SYSTEM BALANCE
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# — 1 Energy System

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# INTRODUCTION

Energy consumption is interwoven with almost all activities in our society. Each sector (agriculture, industry, trade & services, transport and households) needs energy; the composition of the energy mix may vary according to the activities. In the food supply chain, energy is needed for the production of fertilisers, the heating of stables and greenhouses, the cultivation of agricultural land, the processing of agricultural products in the food industry, and the distribution of food to consumers. Industrial production processes require energy for the manufacture of intermediate and finished products. Fuels are also needed for the transport of goods and passengers. Energy is often still required for the heating, ventilation and cooling of the buildings in which we live and work. In addition, there are many other activities in our society that require energy: extensive communication and information technology systems (GSM towers, servers), indoor and outdoor lighting, household appliances (freezers, refrigerators, hobs, washing machines, etc.), leisure activities (travels and trips, sports and cultural activities, social activities, TVs, tablets, PCs ...) etc.

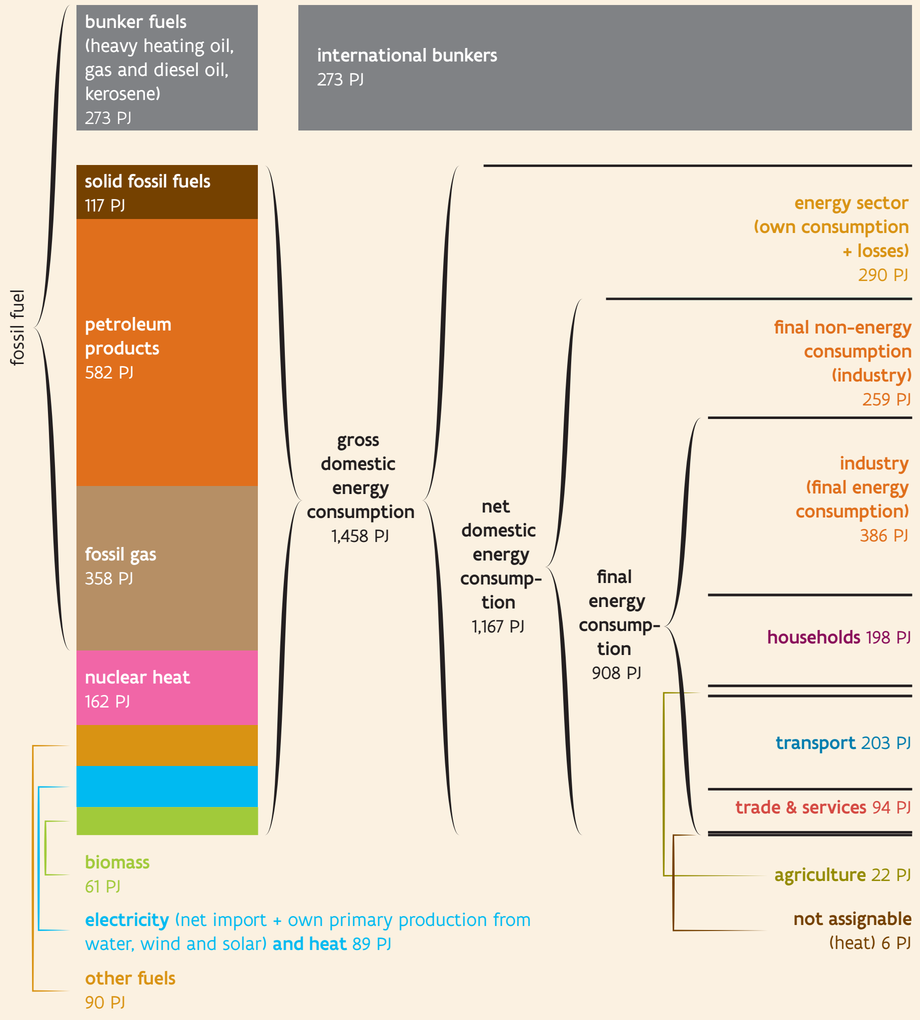
To meet this energy demand, we need to rely on primary energy sources: fossil fuels (coal, natural gas, and petroleum products), nuclear heat, biomass and other renewable energy sources like wind and solar. In this text, the supply side is defined as the production, conversion and distribution of different forms of end energy to the end users in the different sectors. The supply side includes, among others, power plants, oil refineries and natural gas distribution systems. The demand side of the energy system are the end-users who use energy carriers to meet their respective needs, for example, households using natural gas for residential heating, public services using electricity for street lighting, or the steel industry using coal or coke to smelt iron in their blast furnaces.

Both on the supply side and the demand side, imported fossil energy sources still play a major role. Electricity accounts for only a portion of the end energy consumption in Flanders. Electricity generation is to a large extent based on nuclear facilities that were commissioned between 1975 and 1985 and on the flexible use of a number of fossil fuel power plants. The share of green electricity in Flanders' electricity production is increasing steadily, amounting to 12.7 % in 2015[1]. End energy consumption in particular, but also electricity production and oil refineries cause a good deal of environmental pressure. This environmental pressure is attributable above all to emissions of greenhouse gases (mainly $CO_2$) and emissions into the atmosphere of pollutants such as $NO_x$, $SO_2$, NMVOCs, PAHs, dioxins, particulate matter and heavy metals. To further reduce the environmental pressure from the energy system, energy consumption should be limited wherever possible (e.g. turning off the light when leaving a room), remaining energy consumption needs to be organised as efficiently as possible (e.g. replacing halogen lamps with LED lamps), and energy production should be renewable wherever possible with respect for people and the environment (e.g. generation of electricity by solar panels). Moreover, the growing share of variable renewable electricity generation (wind and solar energy) calls for a better alignment of electricity generation and energy consumption (e.g. deploy electric boilers on moments with a large supply of renewable electricity). Insight into the distribution of energy consumption across the various energy services allows potential efficiency gains to be identified.

Until two decades ago, the energy system consisted of two large blocks: central production at a few refineries and large power stations, and decentralised energy consumption by end-users in economic sectors and by households. Together with efforts to achieve increased use of renewable energy sources, a third segment, that of the so-called prosumers, i.e. producers and consumers of their own energy, gradually emerged. Also in the efforts to identify efficiency gains, smaller decentralised networks are created via which (secondary) energy flows such as residual heat are exchanged locally.

The first part of this chapter deals with the demand side and the supply side of the energy system. For the demand side, the energy demand of the sectors, the consumption of the energy carriers and the energy services will be addressed. For the supply side, we will discuss how the final energy demand in Flanders is met and which primary energy sources are used for this purpose. Subsequently, the environmental pressure from both the consumption and the production of energy will be described. To conclude, solution directions will be presented that enable the energy system to be made more sustainable through a combination of optimisation and innovation.

**Figure 1.1** Flowchart energy consumption and shares of energy carriers in primary energy consumption (Flanders, 2014)




For primary energy consumption, different definitions are used by IEA, Eurostat and other agencies. In contrast to this figure, some of these definitions exclude the final non-energy consumption and maritime bunkers (but not aviation bunkers).
International bunkers, i.e. fuels for international maritime and aviation transport, are not taken into consideration in this text.
Some 6 PJ heat cannot be assigned to one particular sector for 2014, and is not taken into consideration in the text. As a result, the domestic energy consumption (discussed here) lies just below 903 PJ.

**Source:** MIRA based on Aernouts et al. (2016)[2]

# SOCIETAL DEVELOPMENTS AND ACTIVITIES

## Demand side of the energy system

### Energy consumption in Flanders

The total energy consumption in Flanders or gross domestic energy consumption (GDEC) in Flanders comprises all energy consumed by the energy (conversion) sector, industry, households, trade & services, agriculture and transport (**Figure 1.1**). In 2014, the GDEC in Flanders amounted to 1,458 PJ; it peaked in 2010 at 1,654 PJ.

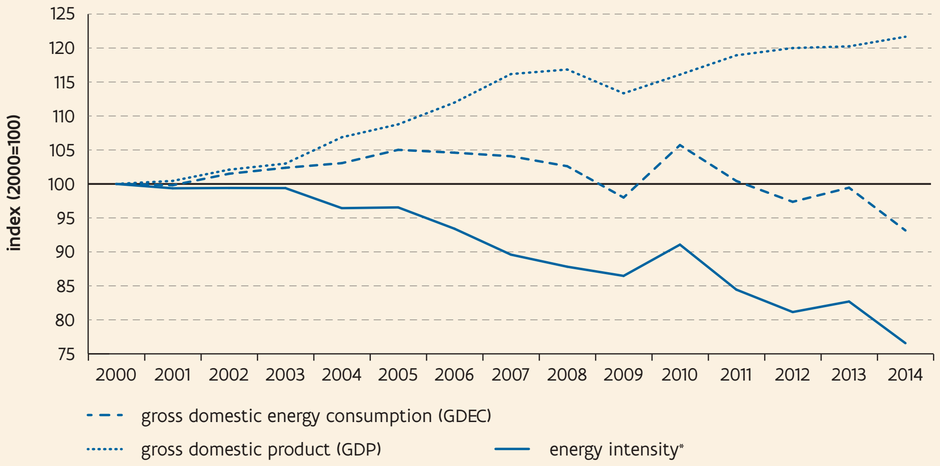
The difference between gross and net domestic energy consumption is the energy use in the energy sector including transformation, transmission and distribution losses, and amounted to 290 PJ or 20 % of the GDEC in 2014. Energy consumption in the energy sector (supply side) is determined by the activities in the other sectors (demand side), the need for heat being determined in part by climatic conditions. The energy sector in Flanders comprises mainly oil refineries, electricity producers and companies ensuring the transmission and distribution of electricity and natural gas to end users.

The net domestic energy consumption can be split up into final energy consumption and final non-energy consumption whereby energy sources are used as raw material. The latter takes place almost exclusively in the (chemical) industry, and mainly involves the use of natural gas for the production of ammonia and fertilisers, the use of naphtha for the manufacture of various plastics (polypropylene, polyethylene, etc.) and the use of derivative petroleum products as organic lubricants. In 2014, the final non-energy consumption amounted to 259 PJ or nearly 18 % of the GDEC. Limiting the non-energy consumption of (fossil) energy sources is not an energy issue, but is related above all to materials management.

The final energy consumption refers to the use of energy carriers such as coal, natural gas and electricity for applications such as heat supply and propulsion. In 2014, the final energy consumption amounted to 908 PJ or 62 % of the GDEC. **Figure 1.1** shows that industry is the biggest energy consumer with over two-fifths of the total final energy consumption. The industry in Flanders is very energy intensive. Energy consumption in agriculture, with slightly over 22 PJ, is limited (2 % of the final energy consumption). Compared with industry, agriculture also has low employment and low added value. The activities in trade & services, the most important sector in Flanders in terms of added value and employment, are not very energy intensive and account for only one-tenth of the final energy consumption. Households and transport each have a share of slightly over one-fifth of the final energy consumption.

In the evolution of energy consumption, a distinction can be made between the annual variations and the longer-term trends. The energy consumption in industry, transport and trade & services fluctuates depending on the economic activities. Thus, energy consumption decreased sharply as a result of the financial-economic crisis of 2008-2009. Climatic conditions such as, for example, the severe winters of 2010 and 2013, play a significant role in the energy consumption for heating and possible cooling of buildings and greenhouses by households, trade & services and agriculture. Between 2000 and 2014, all sectors exhibit an overall decreasing energy consumption, after having peaked between 2000 and 2010. An exception is the transport sector where an increase in the number of vehicle kilometres travelled leads to a further increase in energy consumption.

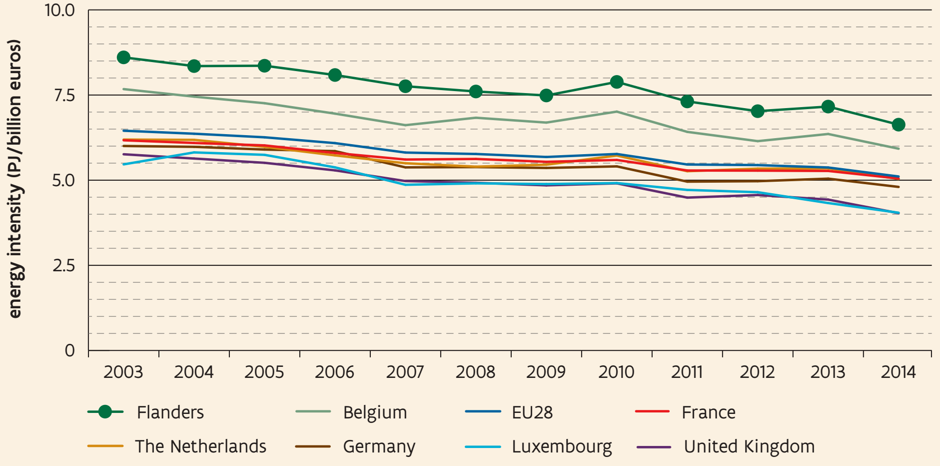
## Figure 1.2.a Evolution energy intensity (Flanders, 2000-2014)




* energy intensity = amount of gross domestic energy consumption (GDEC) per unit of gross domestic product (GDP; expressed in chain euros)

**Source:** MIRA based on Aernouts et al. (2016)[2] and Departement Kanselarij en Bestuur

## Figure 1.2.b Evolution energy intensity (Flanders, Belgium and neighbouring countries 2003-2014)




* energy intensity = amount of gross domestic energy consumption (GDEC) per unit of gross domestic product (GDP; expressed in chain euros)

**Source:** MIRA based on Aernouts et al. (2016)[2] and Departement Kanselarij en Bestuur

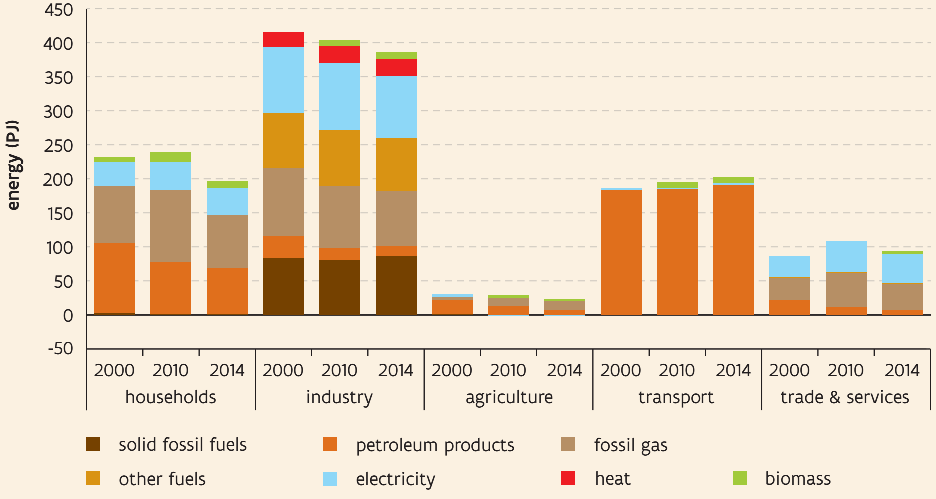
## Trend towards a less energy-intensive economy continues

**Figure 1.2.a** shows that Flanders achieved a clear decoupling between economic growth and energy consumption between 2003 and 2009. As a result, the energy intensity of the Flemish economy decreased by almost 7 % between 2000 and 2009. This change in energy intensity was the result of both structural effects (shifts in the importance of sectors within the Flemish economy) and changes in energy efficiency (for example, changing energy consumption per unit produced or per service delivered, also under the influence of energy policy agreements and benchmarking covenants). The financial-economic crisis slowed this favourable trend in 2008 and 2009, when in a number of energy-intensive industrial sub-sectors (e.g. chemicals) the activity level fell more sharply than the total energy consumption. In fact, also at lower production rates, plants and machinery must be kept running, buildings heated, storage areas refrigerated, etc. In general, energy efficiency will be lower at part load or when underutilised. Furthermore, companies planning to invest in energy-saving technology were confronted with tighter constraints for obtaining credit. In 2010, the trend was even abruptly interrupted as the energy intensity in Flanders increased again (+6 % in one year), mainly due to the extremely cold winter months. Thanks to a few years with mild winter months and a reduced central non-renewable electricity production, the overall downward trend was resumed between 2011 and 2014. Today, the energy intensity is 23 % below the 2000 level, whereas the GDEC over the period from 2000 to 2014 decreased by only 7 %. With this decrease in energy intensity, Flanders is keeping pace with the evolution in neighbouring countries (-18 % to -30 %) and the EU28 (-21 %). However, given the higher starting point, the Flemish economy remains substantially more energy-intensive than its neighbouring countries (**Figure 1.2.b**).

## Energy carriers: fossil fuels predominate

In 2014, the energy needs of end users were met by four final energy carriers: fossil fuels (solid fuels, petroleum products, gas and 'other fuels'), electricity, biomass and useful heat (**Figure 1.3**). The share of fossil fuel combustion processes gradually fell from 83 % (636 PJ) in 1990 to 73 % (666 PJ) in 2014, yet these processes remain dominant among end users. An electrification of the energy consumption may lead to a reduction in the total environmental pressure, especially when the electricity is generated by means of renewable energy sources. There is as yet no real indication of such an electrification of the final energy consumption in Flanders. The electricity share has for ten years been fluctuating around 19 %. Slightly more visible is the advance of biomass by a factor of 4: its share increased from 1 % in 1990 to 4 % in 2014. The remainder is related mainly to the useful application by industrial companies of residual heat originating from the energy sector (slightly less than 3 %) and net green heat extracted from the environment by solar boilers, heat pumps and heat pump boilers (less than 1 %)[2, 4].

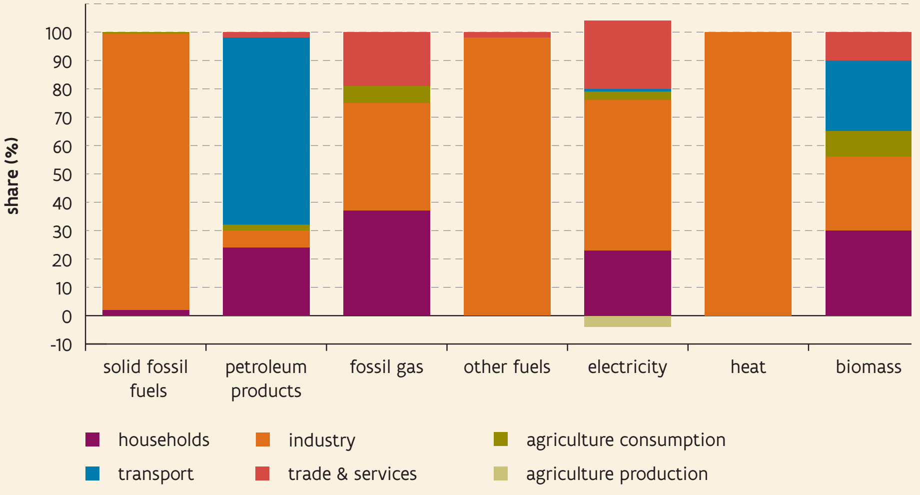
## Figure 1.3 Evolution of energy end use by sector broken down by energy carrier (Flanders, 2000-2014)




'Other fuels': mainly by-products – usually of fossil origin – of the chemical industry where they are used as energy carrier.

**Source:** MIRA based on Aernouts et al. (2016)[2]

## Figure 1.4 Energy end use by energy carrier broken down by sector (Flanders, 2014)



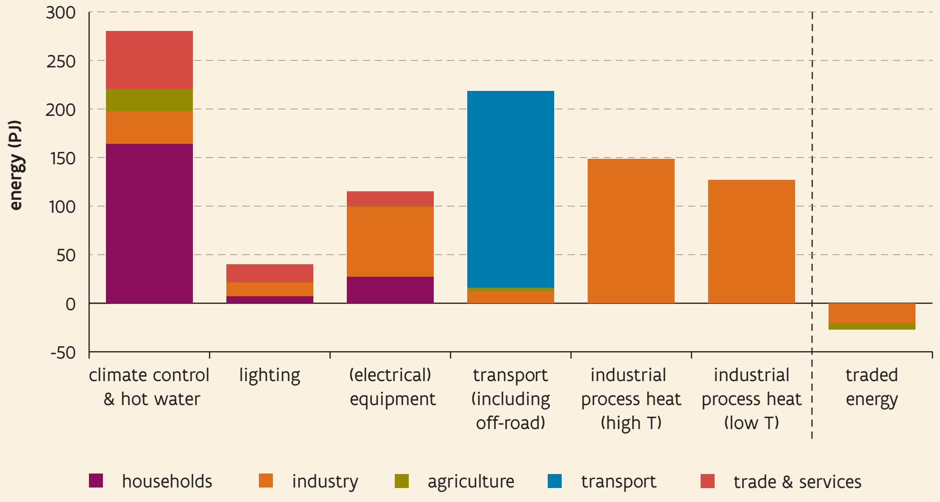

**Source:** MIRA based on Aernouts et al. (2016)[2]

Solid fossil fuels such as coal, coke and coal tar are used almost exclusively in industry and more specifically in the sub-sector of iron & steel (**Figure 1.4**). Half of the fossil fuels are petroleum products, with diesel, petrol and heating oil as main energy carriers. The biggest user of petroleum products is the transport sector (petrol and diesel). Natural gas is the most widely used fossil gas, alongside a small portion of coke and blast furnace gas produced and traded by the industry. Three-fourths of the fossil gases are consumed by households and industry.

The industry accounts for half of the electricity consumption. Other major electricity consumers are trade & services and households. In the transport sector, by contrast, the relative share of electricity (tram, metro, electric train and electric road vehicles) remains, as yet, limited. Agriculture has been a net electricity producer since 2014. Co-generation or combined heat and power plants (CHPs) supply not only heat and $CO_2$ to promote crop growth in greenhouses, but at the same produce a surplus of electricity that is subsequently traded.

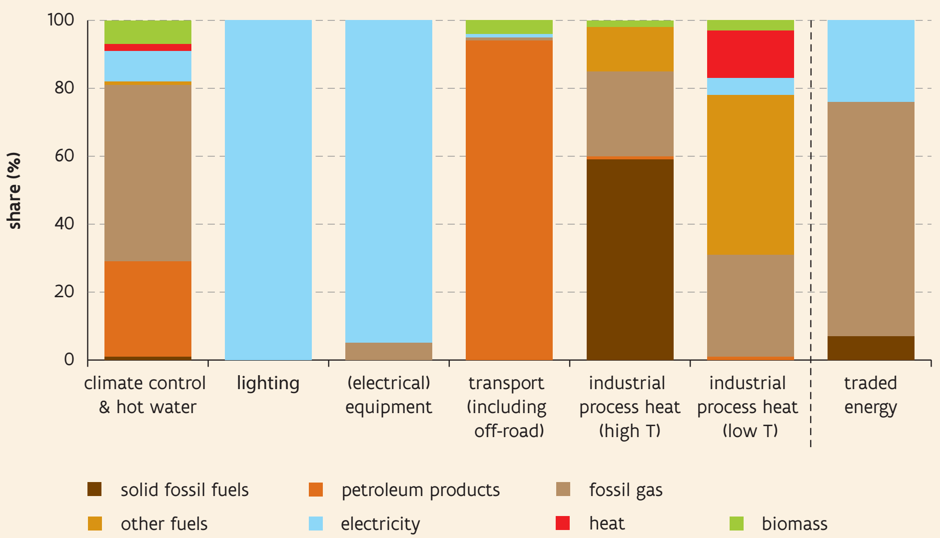
Biomass (solid, liquid and gaseous) and (traded) heat together account for almost 7 % or 61 PJ of the total energy end use. In contrast to biomass, which is used in all sectors, (traded) heat is used almost exclusively in industry. The final consumption of biomass has quadrupled since 2000. The increase was noticeable in virtually all sectors, but above all in the paper sector, road traffic, and households.

**Figure 1.5** Energy end use by energy service broken down by sector (Flanders, 2014)




**Source:** MIRA based on Aernouts et al. (2016)[2], Couder (2013)[5], ODYSSEE-MURE (2016)[6], CLO (2016)[7], Pennartz & Van den Bovenkamp (2016)[8]

**Figure 1.6** Energy consumption by energy service broken down by energy carrier (Flanders, 2014)




**Source:** MIRA based on Aernouts et al. (2016)[2], Couder (2013)[5], ODYSSEE-MURE (2016)[6], CLO (2016)[7], Pennartz & Van den Bovenkamp (2016)[8]

### Energy services: climate control & hot water in first place

To identify where energy savings or efficiency gains can be made, it is important to know for which purposes energy is used. **Figures 1.5** (by sector) and **1.6** (by energy source used) map the energy end use, broken down into seven energy services: climate control & hot water, lighting, (electrical) equipment, transport, industrial process heat at high temperature, industrial process heat at low temperature, and traded energy.

Climate control & hot water (for bath, shower, etc.) accounted for approximately 278 PJ or 31 % of energy end use in Flanders in 2014. By climate control is meant the heating, ventilation and cooling of buildings. Slightly more than four-fifths of the energy consumption for climate control & hot water is used for building heating, and over 80 % of it is generated with fossil fuels (**Figure 1.6**)[2, 5, 6, 7, 8].

Only a small portion of the energy end use in Flanders goes to lighting: 4 % or 40 PJ. The share of electrical lighting in agriculture, households and industry is fairly similar, varying between 3 and 4 %[2, 5, 6, 7, 8]. In the trade & services sector, 20 % of energy consumption goes to lighting. With a 40 % share of energy consumption for lighting, the sub-sector of offices & administration, including street lighting, is the biggest consumer[2, 5].

All sectors use electric/electronic devices such as computers, TVs and domestic appliances such as refrigerators or coffee makers. Many of these devices contain motors of widely varying capacities, from very small as in the case of hand blenders or shavers to very large as in the case of pump systems or conveyor belts in industry. Most of these motors are electrically powered (95 %), the remaining devices are powered by, for example, diesel and petrol engines. In Flanders, 13 % or 115 PJ of energy end use is used to operate this equipment. The majority or 62 % of energy for (electrical) equipment is used in the industrial sector[2, 5, 6, 7, 8].

Just under one-fourth (or 219 PJ) of the final energy consumption in Flanders is used for transport, both on-road and off-road. On-road includes both road transport and rail transport and inland navigation and aviation, together accounting for 203 PJ. Road transport (motorcycles, cars, lorries, etc.) consumes 95 % of all energy on-road. Off-road transport in industry (12 PJ) includes, for example, excavators, cranes, bulldozers, fork lifts, etc. In agriculture, this mainly involves tractors[2, 7, 8]. Just over 93 % of transport is powered by fossil fuels, slightly more than 4 % by biomass, and gas and electricity each account for over 1 %. With a share of about four-fifths, diesel is the most widely used energy carrier[2, 7, 8]. Innovative vehicle technology in the form of zero-emissions vehicles is slowly taking off.

Industry uses a great amount of process heat, which can be divided into process heat at high temperature and process heat at low and medium temperature. To bring all kinds of ovens, dryers and other furnaces to temperature, high temperatures in excess of 300 to 400 °C are required. Lower temperatures are used for steam generation and distribution, firing of distillation columns, fractioning, etc.

Almost a third of the final energy consumption in Flanders is used for process heat, of which 16 % or 149 PJ for high temperatures and 15 % or 127 PJ for lower temperatures. 85 % of the heat needed for high temperature processes originates from the burning of fossil fuels. Almost three-fifths of the fuels used are solid fossil fuels, almost exclusively within the iron and steel industry. In lower temperature processes, only one-third of the required energy originates from the direct use of fossil fuels, although indirectly a higher proportion is involved. Slightly less than half of the energy carriers for the low temperature processes are 'other fuels', which are by-products of the chemical industry - often of fossil origin - nearly all of which are used as energy source in the chemical industry[2, 7, 8].

As already mentioned, agriculture became a net electricity producer in 2014, meaning it fed electricity into the public grid. In industry, too, a portion of the energy is traded (just over 20 PJ). This is mainly blast furnace gas and a small portion of coke furnace gas and coal tar[2, 7, 8].

## Supply side of the energy system

### Imports dominate the fulfilment of the energy demand

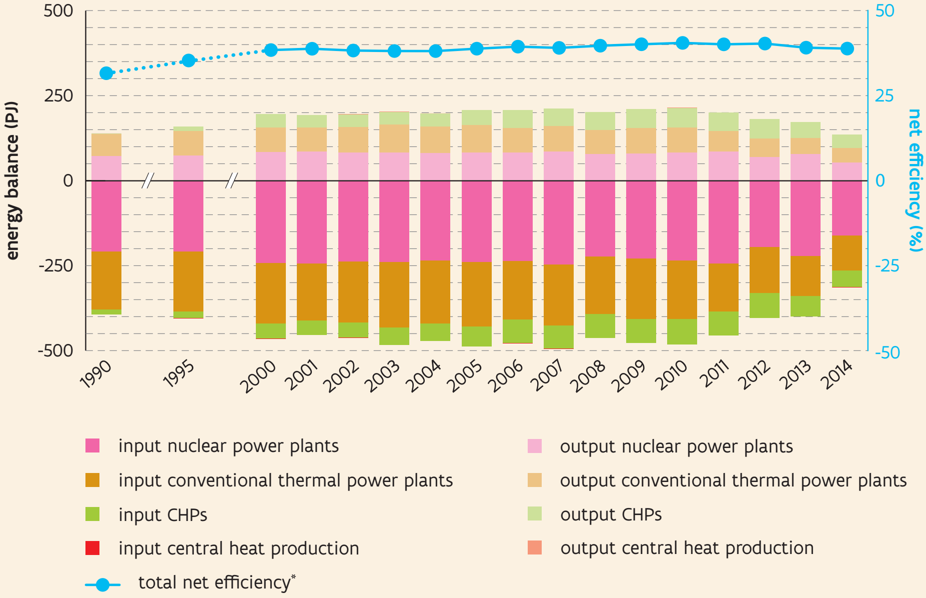
The bulk of all (traded) energy carriers used by end users is supplied from the energy sector, often after transformation of primary sources such as petroleum, nuclear fuel, natural gas and coal. These primary energy sources almost always originate from abroad. Flanders has no known uranium, petroleum or natural gas reserves. The world's major uranium suppliers are Kazakhstan, Canada and Australia. In 2014, natural gas and petroleum products were imported into Flanders mainly from other European countries (especially the Netherlands and Norway and to a lesser extent the UK for natural gas; especially Russia and to a lesser extent Norway and the UK for petroleum), supplemented with supplies mainly from the Middle East. Flanders does have over 8 billion tonnes of technically recoverable coal in the Campine coal basin. Due to the much cheaper prices on the world market, underground mining in Flanders was definitively stopped in 1992. Since then, Flanders has imported all its coal, mainly from South Africa, the United States, Australia and Russia. The Campine coal reserves also contain methane gas. VITO estimates that 7 to 31 billion $m^3$ methane gas are located in the best recoverable areas. Due to unfavourable market conditions, however, the mining activities have become highly uncertain. Finally, shale layers from which (fossil) shale gas can be extracted, occur even deeper in the Flemish soil. The potential of shale gas in the Flemish soil is as yet totally unknown, and its extraction requires the use of the controversial fracking technique. One cause of concern is the possible impact of chemicals used on water collected from the aquifers. Flanders has imposed a moratorium on fracking until it is proven safe for the environment and citizens.

### Supply of fossil fuels: possible efficiency gain limited

The efficiency of the petroleum refineries in Flanders has for years hovered around 94 %. This means that the energy content of all the petroleum products produced by the refineries, such as fuel oil, petrol and diesel, is only 6 % lower than that of the supplied petroleum. This 6 % breaks down into approximately 5 % own energy consumption in furnaces and boilers, and 1 % transformation losses (e.g. leakage losses). The possibilities of further boosting the efficiency of oil refineries are limited. Alongside further reducing the above losses, refineries can try to further reduce their own fuel consumption by minimising reflux in distillation towers, air excess in furnaces, and pressure in certain processes. Furthermore, additional investments in better insulation, heat recovery and heat integration may have an energy-saving effect.

Together with the refineries, the gas companies ensure the supply of fossil energy sources to end users. Natural gas does not undergo any transformation between the location where it is imported and the user's gas meter. However, gas companies use part of the energy themselves (e.g. in the compression stations on the network of transmission and distribution pipelines) and various leakage losses occur. Finally, gas companies have a limited electricity consumption. Own energy use and losses at gas companies together amounted to 2 PJ in 2014, or only 0.5 % of the total natural gas consumption in Flanders. In previous years, gas companies managed to limit leakage losses by gradually replacing all old cast-iron pipelines - still dating from the period of 'city gas' and located mainly in the cities - and asbestos-cement (fibre cement) pipelines with polyethene or steel pipelines that are less permeable by a factor of up to 100.

**Figure 1.7** Energy balance and net efficiency of central power and heat production (Flanders, 1990-2014)




* net efficiency = (output - own consumption - network losses) / input
Power and heat production based on solar, wind and water are not taken into consideration. For these renewable energy sources a theoretical efficiency of 100 % is assumed.

**Source:** MIRA based on Aernouts et al. (2016)[2]

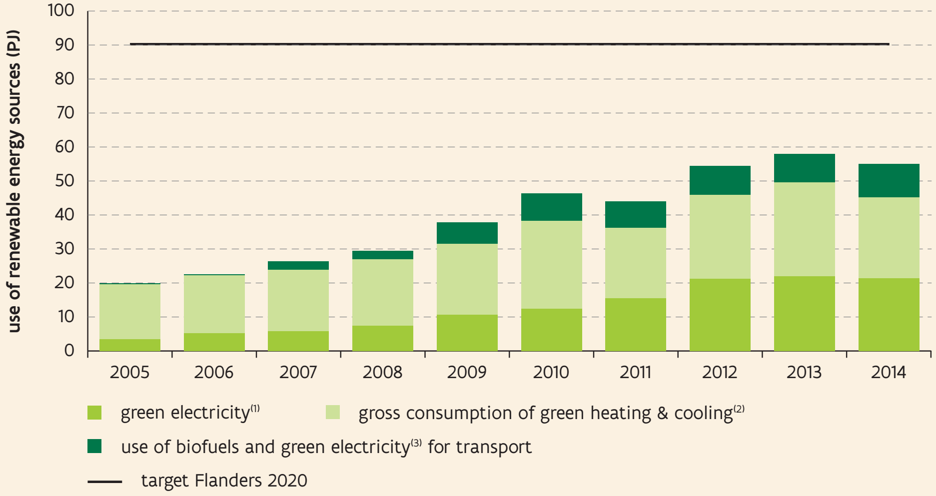
### Central electricity production: only two-fifths of primary energy converted into useful energy for end users

During the central production of electricity (and heat), only a portion of the primary energy used is converted into useful energy for end users. Alongside transformation losses and own use by power plants, energy is also lost during transmission and distribution to end users. The net efficiency of production, transmission and distribution of electricity and heat within the energy sector in Flanders takes all these losses into account. Between 1990 and 2010, efficiency increased from 31.6 to 40.5 %. Since then, efficiency declined again to 38.9 % in 2014 (right Y-axis in **Figure 1.7**). To interpret this finding, an overview of the different techniques used for electricity production in Flanders is given below.

The electrical efficiency – or the ratio of the energy content of the produced electricity and the energy content of the fuels used - of a conventional thermal power plant running on fossil fuels, amounts to 34 to 40 %. Steam and gas power plants or STEG plants attain a higher electrical efficiency of 50 to 60 % thanks to the use of two turbines. However, just as with nuclear power plants, a significant amount of residual heat is lost also in fossil power plants. Following the reduced use of coal and natural gas fired power plants, the transformation losses (and also the own energy use) have decreased sharply in absolute figures in recent years. The use of coal came under pressure due to the tightened environmental legislation, which caused a shift to natural gas power plants, and the emergence of biomass (both co-firing and pure biomass power plants) as part of the effort to increase the share of green electricity (and the associated allowance for green electricity certificates). The input of coal in power plants decreased by 83 % between 1990 and 2014. After it had quadrupled between 1990 and 2009, the use of natural gas power plants has also halved. The reason for this is that they only have to meet the remaining demand that cannot be covered by nuclear energy and the increasing supply of renewable energy sources. The latter have priority access to the power grid, whereas the electricity supplied by gas power plants can be flexibly upscaled or downscaled in relation to the remaining electricity demand. In recent years, the marginal costs of variable renewable energy sources (wind, solar), nuclear energy and coal were lower than those of gas-fired plants, so that, based on economic logic, these sources will be used first before electricity is produced on the basis of natural gas. This also means that the import of electricity from neighbouring countries, produced in nuclear power plants, coal or ignite plants, wind turbines and solar panels caused a decline in profitability of our gas-fired power plants. Net import of electricity into Belgium has steadily increased since 2010, reaching one fourth of total electricity consumption in 2015.

The nuclear power plants that were commissioned between 1975 and 1985 have dominated electricity generation in our country. Nuclear power plants are particularly suitable for the production of so-called base-load electricity and are therefore designed for continuous operation almost throughout the year. With a share of 50 to 60 % in total electricity generation, Belgium was invariably one of the top 5 countries in the world with the highest share of nuclear energy[9]. Only after 2013 did the share in Belgian electricity production drop below 50 % for the first time in over three decades, following the repeated shutdown of a number of reactors: to 47.5 % in 2014 and 37.5 % in 2015. The Nuclear Power Phase-Out Act of 2003 stipulates that no new nuclear power plants may be erected, and that the existing nuclear power plants must be closed down after 40 years of operation. According to this Act, the oldest three reactors (Doel 1 and 2, and Tihange 1) were to close in 2015 and the youngest (Doel 4 and Tihange 3) in 2025; Doel 3 and Tihange 2 were to close in 2022 and 2023 respectively. However, fearing that the security of supply might no longer be guaranteed, the Belgian government decided to prolong the operational lifespan of the first three reactors by 10 years. As a result, the nuclear power phase-out is now concentrated in the period between 2022 and 2025. In Flanders, the share of nuclear reactors in total net electricity generation has fluctuated around 45 % over the last 20 years. However, due to unforeseen, temporary shutdowns in the Doel nuclear power plant from the summer of 2012 (caused, among other things, by the investigation into possible hydrogen inclusions in the reactor wall

## Figure 1.8 Use of renewable energy (Flanders, 2005-2014)




Datasets calculated in accordance with the definitions in European Directive 2009/28/EC:
(1) The total gross power production from renewable energy sources also includes network losses and the consumption of electricity by the producers themselves. Exclusive of green power used for transport purposes.
(2) The gross consumption of green heating & cooling includes the amount of heat and cooling that is produced in Flanders from renewable energy sources, plus the consumption of other energy from renewable sources for heating, cooling and processing purposes.
(3) Applying a correction factor of 2.5 for electric road vehicles to convert to primary energy input.

**Source:** MIRA based on Jespers et al. (2016a)[4] of Doel 3), the share decreased to 37.5 % in 2014. Alongside the decreasing availability of the reactors and the planned nuclear power phase-out, it is also important to note that in nuclear power plants, only one third of the input (nuclear heat) is converted into electricity. This is also clearly indicated by the difference between input and useful output in **Figure 1.7** (left Y-axis). The remainder of the heat is not used and is largely cooled away in the cooling towers.

The final element in the difference between electricity demand and supply is the import of electricity. The net import of electricity increased sharply in recent years mainly as a result of the repeated nuclear reactor shutdowns. The net import peaked in 2014 at 67 PJ, six times more than the net electricity production from solar, water and wind in Flanders (see below).

### Combined heat and power accounts for more than one quarter of electricity production

Combined heat and power or CHP is the simultaneous conversion of an energy source into power (generally used to generate electricity) and useful heat. CHP plants make better use of the primary energy sources and reduce emissions as compared to separate generation of power and heat. Furthermore, CHP allows for distributed generation, thereby minimising transmission losses. CHP plants are operated not only by or in collaboration with electricity companies (energy sector), but also by self-producers (= companies which, in addition to their core activity, produce electricity themselves for their own use and possibly sale to third parties, e.g. a greenhouse horticulture company) from other sectors. After initial strong growth in the second half of the 1990s, the construction of new CHP plants nearly came to a halt due to the liberalisation of the electricity market with an unfavourable ratio between fuel and electricity prices. However, since the end of 2004, the further utilisation of the CHP potential is supported by a certificate system imposed on the electricity suppliers by the Flemish government. The introduction of the certificates led to a doubling of the installed capacity of CHP installations between 2004 and 2012. For all CHPs in Flanders, the useful energy output in 2014 consisted for 67 % of steam and other heat, for 29 % of electricity and for 4 % of direct drive power. Between 2005 and 2014, the ratio of useful output to energy input of CHPs fluctuated around 80 % (**Figure 1.7**). However, with a total efficiency of 83 % the transformation losses could be limited to 17 % in 2014. This efficiency is much higher than for the above-mentioned power plants. The input still consists mainly of natural gas, with a share of 61 % in 2014. The use of renewable fuels (biomass, vegetable oil, biogas) in CHPs, however, continues to increase year on year. The advance of these so-called bio-CHPs led to a share of renewable energy of 12 % in the fuel input of CHPs in 2014. In 2014, the useful output of electricity by CHP plants accounted for 17.6 % of the gross domestic electricity consumption and even 27.2 % of the total net electricity production in Flanders. In recent years, however, the growth in operational CHP capacity has levelled out and electricity output of the CHPs has decreased by one fifth from its peak in 2012 and 2014, due to the reduced use of natural gas fired plants[10].

### The three tracks of renewable energy

The bulk of energy consumption in Flanders is still based on non-renewable energy sources. Renewable sources are, however, gaining in importance, especially over the last ten years. This is accomplished via three tracks: green electricity, green heating & cooling, and biofuels for transport (**Figure 1.8**).

The European Renewable Energy Directive requires Belgium to increase the proportion of renewable energy in its gross final energy consumption from 2.3 % in 2005 to 13 % in 2020 (the 2014 level was 8.0 %[11]). This includes both the inland production of green electricity, green heating and cooling, and the use of renewable energy sources for transport purposes. Gross final energy consumption is defined as the total of energy carriers supplied for energy purposes to all sectors outside the energy sector (electricity and refineries), including the use of electricity and heat by the energy sector itself and the network losses during the production and distribution of electricity and heat, but excluding final non-energy consumption by industry. To reach this target in time, Flanders has agreed to produce 90.267 PJ renewable energy by 2020. In addition, each member state is required to use at least 10 % renewable energy in road and rail transport by 2020. This includes both biofuels and green power and hydrogen from renewable energy sources. In Flanders, biofuels are produced from first-generation feedstocks (such as rape seed, maize, cereals and sugar beet) at three biodiesel and two bioethanol plants. However, because first-generation biofuels result in a rather limited or even no net $CO_2$ reduction and could get in competition with food production, they may only account for 7 of the aforementioned 10 %. The remaining 3 % will have to come from second-generation biofuels (extracted from waste oil and greases, harvest residues, or wood waste) and the use of green electricity for electric vehicles.

**Figure 1.8** illustrates the significant growth in the use of the three renewable fractions between 2005 and 2014 in Flanders. The production of green electricity has continued to increase every year, except in 2014 when a slight decline (-2 %) was recorded. That year was the first time that more than half of the green electricity originated from solar panels and wind turbines (onshore), and no longer from biomass and gas. Fuelled by a favourable support mechanism of green electricity certificates, electricity production by solar panels in particular increased sharply in Flanders: +330 % between 2010 and 2014. Onshore wind turbines also experienced a substantial production increase of 158 %. Green electricity production from biomass, by contrast, decreased significantly after 2012. Reasons were the closure of the co-combustion power plant in Ruien in the spring of 2013, and the temporary shutdown of electricity production in the Rodenhuize biomass power plant in 2014. OVAM and the Fedustria and Cobelpa federations had failed to timely deliver a positive opinion on the wood species used, so that the power plant was no longer entitled to subsidies in the form of green electricity certificates for the burning of biomass. In the absence of the above opinion, it could no longer be excluded that the biomass might also be used as industrial raw material, for example, in the Flemish furniture or paper industry.

After application of the calculation rules of European Directive 2009/28/EC, the total use of renewable energy sources in Flanders appears in the meantime to have increased to 54.9 PJ. This means that the total use of renewable energy needs to increase by another 64 % compared to 2014 if Flanders is to achieve the set target by 2020. Provisional figures for 2015 indicate that the use of renewable energy sources has further increased to 58.7 PJ thanks to the increase in the production of green electricity and green heat[1], but at a growth rate of almost 4 PJ extra per year the target will not be reached by 2020.

Closing the gap to reach the target for 2020 will require additional efforts on each of these tracks. Earlier initiatives pushed the share of green electricity in the gross final electricity consumption from 1.8 % in 2005 to 10.5 % in 2014 (and 12.7 % in 2015). The growth rate of renewable energy production thus far appears to be highly dependent on legislation and support measures. Thus, the annual increase in installed peak capacity of solar panels following the abolition of the favourable subsidy programme since 2013, for example, has fallen below 50 MW, whereas in the record year 2011 a capacity of around 800 MW was connected to the grid. The shares of green heating & cooling (mainly biomass, but gradually also more heat pumps, pump boilers and solar boilers) in total energy consumption for heating & cooling in Flanders and of biofuels and green power for transport, grew strongly until 2010. This was the result of a combination of green power and CHP certificates and a biofuel blending obligation, combined with a temporary exemption from excise duty, respectively. Since 2010, however, the shares of green heating & cooling and renewable energy for transport have fluctuated between 4 % and 5 %. Fuelled by a new support system for green heating from biomass or deep geothermics, the revamped premium scheme for heat pumps, pump boilers and solar boilers, the introduction of the mandatory share of renewable energy for new builds, and a tightened blending duty for biofuels, these shares can increase again over the coming years.

**Shift from central to distributed energy production blurs the boundary between demand and supply side**

Until ten years ago, the Flemish energy system made a clear distinction between supply side and demand side, between producer (centralised) and consumer (decentralised). This distinction is blurring due to efforts to increase the use of renewable energy sources (solar panels, prosumers) and the search for efficiency gains (e.g. CHPs, use of by-products and residual heat).

## ENVIRONMENTAL DISRUPTIONS

### Environmental disruptions by the energy system

To what extent does our energy system play a role in the environmental pressure in Flanders? This question can be answered by breaking down the total environmental pressure in Flanders into the contribution of:

- energy consumption: the demand side of the energy system with the final energy demand for various energy services (heating & cooling, lighting, motor drive systems, etc.) in dwellings, companies, vehicles, businesses and services;

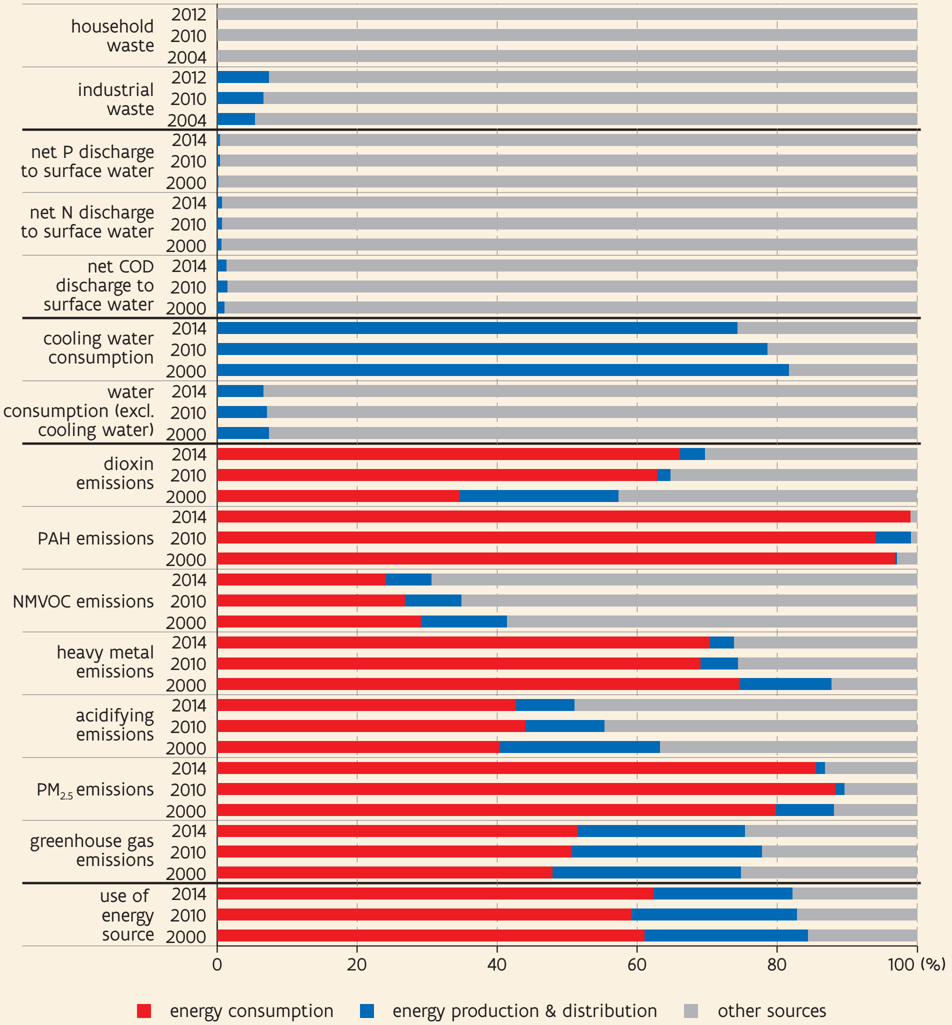
- energy production & distribution: the supply side of the energy system with the transformation of energy sources into energy carriers suitable for the end users, and the transmission and distribution of that energy to the end users. This therefore includes both environmental pressure related to activities in the energy sector (central production) itself, and in distributed energy production (e.g. CHP installations);

- non-energy activities: other sources of environmental pressure that are not directly linked with energy consumption or production account for important shares in environmental pressure. Examples are household and industrial paint use, composting, industrial process emissions, waste incineration without energy recovery, digestive processes in agriculture, and manure storage.

**Figure 1.9** provides an overview of the shares in the environmental pressure of energy consumption, energy production & distribution and non-energy activities, for the environmental topics of waste production, emissions to air (including greenhouse gases), discharges to surface water, water consumption and consumption of energy sources. It thus becomes clear to what extent environmental pressure related to the energy system is to be attributed to the demand side (red bars) and the supply side (blue bars). The grey bars indicate the share in environmental pressure of non-energy activities in Flanders. The three focus years, 2000, 2010 and 2014, are characterised by differences in economic activity levels of the three sectors, changes in the population (increase, reduction in family size, ageing) and the climate (very cold winter in 2010 versus exceptionally mild winter in 2014). These differences do not result in clear patterns of changed shares for energy consumption and energy production & distribution over the 2000-2014 period, possibly because other factors are involved, such as shifts in shares of energy sources used, technology used, possible efficiency gains, etc.

Due to the blurring of the boundary between energy production & distribution and energy consumption (e.g. due to the growing share of prosumers or energy consumers generating part of their energy themselves), environment gain on one side may (partly) be at the expense of environmental gain

**Figure 1.9** Share of energy consumption, energy production & distribution and non-energy activities in environmental pressure (Flanders, 2000*, 2010, 2014*)




* For waste production no basic data are available for the years 2000 and 2014, and the first and last available years were used, i.e. 2004 and 2012.

**Source:** MIRA based on VMM, VITO and OVAM on the other side. Energy production & distribution and energy consumption act as communicating vessels. Thus, the increasing electricity consumption among end users (e.g. heat pumps: already 14,162 installed in Flanders at the end of 2014; electric cars: in 2015, 991 fully electric passenger cars and 1,860 plug-in hybrids were registered in Flanders) may lead to lower environmental pressure on the consumption side but higher environmental pressure on the production side, especially if the electricity required is not generated with renewable energy sources. To the extent that consumers generate green electricity themselves, as for example in nearly zero-energy dwellings, the shift of environmental pressure to the central supply side can be partly avoided.

## Energy consumption has greatest share in air pollution

The emissions of various air pollutants are responsible for the bulk of the environmental pressure from energy consumption. During the conversion into mechanical energy, useful heat, etc. (combustion engines, industrial combustion plants, stoves, central heating, etc.) various fossil energy carriers are burnt. In these combustion processes, numerous pollutants are released into the air: always $CO_2$, and depending on the fuel and the efficiency of the combustion process, also $SO_2$, $NO_x$, NMVOC, PAHs, particulate matter such as $PM_{2.5}$, heavy metals, etc.

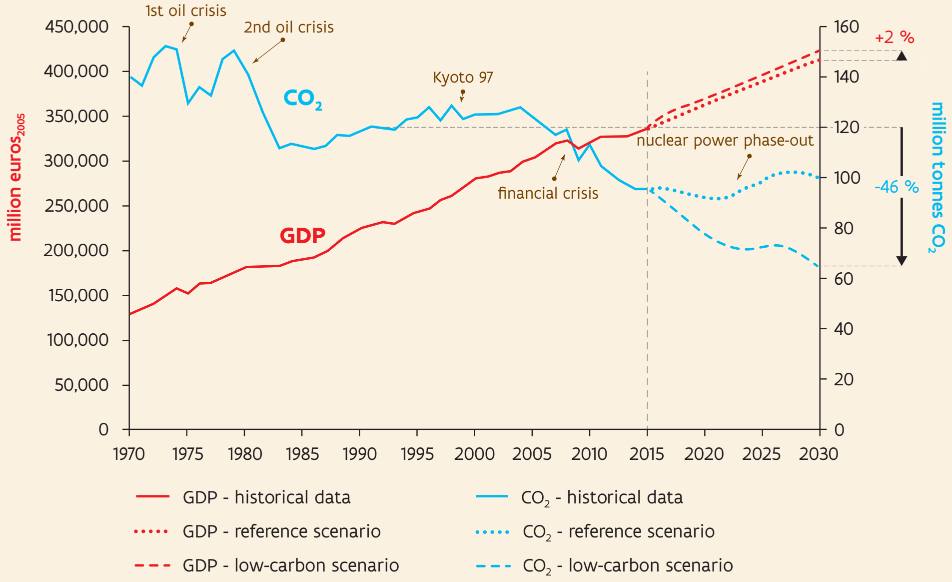
In 2014, energy consumption accounts for 51 % of the greenhouse gas emissions (almost exclusively $CO_2$) and 43 % of the total acidifying emissions (with shares of 81 % in total $NO_x$ and 55 % in total $SO_2$ emissions) in Flanders. The $CO_2$ emissions originate from the burning of fossil fuels, mainly for transport, building heating and industrial process heat. The $NO_x$ emissions in 2014 are for 68 % attributable to diesel and petrol combustion engines in the transport sector (mainly road traffic). The $SO_2$ emissions in 2014 are for 66 % attributable to industrial combustion processes (firing based on energy carriers with a high sulphur content, such as coal, coke and heavy heating oil).

For the emissions of heavy metals, PAHs and particulate matter ($PM_{2.5}$) the shares of energy consumption are even higher (70 %, 99 % and 86 % respectively in 2014). This is due, among other things, to the burning of solid fossil fuels, biomass (wood) and (heavy) heating oil. Climate control in buildings and hot water production at end-users represent 31 % of the energy consumption, and are subject to fluctuating weather conditions (severe or mild winters). Because of non-optimal combustion conditions, the associated combustion processes contribute significantly to emissions to the air. Especially residential heating using solid fuels (coal and wood) and heating oil in obsolete stoves, heating boilers and multi-burners is not always done efficiently. This explains the dominant share of residential heating in energy emissions of $PM_{2.5}$ (almost 62 % in 2014) and PAHs (90 % in 2014).

In industry, too, relatively large amounts of fossil fuels (including coal, coke, etc.) and diesel continue to be used, among other things for the generation of process heat at both high and low(er) temperatures. As a result, industry has a share of 23 % in the energetic emissions of $PM_{2.5}$. The transport sector is responsible for over 10 % (in 2014) of energetic $PM_{2.5}$ emissions, to be attributed to the use of diesel in passenger and freight transport.

As far as air emissions are concerned, energy production and distribution causes less environmental pressure than energy consumption. An important factor here is that large combustion plants - more than small-scale combustion installations - can be equipped with dust removal, desulphurisation and denitrification techniques. However, in particular electricity and heat production and oil refineries continue to contribute significantly to environmental pressure in Flanders through the use of fossil fuels. For emissions to air in 2014, this contribution is especially noticeable in the emissions of greenhouse gases (mainly $CO_2$) with a share of 24 % in total emissions, and acidifying substances with a share of 8 % (shares of 9 % in $NO_x$ and 30 % in $SO_2$ emissions). More than 75 % of the cooling water

**Figure 1.10** Evolution of GDP and of $CO_2$ emissions from a historical perspective and under a scenario with transition to a low-carbon economy (Belgium, 1970-2030)




**Source:** Lemercier et al. (2016)[15]

consumption is to be attributed to electricity production (both the Doel nuclear power plant and the conventional thermal power plants).

Waste production (household and industrial waste), discharges to surface water of various pollutants (P, N, COD, BOD, etc.), water consumption (excluding cooling water) are mainly attributable to activities that are not directly linked to energy consumption and energy production and distribution. And also a considerable portion of emissions of NMVOCs, dioxins and acidifying substances originates from non-energy activities (for instance, numerous evaporative emissions from coating, printing and cleaning processes, household and industrial paint use, composting plants, digestive processes in agriculture, manure storage, household waste water, etc.).

The energy consumption of all energy services constitutes the largest part of gross domestic energy consumption (62 % in 2014), followed by own consumption of energy sources in energy production & distribution (20 %). The remaining energy sources (18 %) are used for non-energy purposes, for example as 'building blocks' for the production of various plastics in the chemical industry.

## SOLUTION DIRECTIONS

### Towards a low-carbon economy by 2050

In addition to reducing greenhouse gas emissions by 20 % by 2020 as compared to 1990, the EU also aims to reduce emissions by 40 % by 2030. The latter is a first intermediate target to put the EU on the right track for the energy transition to a low-carbon economy by 2050, with emissions reductions of 80 to 95 %. In early 2016, Belgium signed the Paris Climate Agreement, committing itself to reducing greenhouse emissions by at least 40 % by 2030. The agreement is conceived as an action plan to keep the average temperature increase on our planet below 2 °C or even 1.5 °C with respect to the pre-industrial era.

If Flanders also wants to qualify for such a low-carbon economy, our energy system will have to undergo a genuine transition. Previous studies have shown that a transition to a low-carbon economy with at least 80 % fewer greenhouse gas emissions by 2050 is actually possible for Belgium, based entirely on existing technology complemented with carbon capture and storage (CCS) in industrial processes and deep geothermics[12, 13, 14]. Furthermore, it was demonstrated that such a scenario would not involve any additional costs for society[12]. What would be needed are shifts in the expenditure pattern of individuals and companies: big investments in the short and medium term in energy efficiency, new infrastructure, flexible alignment of demand and supply, renewable energy and the interconnection of networks will be compensated by lower fuel costs in the longer term. A recent follow-on study concludes that such a transition not only leads to environmental gain but may also result in favourable macroeconomic effects[15]. **Figure 1.10** clearly shows that a transition scenario with a reduction in $CO_2$ emissions by 46 % by 2030 may nevertheless cause an additional increase in the gross domestic product (GDP) by 2 % with respect to a reference scenario without additional energy and climate policy. In a low-carbon economy, however, such growth will come partly from other activities as compared with a traditional economy. Employment, too, will increase in net terms, the biggest increase being in construction and in a number of industrial sub-sectors. Subject to the homogeneous introduction of policy initiatives at European or international level, Belgian sectors, which are among the most competitive within the EU, are guaranteed to expand their exports and market shares.

## Energy transition: a house with many rooms

The energy transition on which Flanders and Europe have embarked is one of the greatest challenges for policymakers and stakeholders from an economic, ecological and social perspective. Apart from climate change mitigation, such an energy transition has other major objectives such as ensuring the security of supply under virtually all foreseeable conditions, a safe energy supply and the availability of affordable renewable energy. In view of the many uncertainties, it is impossible to predict what the energy system in Flanders will look like by 2050. The price evolution of techniques and energy sources, the social acceptance, and the changing international framework are only a few factors that will determine the path of the energy transition to a low-carbon economy. Also the way in which we will or will not adjust our spatial planning over the next decades, will help to determine the final path. Moreover, the energy transition will have not only winners, and will therefore also have to contend with countervailing forces.

However, certain choices must be made now, and a number of breakthroughs are required to allow greenhouse gas emissions to be reduced by at least 80 % by 2050. A number of elements that certainly will or can contribute are listed below based on Ros & Schure (2016)[16], Cornet et al. (2013)[12], VMM (2016)[17], EEA (2016)[18] and own insights.

### Demand side of the energy system

- In light of the necessary energy transition, we need to critically reconsider the way in which **social activities such as living, working, transport and leisure activities are organised**. Thus, spatial and urban developments may to a large extent be decisive for the supply and use of renewable energy. The well-considered siting and sun-facing design of dwellings, for instance, would allow the sun to provide up to 40 % of the necessary heating. And for major new area developments (residential districts, industrial estates), it should always be carefully considered, based on local possibilities and opportunities, whether or not heat networks, gas networks, heat pumps or other sustainable options are to be used.

- A **sustained focus on energy efficiency** is needed to achieve the renewable energy targets and to push back greenhouse gas emissions. Due to the absence of its own, economically recoverable fossil energy sources, Flanders has the key to a higher degree of self-sufficiency and a guarantee for stable energy supply with the combination of increased energy efficiency and the switch to renewable energy sources. In addition to lower energy consumption and the associated emissions reduction, energy efficiency in climate control for houses and buildings offers additional potential advantages. Measures for energy efficiency among the lowest income groups and for so-called energy poverty may have a significant social impact. After all, a lower energy bill results in a higher disposable income, so that more money can be spent on other cost items such as food. Better insulation and heating systems in obsolete dwellings also result in better physical and mental health of the occupants. Improvements in energy efficiency in commercial and public buildings may have a positive impact on labour productivity[19].

- An increase in the **share of electricity in the energy mix** is desirable because (part of) that electricity can be provided by renewable energy sources. Thus, increasing insulation of existing buildings and the construction of nearly zero-energy dwellings results in the growing use of alternative systems. Examples are heat pumps and solar boilers, either with or without electric heating systems. Electric heat pumps can also be used for heat supplies below 100 °C in industrial processes.

- An advanced **electrification of passenger transport** reconciles multiple objectives. It pushes back the harmful emissions of road transport and allows batteries in vehicles to absorb fluctuations in the supply of green electricity via the power grid (together with stationary batteries in dwellings and collectively in apartment blocks or at district level).

- The previously mentioned trend from central to distributed production and blurring of the distinction between energy producers and energy consumers continues under the influence of **citizen cooperatives**. These cooperatives allow citizens to participate in local initiatives on generation of green electricity, green heating and energy services aimed at energy savings without loss of comfort. Group cohesion and profit sharing are levers for a broadened consensus (e.g. for the installation of wind turbines) and empowerment (e.g. alertness with regard to own energy consumption).

### Supply side of the energy system

- **Solar electricity** is becoming highly competitive through further reduction of the total cost of PV systems (solar panels), and, together with the previously mentioned cooperatives, constitutes a major stimulus for one's own energy supply and greater involvement of citizens in the operation of the energy system. In addition to today's solar panels, thin photovoltaic films with applications on walls, glass, vehicles, etc. are expected to come onto the market in the medium term.

- Offshore wind farms are a federal competence. The concessions granted thus far allow the current capacity (701 $MW_e$) to be expanded to 2,089 to 2,480 $MW_e$, i.e. an annual electricity production of approximately 8 TWh or around 10 % of total Belgian electricity consumption[20, 21]. However, in addition to the possible expansion of offshore wind farms, there is also need as well as potential for **additional onshore wind energy**. This requires a better integration of wind energy into the spatial planning, together with a relaxation of the authorisation procedures and increased attention for local support (e.g. possibility of financial participation in a local wind farm through the above-mentioned cooperatives). Because large wind turbines often clash with spatial planning and the NIMBY syndrome *(not in my backyard)* among local residents, another option is to integrate small(er) wind turbines (0.1 to 0.5 $MW_e$) into the landscape (on office buildings, near farms, at factory premises, etc.).

- To ensure the balance between demand and supply on the power grid, **flexible installations running on natural gas and/or biomass** will still be necessary for some time. Provided they are economically profitable, these installations can in the future be equipped with $CO_2$ capture and storage (CCS). However, the breakthrough of the CCS technology has been overdue for some years, because none of the 12 large pilot projects planned within the EU were operational by 2015[18]. The supply of sustainably produced biomass is highly uncertain in the long term. This is partly due to the fact that the carbon balance for biomass production on agricultural land and in forests is not always favourable.

- Large-scale conversion of sustainably produced biomass into **green gas and/or biofuels**, is a real and perhaps the only option for a number of major energy consumers such as a part of the built-up environment, air traffic, and heavy transport by road and water. Combined with $CO_2$

capture and storage (CCS) or carbon capture and utilisation (CCU), this could lead to net negative emissions or sinks.

- The further development of **heat networks** can be an important source of energy savings. Heat networks allow the heat demand of buildings to be linked to companies that have residual heat at relatively low temperature, or to a sustainable central heat source (geothermics, biomass CHPs, etc.). Heat networks offer also other advantages: thanks to the economies of scale, heat sources and heat storage can be used as efficiently as possible from an energetical, ecological and economical perspective. Moreover, the switch to another (more sustainable) source in a central system such as a heat network is more straightforward than a set of distributed generators. However, these techniques can only be deployed locally, due to the heat loss that occurs during the transport through pipelines. Both because of the energy efficiency and because of the economic cost, heat networks are ideal for areas with a sufficiently high building density. Furthermore, the possibilities of heat networks with industrial residual heat are directly dependent on the continuity of companies over periods of many decades. For deep geothermics, aquifers with a sufficiently high temperature are available only in the Campines from 3 km depth. From a human time perspective, the supply of heat in the soil proceeds slowly but constantly over time, and is virtually inexhaustible. That is why geothermal heat, like solar energy, is considered a renewable energy source. A recent variant is heat recovery from sewage.

### Integration of demand and supply side

- The numerous changes in the area of electricity supply require major modifications to the electricity grid. The current grid, built around a limited number of central production sites, must be transformed to an **international, well-interconnected and smart network**, to which distributed generation units and new applications can be linked. For this, information technologies are used to optimise electricity production and distribution and to align flexible demand and supply. An extensive interconnection capacity allows temporary deficits and surpluses on the production side or unavoidable peaks on the consumption side to be absorbed through power exchange with neighbouring countries, as well as green power from areas with the largest production potential to be transmitted over even greater distances within Europe: for example, solar electricity from Southern Europe, wind energy from the North Sea, and hydropower from Scandinavia and the Alps. With its central location, Flanders can play a strategic role within the European supergrid, as it already does for natural gas. An important factor here is the connection to the planned North Sea network of offshore wind farms.

- The technical potential for the production of low-$CO_2$ electricity is such that it can also be used for purposes other than making current electricity consumption more sustainable. For forms of energy consumption where an alternative to (methane) gas or liquid fuels such as diesel or kerosene is hard to find, gas or liquid fuel produced by means of green power may offer a solution: the so-called ***power-to-gas*** and ***power-to-liquids***. This may also contribute to solving the energy storage issue, which becomes relevant when the supply of solar and wind energy exceeds demand: unlike electricity, hydrogen gas and liquid fuels can easily be stored.

Even if they often vary greatly in nature, most of the transition elements incorporate aspects of both optimisation and innovation and they often combine several tracks towards a sustainable energy system: limiting energy needs, maximising energy efficiency, and increased use of renewable energy sources. This involves more than low-$CO_2$ technology. As we have already seen, there is also a great need for drastic infrastructure renovations and the transition can only succeed if also the institutional design is modified accordingly. Both are essential marginal conditions that need to be addressed already in an early stage. In practice, they take much time.

## Ready for the start

Uncertainties are almost inherent in each of the above-mentioned transition elements. They may be related to social acceptance as a result of possible side effects (e.g. of underground $CO_2$ storage), uncertainty about the scope of sustainably exploitable energy sources (biomass, deep geothermics) or the possible successful development of technology. However, these uncertainties are not a reason to adopt a wait-and-see attitude. The time to bring about the energy transition is too short for this[16].

Targeted investments are a basic requirement to realise the energy transition in time. Thus, power supply investments in the prolonged lifespan of existing carbon-intensive power plants or in new fossil installations (mainly coal power plants) threaten to result in so-called lock-ins whereby existing technologies are used longer than is necessary and desirable. The majority of coal power plants used within Europe are 25 to 30 years old, and on average twice as carbon-intensive as gas power plants. That is why gas power plants are better suited than coal power plants to be used as back-up capacity to guarantee the stability of the power grid - which will also remain necessary in our country in the coming decades[14, 22] – and to ensure the balance between power demand and supply with the integration of intermittent energy sources such as solar panels and wind turbines. Given their long lifespan (35 to 40 years, to be extended to 45 to 50 years through investments) and the delayed market introduction of CCS, investments in fossil power plants (mainly coal) could curb the dissemination of the low-carbon technology in the coming decades. Finally this increases the total cost for the greening of the power supply in Western Europe, while at the same time investors and shareholders are exposed to unnecessary financial risks due to the threat of the premature closure of fossil power plants[18]. In addition, the Federal Planning Bureau demonstrated the downward impact for Belgium of prolonged nuclear electricity generation on wholesale prices for electricity. Lower wholesale prices prevent the upscaling of investments in renewable energy sources and in efficiency-enhancing technology. The revision of the existing calendar for the phase-out of our nuclear power plants in the Nuclear Phase-out Act could therefore slow down the necessary energy transition[23].

A widely supported and consistently maintained long-term vision of how the energy system should contribute to the timely realisation of a low-carbon economy in Flanders and Belgium, is therefore of paramount importance. Such a vision implies clear objectives and requires a stable investment climate. It also adopts an integrated approach across policy areas an levels, linking up the different energy services: heating & cooling, lighting, mobility and motive power.

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