildings renovation rate which attains on average (2020-2050) 1.69% (in REF, the average renovation rate is 1.18%)
- Energy management systems introduced gradually over time
- Extended and more ambitious energy efficiency obligations
- The measures above are most strongly driven by EVs to trigger energy savings. For Belgium, the EV ranges from 288 €/toe in 2020 to 716 €/toe in 2030 further increasing to 1955 €/toe in 2050
- The efficiency standards for products driven by Eco-design Regulations are continuously tightened, broadened and extended to not yet regulated products to cover all energy product categories represented in the model
- Additional support for smart grids and efficiency standards for power networks
- Wide deployment of CHP and district heating/cooling
- Stringent $CO_2$ standards for passenger cars: 70 $gCO_2$/km in 2030 and 25 $gCO_2$/km in 2050
- Other additional transport related measures as reflected in the White Paper on Transport.

#### RES policies

There is no pre-set RES target and consequently no dedicated policy in support of RES (in addition to the *Reference* scenario), increased EU RES share of 26.4% is mostly achieved in the ETS sectors. EE policies contribute to higher shares of RES as they reduce total energy consumption.

### c. GHG40EERES30

This scenario is set in enabling conditions – it does achieve GHG emission reductions in line with the Roadmaps in a 2050 perspective. This implies a tightening of the linear reduction factor in the ETS.

#### General description

This scenario presents a medium ambition in terms of GHG emission reductions and is mainly driven by explicit ambitious energy efficiency policies and pre-set RES target that ensure progress by addressing market imperfections and failures. Beyond concrete EE policies, carbon pricing continues to incentivise fuel shifts, energy savings and non-energy related emission reductions.

#### GHG policies

The achievement of the 40% reduction target in 2030 is realised. There is an equalisation of the overall cumulative GHG emissions up to 2050 to projections of the *GHG40* scenario with overall ETS emissions approximating cumulative ETS emissions of *GHG40*.

#### EE policies

They are ambitious (identical to those in *GHG40EE*, including $CO_2$ standards for passenger cars).

#### RES policies

There is a pre-set EU RES target of 30% and in modelling, RES values are applied in order to represent the policies necessary to achieve this target. For Belgium, the RES values rise from 28 €/MWh in 2020 to 42 €/MWh in 2030 and decline to 29 €/MWh in 2050. EE policies contribute to higher shares of RES as they reduce total energy consumption.

# Acronyms

| | |
|---|---|
| boe | barrel of oil equivalent |
| CAPEX | Capital expenditures |
| CHP | Combined Heat and Power |
| $CH_4$ | methane |
| $CO_2$ | carbon dioxide |
| $CO_2$-eq. | carbon dioxide equivalent |
| DC | Direct Current |
| DSO | Distribution System Operator |
| EC | European Commission |
| EE | Energy Efficiency |
| EED | Energy Efficiency Directive |
| ENTSO-E | European Network of Transmission Operators for Electricity |
| ESCOs | Energy Service Companies |
| ETS | Emission Trading Scheme |
| EU | European Union |
| EV | Electric Vehicles |
| FBMC | Flow-Based Market Coupling |
| FPB | Federal Planning Bureau |
| FTE | Full-Time Equivalent |
| GDP | Gross Domestic Product |
| GFEC | Gross Final Energy Consumption |
| GHG | Greenhouse Gas Emissions |
| GW | gigawatt |

| | |
|---|---|
| IIASA | International Institute for Applied Systems Analysis |
| LDV | Light Duty Vehicles |
| Mtoe | million tons of oil equivalent (or million toe) |
| $N_2O$ | nitrogen dioxide |
| NGC | Net Generating Capacity |
| NTC | Net Transfer Capacity |
| NTUA | National Technical University of Athens |
| OPEX | Operating expenditures |
| PL | Peak Load |
| PV | (solar) photovoltaic |
| RAC | Reliable Available Capacity |
| RC | Remaining Capacity |
| R&D | Research and Development |
| RES | Renewable Energy Sources |
| RES-E | Renewable Energy Sources for electricity production |
| RES-H | Renewable Energy Sources for heating and cooling |
| RES-T | Renewable Energy Sources for transport purposes |
| SRM | System Reserve Margin |
| TSO | Transport System Operator |
| TWh | Terawatt-hour or $10^9$ kWh (kilowatt-hour) or $10^6$ MWh (megawatt-hour) |
| UC | Unavailable Capacity |

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