FLANDERS
ENVIRONMENT REPORT

MIRA

System Balance 2017

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ENVIRONMENT REPORT

MIRA

System Balance 2017

Environmental challenges for the energy, mobility and food systems in Flanders

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INTRODUCTION

Indicator reporting with a system lens

MIRA has for many years been monitoring the state of the environment in Flanders by means of indicators. What is the state of the air quality? What are the major sources of water pollution? What is the impact of environmental disruption on our health? In order to answer such questions, policymakers and stakeholders have access to a set of 200 or so up-to-date indicators at www.milieurapport.be. Indicators are also appropriate building blocks to document and analyse environmental problems. Combining the information of different indicators allows new insights to be gained and enhances the information value.

The MIRA indicators show that the quality of the environment is improving in different areas, but also that progress is often too slow to reach the targets. We are also increasingly having to cope with persistent environmental problems such as climate change and biodiversity loss. If we want to sustain our prosperity within the planet's limits, fundamental changes are needed in the way in which we consume & produce, live, work, eat and recreate Societal systems are reaching their limits: we face the challenge of meeting both our present and future needs within the capacity of our planet. Hence the choice for a system approach in this publication. Such a system approach enables us to identify both the complexity of the environmental issues and the levers for the necessary changes. Healthy systems are sufficiently resilient, self-organising and hierarchically structured. All too often, however, these characteristics are thrown onto the scales, or balance, together with productivity and uniformity, resulting in suboptimal systems. An evaluation is necessary.

With this new publication "System Balance", we aim to investigate how major societal systems perform from an environmental perspective, where there are structural flaws, and what improvements are required. We want to investigate to what extent these systems are, or are not, environmentally balanced and what system changes are needed. The urgency, scope and geographical range of the environmental challenges call for structural innovations in the various system components and of the actors concerned.

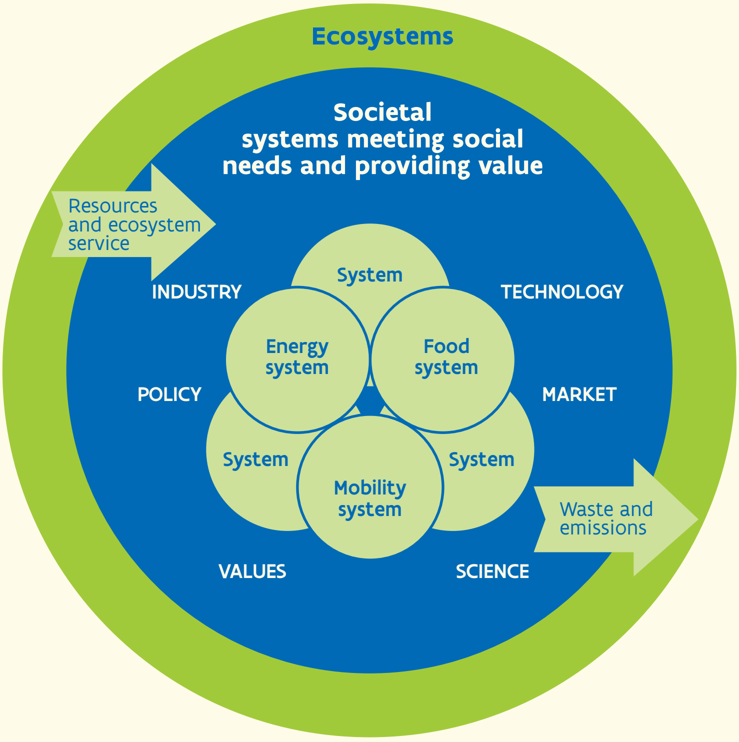
The MIRA report "Megatrends" (2014)[1] focused on three socio-technical systems: energy, mobility, and production & consumption, with spatial planning as a fourth 'system'. For this publication our choice fell on the energy system, the mobility system and the food system (the latter as part of the general production & consumption system). Notice that also the Megatrends report came to the conclusion that societal systems need to be made more sustainable, more resilient and therefore more future proof.

The present System Balance is basically an indicator-based analysis, supplemented with information that is still missing in the current set of MIRA indicators (e.g. energy consumption by the different energy services). This may also include information from recent research projects commissioned by MIRA (e.g. the carbon footprint of food consumption).

With this publication we attempt to unearth information that is buried within the indicators. We do this through a well-considered selection of figures and numbers, along with a detailed interpretation of the findings.
This publication therefore fits in with MIRA's mission, which is to provide a state analysis, and its form and content make it complementary to the individual indicators at www.milieurapport.be.

1 VMM (2014) Megatrends: far-reaching, but also out of reach? How do megatrends influence the environment in Flanders? MIRA Future Outlook Report 2014, Flanders Environment Agency. www.environmentflanders.be

Figure Core societal systems meet diverse human needs, but also account for much of humanity's environmental burden.



Source: EEA 2016, Sustainability transitions: Now for the long term. Eionet report No1/2016.

The long-term vision of the 7th Environment Action Programme of the European Union 'Living well, within the limits of our planet':

"In 2050 we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society."

What can and cannot be expected from the present System Balance

Which (sub-)systems are at the basis of the environmental pressure in Flanders and which improvements can already be observed? Which environmental bottlenecks remain to be solved? Which solutions are emerging? These were the questions presented to the authors of this new publication (see also **figure**).

All of the three system chapters have an identical structure, starting with a description of the structure and the functioning of the system, and the resulting environmental challenges. In this introduction we also describe the focus used. For the energy system, for example, the demand side with the different energy services is set off against the supply side. The mobility system focuses mainly on passenger transport and the link with air quality and health; the food system takes a closer look at two major environmental challenges: climate change and eutrophication.

The introduction is followed by a discussion of the societal developments and activities, based mainly on MIRA indicators (e.g. energy intensity and use of renewable energy for the energy system). The section Environmental disruptions, too, is largely built up by means of existing MIRA indicators (e.g. emissions into the air, air quality, and impact on health for the mobility system).

Each system chapter is concluded with a description of possible solution directions: “What is not functioning well today, can be better if we do things differently tomorrow.” Environmental challenges do in fact require structural innovations within the entire system. Also notice that spatial planning is part of the solution in all three of the investigated systems. The choices must be made now and by combining solution directions, we aim to provide policymakers and stakeholders with inspiration for the necessary transition to more sustainable systems. While the solution directions are addressed primarily from an environmental perspective, they may also be suitable for other societal challenges facing the different systems. Examples are the positive impact of energy efficiency on energy poverty and of walking or cycling on health.

For the text of each system chapter, we consulted the information as reported in the MIRA indicator sheets and the basic data as collected in the MIRA Core Set of Environmental Data 2016, both available at the website. For the section ‘Solution directions’ we had to collect additional or new information. The consulted sources are included in the reference list at the end of each system chapter. The texts have been written by staff members of the Environmental Reporting unit of the Flanders Environment Agency and presented to experts.

Towards a fully fledged system balance

The present system balance is not yet fully fledged. Much hard thinking remains to be done and the information is insufficiently developed. Despite the comprehensive set of 200 MIRA indicators, there is often still a lack of systemic information to allow the proper monitoring of system changes. As in previous MIRA reports, this should be interpreted as a signal for further knowledge development in general, and indicator development in particular.

The impact of solutions is often still uncertain, especially in the case of new or innovative directions. The impact may, moreover, be context sensitive, hence the plea for the sustained study of global developments and megatrends. Or, in a wider context, a plea for a sustained analysis of core systems. A system analysis allows the relationships between societal and physical processes to be identified. System thinking is therefore aimed both at the structure of the systems - with stocks, flows and feedback loops - and at the behaviour of systems, now and in the future. System analyses also reveal connections between the systems. This is important, because other systems can also be used to act on a system that needs to be changed. The location where food is produced, for example, partly determines the need for transport. The MIRA report 2012 on the agriculture and food system[2] also advocated a continuous process of system analysis and concluded that "the combination of hard (quantitative) and soft (conceptual, qualitative) elements, is a successful combination to provide a narrative on how a (sub-)system functions". The further focus on systems in the indicator reporting should therefore enable us to further develop the basic knowledge for system change, and the policy-related monitoring thereof.

[2] VMM (2012) Transition to a sustainable agro-food System in Flanders: a system analysis. MIRA Topic Report in collaboration with AMS, Department of Agriculture and Fisheries. www.environmentflanders.be

SYSTEM BALANCE
2017

—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.

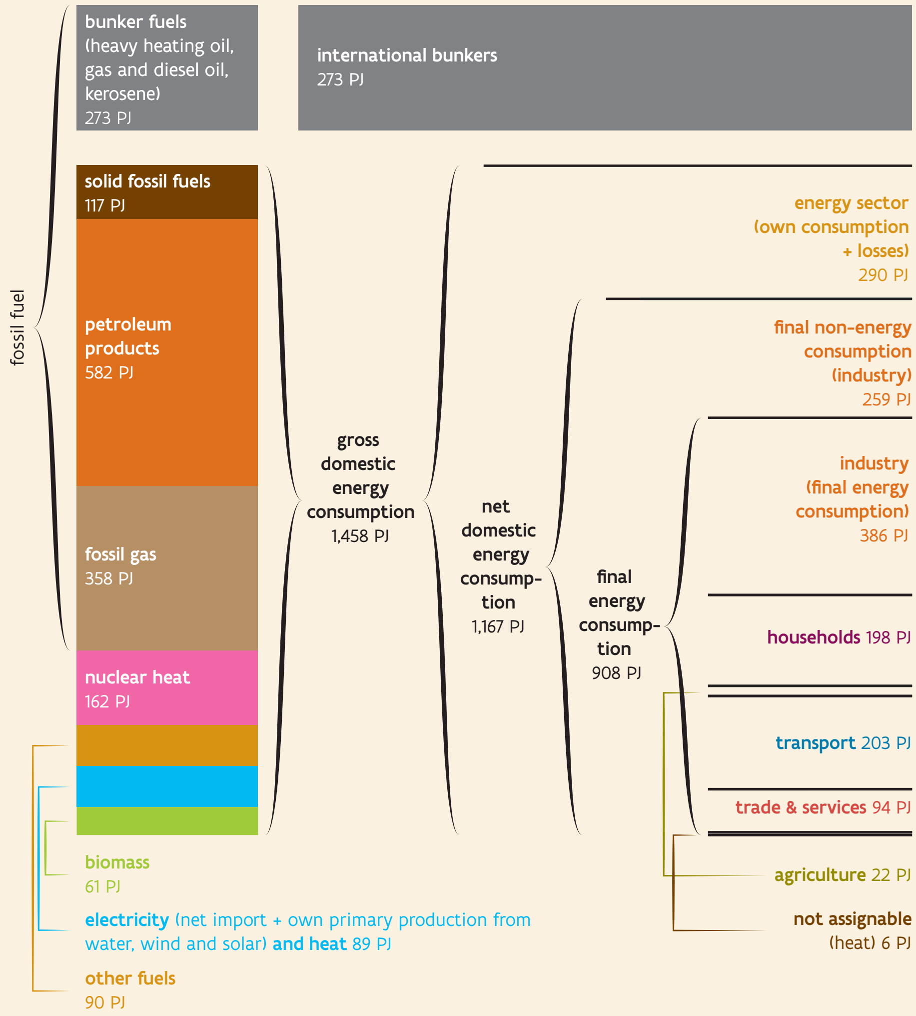
To meet this energy demand, we need to rely on primary energy sources: fossil fuels (coal, natural gas, and petroleum products), nuclear heat, biomass and other renewable energy sources like wind and solar. In this text, the supply side is defined as the production, conversion and distribution of different 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 considera-tion 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.

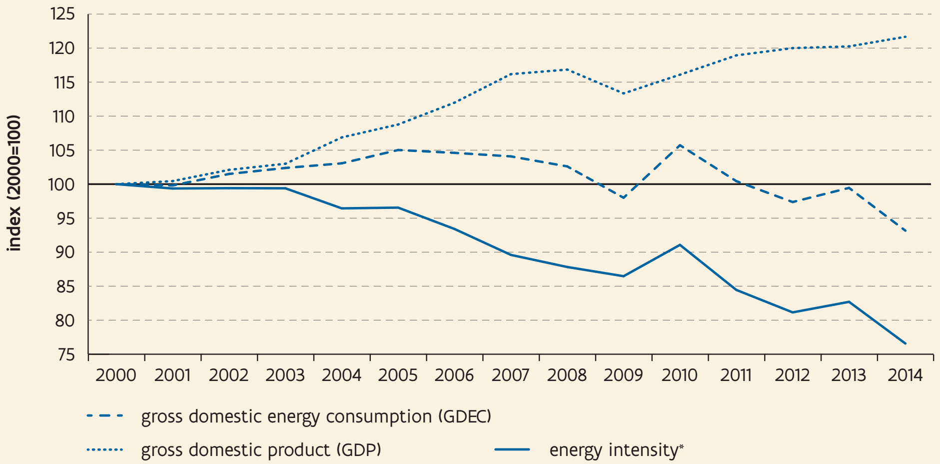
The difference between gross and net domestic energy consumption is the energy use in the energy sector including transformation, transmission and distribution losses, and amounted to 290 PJ or 20 % of the GDEC in 2014. Energy consumption in the energy sector (supply side) is determined by the activities 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.

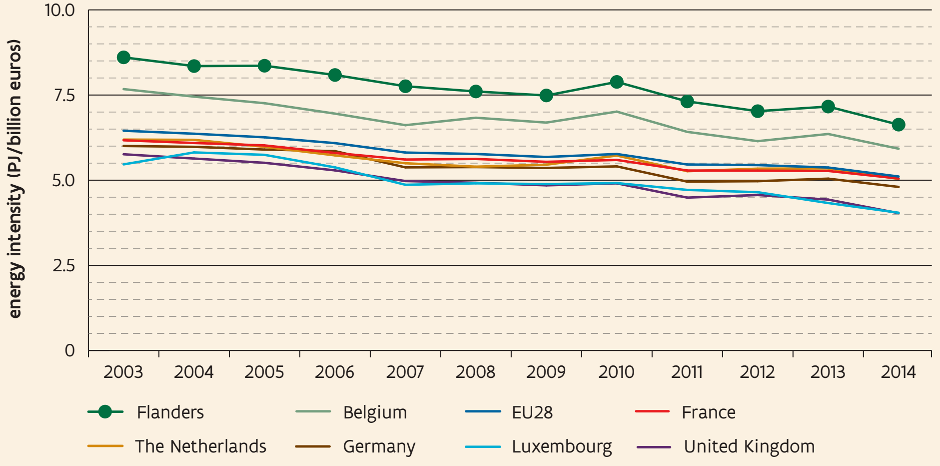
Figure 1.2.a Evolution energy intensity (Flanders, 2000-2014)



* 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

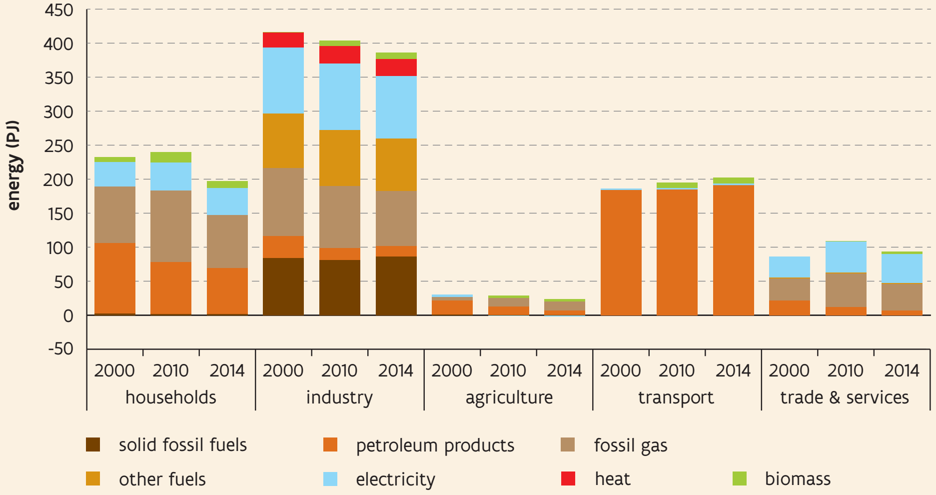
Trend towards a less energy-intensive economy continues

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].

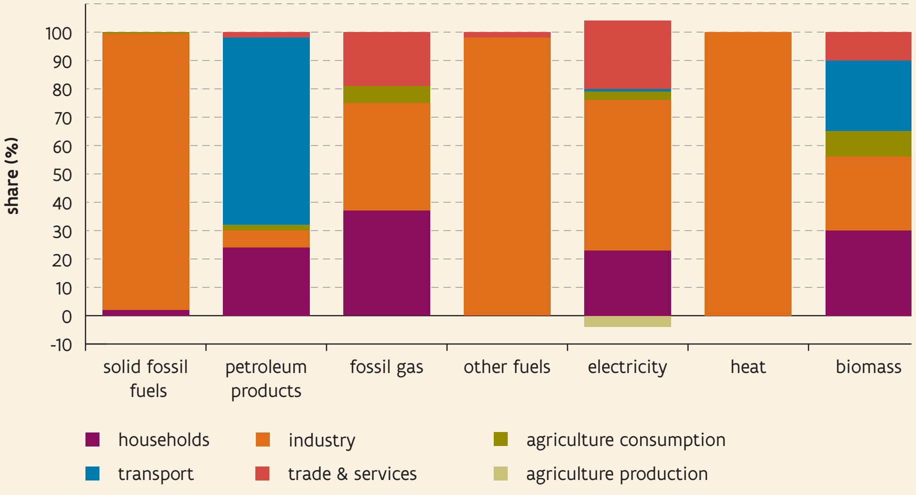
Figure 1.3 Evolution of energy end use by sector broken down by energy carrier (Flanders, 2000-2014)



'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)



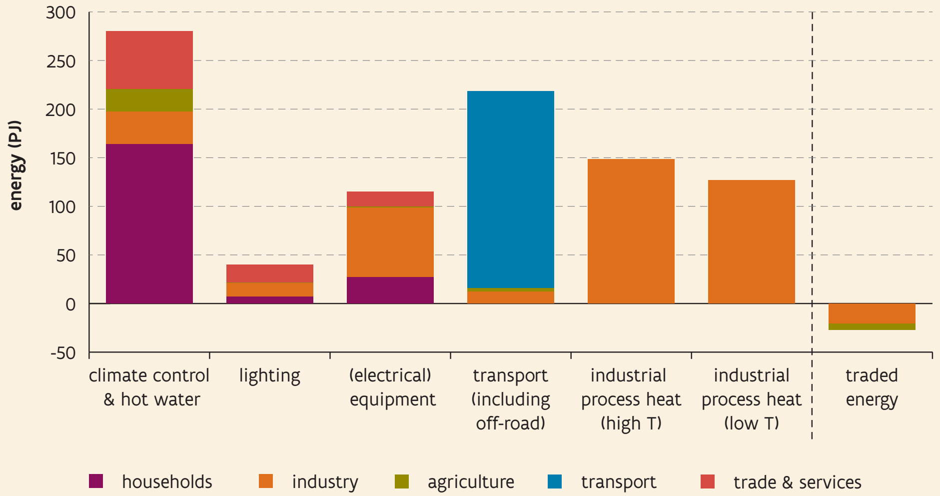
Source: MIRA based on Aernouts et al. (2016)[2]

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.

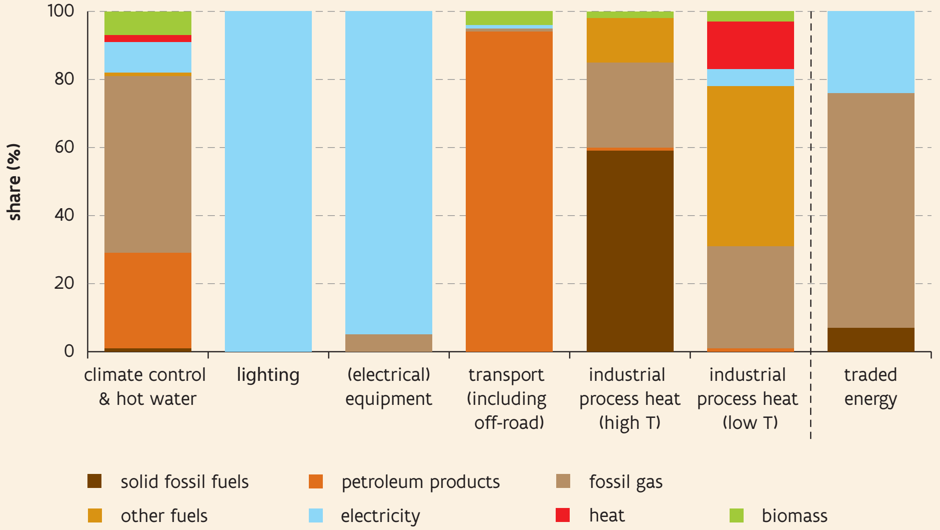
Biomass (solid, liquid and gaseous) and (traded) heat together account for almost 7 % or 61 PJ of the total energy end use. In contrast to biomass, which is used in all sectors, (traded) heat is used almost exclusively in industry. The final consumption of biomass has quadrupled since 2000. The increase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

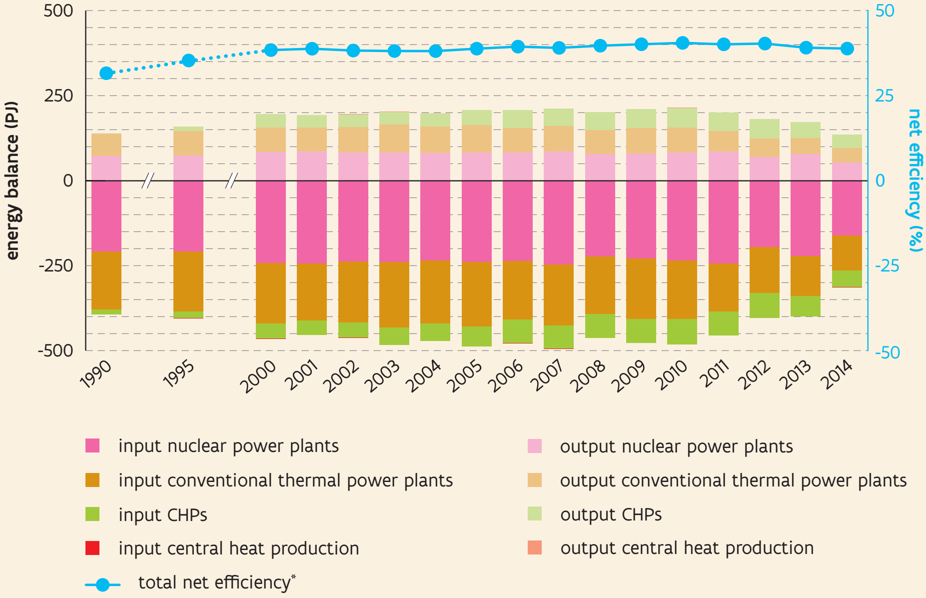
The bulk of all (traded) energy carriers used by end users is supplied from the energy sector, often after transformation of primary sources such as petroleum, nuclear fuel, natural gas and coal. These primary energy sources almost always originate from abroad. Flanders has no known uranium, petroleum 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]

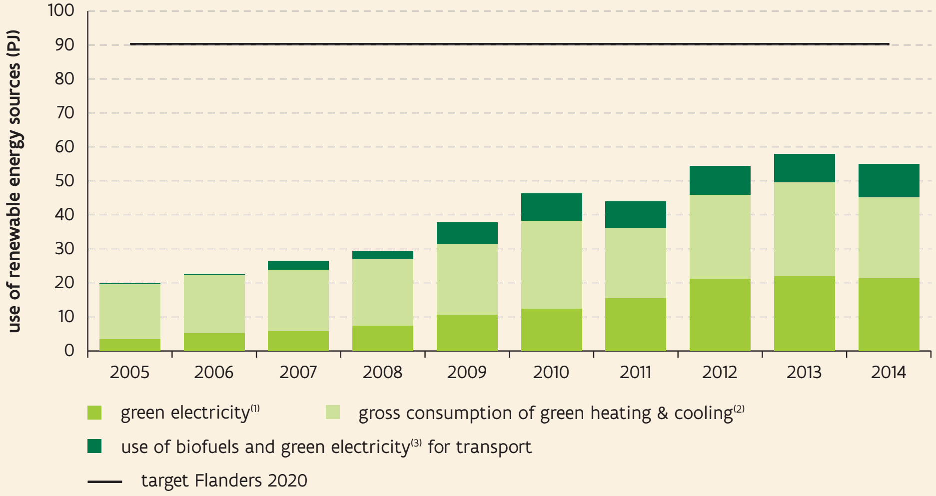
Central electricity production: only two-fifths of primary energy converted into useful energy for end users

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 feed-stocks (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;

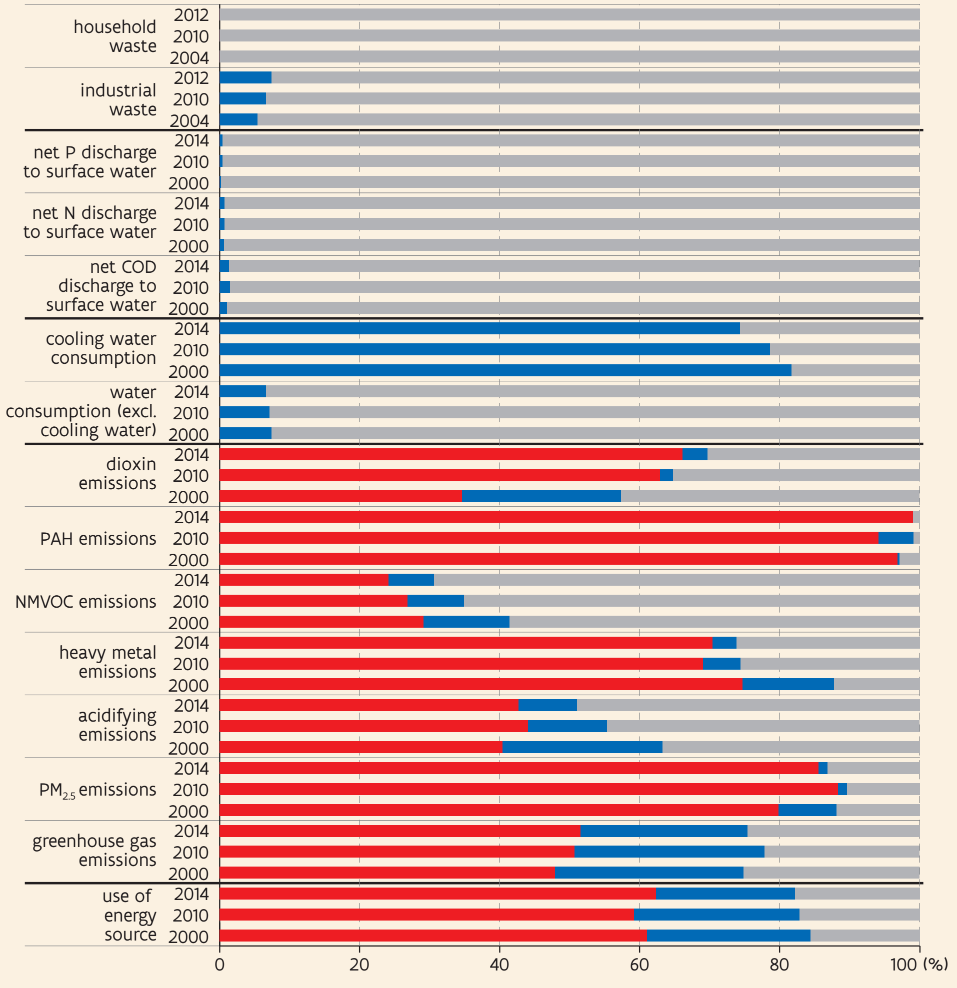
- energy production & distribution: the supply side of the energy system with the transformation of energy sources into energy carriers suitable for the end users, and the transmission and distribution of that energy to the end users. This therefore includes both environmental pressure related to activities 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.

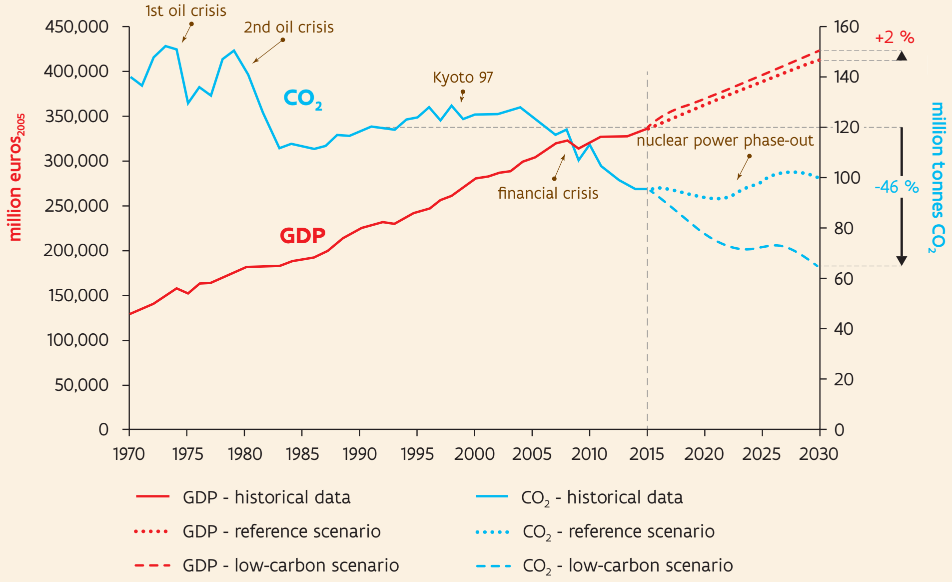
In 2014, energy consumption accounts for 51 % of the greenhouse gas emissions (almost exclusively CO_2) and 43 % of the total acidifying emissions (with shares of 81 % in total NO_x and 55 % in total SO_2 emissions) in Flanders. The CO_2 emissions originate from the burning of fossil fuels, mainly for 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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SYSTEM BALANCE
2017

— 2 Mobility System

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INTRODUCTION

Mobility is of vital importance for the economic functioning of society and offers people the opportunity to develop and relax. To produce and consume, goods must be transported. People travel because they live, work, shop, relax, study, are looked after, etc. in different locations[1, 2, 3]. Spatial planning and mobility are therefore intimately related. Location policy influences mobility, but mobility policy in turn influences the choice of location and the spatial structure[4].

These travel and transport needs result in a wide array of journeys using various modes of transport either motorised or not (walking, cycling, car, bus, motorcycle, rail, shipping, air transport). In order to arrive at an efficient mobility system, an extensive network of roads, railways, railway stations, ports, airports, fuel facilities, parking areas, etc. has been set up, at both the organisational and physical levels. This allows both individual journeys and collective and public transport (train, tram, bus).

Apart from the transport user, many other actors are involved in the mobility system. There are economic actors such as vehicle manufacturers and their suppliers, transport operators, lease companies, project developers, airport and port companies, contractors, banks, etc. Representatives from civil society organisations defend the interests of different mobility groups. The government, too, plays a role through legislation, taxation and subsidisation (e.g. road tax, excise duties on fuels, taxation of company cars, public transport), decisions on infrastructure, organisation of public transport, etc. The actors can substantially influence the organisation of the mobility system, the supply, the policy, and social acceptance.

The mobility system is a complex system where various actors play their respective roles, each from their own perspective and with their own, sometimes conflicting, goals. Ideally, this leads to an efficient mobility system that guarantees accessibility, is safe and affordable, ensures a smooth flow, provides sufficient comfort and has a socially acceptable impact on the environment. The mobility system is, however, under pressure. According to estimates of the European Commission, passenger traffic (measured in passenger-kilometres) is expected to increase by 40 % by 2050 compared to 2010 and freight transport (measured in tonne-kilometres) by 58 %[5]. In Flanders, too, the number of motorised vehicle kilometres continues to increase, resulting in capacity issues and congestion. In the European Union, Belgian drivers take up third place in terms of lost hours due to congestion[6]. Road safety also remains a matter of concern. While the number of road fatalities shows a downward trend, there are still nearly 400 fatalities in Flanders[7] and 28,000 in Europe[8] every year. The pressure on the mobility system is caused in part by the dominant focus over the years on the car as compared with other modes of transport, both in terms of spatial planning (e.g. of cities) and in terms of infrastructure, taxation (e.g. company cars), behaviour and status[9].

The current mobility system has a negative impact on climate change, air quality, health and nature. Traffic emissions and noise pollution are harmful to health. Traffic infrastructures and vehicles take up space and result in fragmentation of space and habitats. Congestion and capacity issues adversely affect flow and accessibility. The current mobility system is therefore reaching its limits and a transition to a more efficient and environmentally friendly system appears to be necessary.

This chapter zooms in on passenger transport and establishes the link with air quality and the impact on health. The climate change issue will not be addressed. Air quality policy may have a positive side effect on climate policy and vice versa, so both should preferably be approached from an integrated perspective. Examples of positive interaction are the reduction strategies for ozone and black carbon. On the other hand, some aerosols have a cooling effect. If these emissions are reduced as part of an air quality and health policy, this may result in an acceleration of climate change as an undesired side effect.

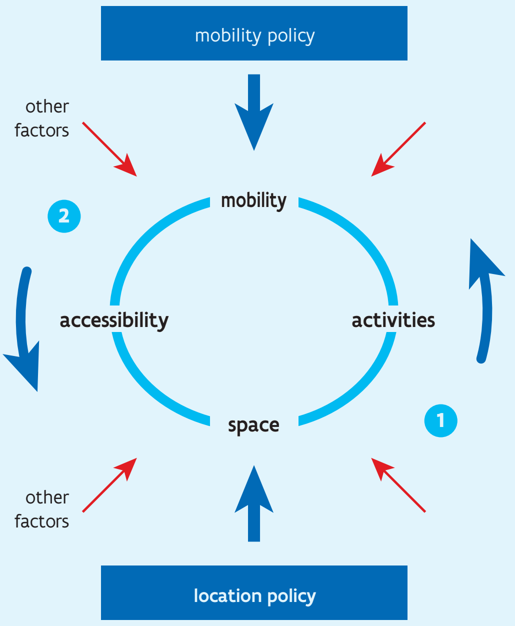
The chapter starts with the mobility motives of passenger transport, with attention being paid to the link between spatial planning and mobility. Subsequently, the traffic activities are described based on the number of (motorised) passenger-kilometres travelled and the modes of transport used. The composition of the car fleet will also be discussed. The environmental disruptions and their health impact are described in detail by means of indicators. Where relevant information is available, the indicators are aimed particularly at the contributions of transport (freight and passenger), or even the share of passenger transport. Other indicators describe the resultant air quality and the health impact, of which passenger transport, or transport in general, is one of the causes. The chapter concludes with a discussion of solution directions that may lead to a more sustainable mobility system.

SOCIETAL DEVELOPMENTS AND ACTIVITIES

Use of space and mobility influence each other

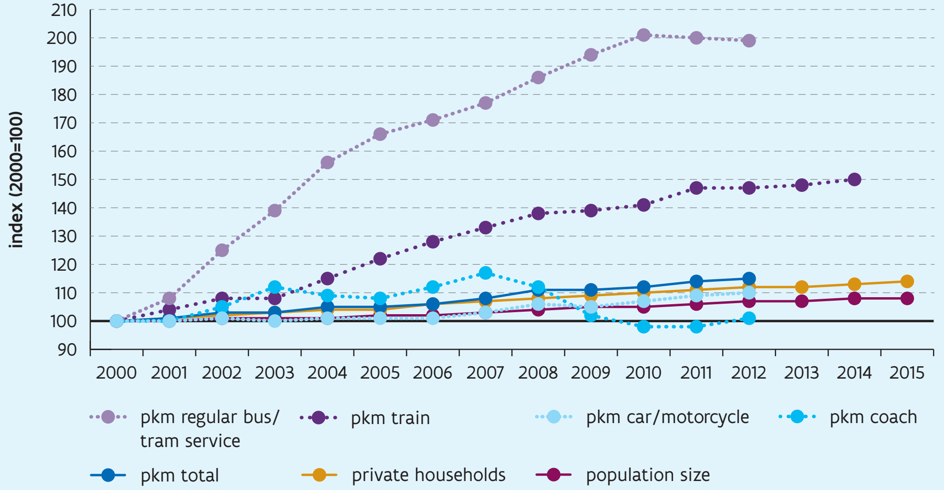
The relationship between the use of space and transport is aptly illustrated in the "use of space transport feedback loop" (**Figure 2.1**): the allocation of use of space to, for example, residential, industrial and commercial purposes, determines where people conduct their activities. The locations of these activities have an influence on the mobility behaviour (1 on the figure) and its characteristics, such as the choice of destination, the choice of mode, and the choice of route. Traffic also results from the fact that the activities take place at different locations. The greater the distance between these locations, the more traffic there will be. Traffic also puts pressure on the infrastructure and thus helps determine the travel time, distance and travel costs, whereby the mobility behaviour can be influenced. The transport system enables this mobility and allows locations to be accessed. As locations become better accessible, they become more attractive as locations for activities; this will influence the location decision of investors, authorities and users (2 on the figure)[4].

Figure 2.1 Relationship between use of space and mobility



Source: Verhetsel (2015)[4]

Figure 2.2 Passenger-kilometres of motorised passenger transport (road traffic and rail), number of private households and population (Flanders, 2000-2015)



Source: MIRA based on ADS, De Lijn (Flemish Region public transport company), FPS Mobility and Transport, Belgian Railways, STATBEL, SVR (Research Department of the Flemish Government)

The spatial structure in Flanders is characterised by a high degree of urbanisation and fragmentation whereby a large area of space at relatively low density is taken up[10]. Typical for Flanders are the spatial pattern of ribbon development and the lack of concentrated residential centres and business zones[11]. Urbanisation of the landscape or dispersed urban development (urban sprawl) is accompanied by higher transport costs and longer travel times for commuters, higher transport demand, higher car use, higher congestion costs and a more expensive public transport infrastructure[12].

Three large groups of mobility motives

In 2015, the Flemish population, on average, made 2.74 trips per person per day. As regards the number of trips, there are three groups of mobility motives with comparable shares: recreational trips, functional trips, and shopping & services. In 2015, recreational trips had a share of 30 %, followed by functional trips (work, school and business trips) with 29 %. Shopping & services (e.g. doctor, bank) accounted for 26 % of the number of trips. In terms of distance travelled, recreational and functional trips are most important. Recreational trips had a share of 39 % in 2015. Functional trips accounted for 38 % of the distance travelled, and shopping & services for 12 %[13].

The level of education and income are by far the most significant socio-economic factors explaining the variability in the mobility behaviour of people. People with a higher diploma and a higher income make more trips and travel greater distances. Moreover, as a general rule, the higher the income, the more likely people are to travel in a less sustainable manner[14].

Number of passenger-kilometres travelled by motorised passenger transport continues to rise

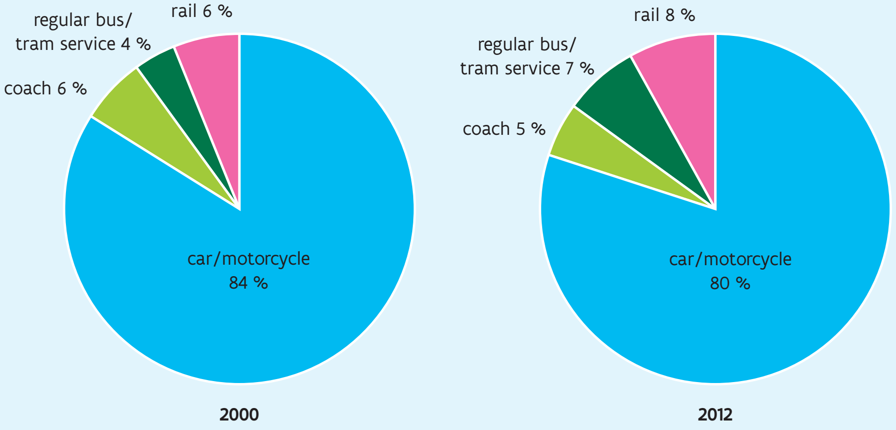
To place the evolution of passenger transport within a wider time frame, only Belgian and no Flemish figures are available. The figures for Belgium[15, 16] show that the number of motorised passenger-kilometres (sum of car, motorcycle, regular bus service, coach and train) has more than doubled since 1970. The car in particular proved very successful. In 2012, almost three times as many passenger-kilometres were travelled by car as in 1970. Automobility grew very rapidly, especially until the 1990s. In 2012, almost 50 % more passenger-kilometres were travelled both by train and by bus/coach than in 1970. They declined in the 1980s and recorded their biggest growth in the early 2000s.

Figure 2.2 zooms in on figures for Flanders from 2000 and shows that the total number of passenger-kilometres travelled by motorised passenger transport (road transport and rail) was 15 % higher in 2012 (80 billion pkm) than in 2000. This is explained in part by the 7 % increase in the population between 2000 and 2012. However, also the number of (motorised) kilometres travelled per person increased, from on average 32 km/day in 2000 to 35 km/day in 2012. The fact that households are becoming smaller, which leads to a larger number of households (+12 % in 2012 as compared to 2000), also plays a role in the increased number of kilometres.

The Mobility Behaviour Survey Flanders 4.5 (OVG)[14] indicates that also the general economic situation affects the number of kilometres travelled. The year 2009, characterised by the financial-economic crisis, is in fact the only year in the period from 2000 to 2012 in which the total number of motorised passenger-kilometres did not increase. The OVG shows that there is an evolution in the number of kilometres travelled per trip, in other words, today (2012-2013) on average we make longer trips than ten years ago (2001). However, this increase cannot be linked to a specific mobility motive.

Public transport and private transport evolved differently between 2000 and 2012. The number of passenger-kilometres travelled by car/motorcycle stabilised from 2000 to 2006 and then increased again. The modes of public transport (regular bus/tram service and train) increased. Until 2010, the

Figure 2.3 Modal distribution of the number of passenger-kilometres travelled with motorised modes (Flanders, 2000 and 2012)



Source: MIRA based on De Lijn (Flemish Region public transport company), FPS Mobility and Transport, Belgian Railways, SVR (Research Department of the Flemish Government) increase was much sharper for the regular bus/tram service than for the train. De Lijn (Flemish Region public transport company) encouraged use through a targeted pricing policy and an extended range of services. Following cuts, the number of services was reduced in 2011, resulting in a decline. Passenger-kilometres travelled by train, by contrast, continued to rise.

Company cars, which are provided to employees as part of their salary package, for both business and personal travel, contribute to the high intensity of road traffic. The number of kilometres travelled by car is also determined by whether or not one has access to a company car[17]. Households with a company car travel 58 km more per week for commuting and 56 km more for personal travel.

No further modal shift in motorised passenger transport in recent years

Figure 2.3 illustrates the modal distribution of the number of passenger-kilometres travelled by motorised passenger transport (road and rail traffic). From 2000 to 2007, the modal share of the car/motorcycle decreased, but in recent years it remained virtually unchanged. With a share of 80 %, the car was still very dominant in 2012. Public transport recorded a modest modal shift. Between 2000 and 2012, the share of the train increased from 6 % to 8 % and of regular bus/tram service from 4 % to 7 %.

The federal commuter survey[18] includes also soft modes (cycling, walking) in its analysis of the evolution of the modal distribution, so these figures are presented here as well. This survey determines the share of transport modes in the number of trips, not in the number of kilometres travelled as indicated above. The share of home-work trips by car (alone and by carpooling) and motorcycle as main mode of transport decreased for employees working in Flanders, from 76.1 % in 2005 to 73.1 % in 2014. This is due almost exclusively to a reduction in carpooling and motorcycle trips. The share of employees using public transport increased to almost one in ten (from 8 % to 9.2 %). Only the share of the train increased (from 4.1 % to 5.3 %), whereas the share of bus/tram/metro remained constant (3.9 %). Cycling also became more popular. As a result, the share of soft modes increased from 14.4 % in 2005 to 16.6 % in 2014. However, fewer people walked to work (from 2.1 % to 1.7 %). The share of collective transport organised by the employer decreased from 1.6 % to 1.1 %. Despite the slightly increased use of the train and the bicycle in 2014 as compared to 2005, the car remains by far the dominant mode of transport for commuting. Since 2005, the car has been abandoned in favour of other modes of transport, mainly in the cities, but to a far lesser extent in other areas.

According to the same study, the commuting distance is a major factor in the choice of transport mode. The car is often used, but mainly for distances between 10 and 30 kilometres. These distances are slightly too long for bicycle traffic, but just not long enough for the train. According to the latest figures of the Mobility Behaviour Survey (2015-2016)[13], the average commuting distance in Flanders is currently 17.9 km.

Dieselification of car fleet curbed

The size of the car fleet and the number of kilometres travelled influence each other. In Flanders, the car fleet has continued to grow[19]. In 2015, there were over 20 % more cars than in 2000. The composition and the age of the car fleet are also relevant for the environmental impact. Diesel cars are more economical and emit on average less carbon dioxide (CO_2) per kilometre than comparable petrol cars. However, they drive more kilometres. Moreover, diesels have a greater impact on health because they emit more particulate matter (PM) and nitrogen oxides (NO_x). For the latest generation of cars (EURO 6), however, the particulate matter standards are equal for diesel and petrol cars. For NO_x the official emission standards for diesel cars are still higher than those for petrol cars. Moreover, for diesel cars there are significant differences between emissions in actual driving conditions and emissions during the official test procedure (see also 'Slight decrease in NO_x emissions in passenger road traffic'), which is not the case for petrol cars. Over the years, there has been a shift in the type of fuel. In 1990, the share of diesels was just over a quarter, in 2000 it already amounted to more than 40 %. The proportion of diesel cars peaked in 2011-2012, with around 62.5 %. This high degree of dieselification has been caused by various factors. The driving performance and comfort of diesel cars improved and the range of smaller diesel cars was extended. The difference in purchase price between diesel and petrol cars also became smaller. Lower excise duties on diesel made diesel vehicles cheaper to use than petrol cars. A number of tax measures differentiating between vehicles in relation to their CO_2 emissions (federal eco premium, taxation of company cars) further contributed to the dieselification. There was also the effect of the rising proportion of company cars, mainly diesel cars. Partly as a result of changes in taxation, but also thanks to the wider range of more economical petrol cars, further dieselification was halted in 2013. The turnaround is noticeable in both personal and company vehicles. In subsequent years, the share fell further to 61 % in 2015. In recent years, the public has also become more aware of the less favourable aspects of some diesel cars, also as a result of the Dieselgate scandal (see also 'Slight decrease in NO_x emissions in passenger road traffic'). Also the fact that diesel cars are less suitable for users travelling mainly short distances, as the particulate filters clog up easily, is becoming more widely known.

Alongside petrol and diesel cars, vehicles using alternative fuels/power trains have in the meantime hit the market. While all types have become more environment-friendly over the years, diesel cars still record the lowest scores in terms of health effects. Alternative vehicles like electric and hybrid vehicles, but also vehicles on CNG/LPG (compressed natural gas/liquefied petroleum gas) are more environment friendly than petrol or diesel cars. In spite of incentives, they represented only 1.2 % of the Flemish car fleet in 2015. Cars using conventional fuels therefore continue to dominate the car fleet. The higher purchase price of alternative vehicles certainly plays a role in this. Other major obstacles preventing their further breakthrough are the limited refuelling/charging infrastructure and the limited action radius of the batteries of electric cars.

ENVIRONMENTAL DISRUPTIONS

Traffic is responsible for the emission of harmful substances. These substances contribute to reduced air quality with adverse effects on health. Air pollution leads primarily to respiratory complaints and cardiovascular effects. Traffic-induced noise pollution also causes health problems. Noise disturbs sleep and prolonged exposure may lead to high blood pressure and cardiovascular problems[2].

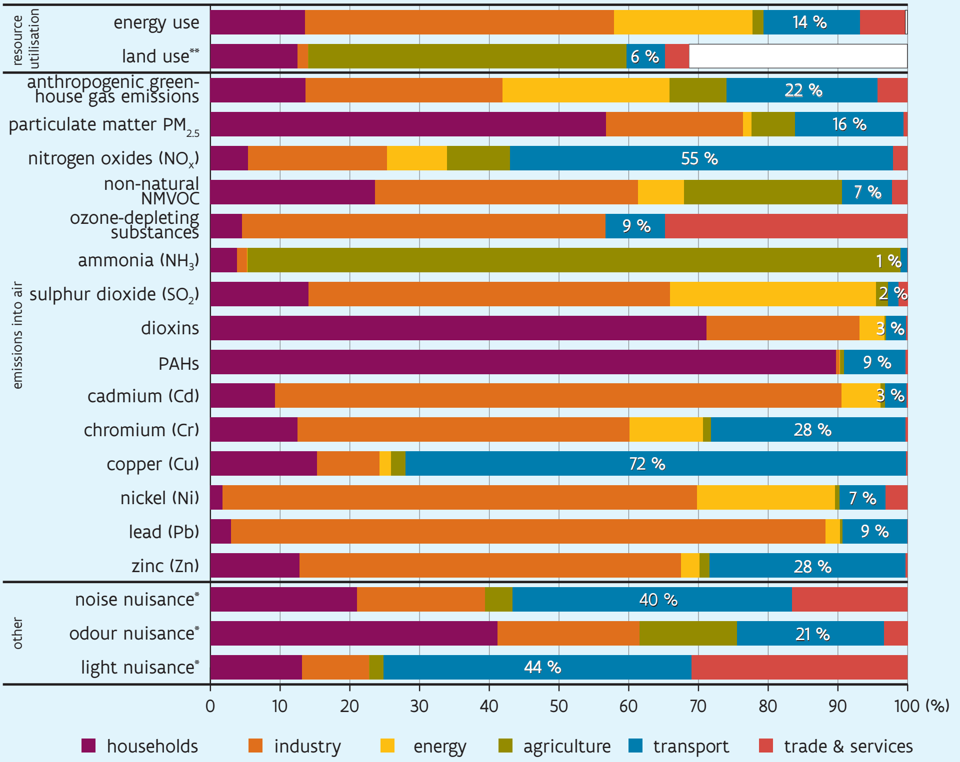
A number of harmful substances (including nitrogen oxides, particulate matter and heavy metals) are emitted directly from the exhausts of vehicles. Some of these substances in turn form new harmful compounds. Non-methane volatile organic compounds (NMVOC) and NO_x form ozone. Together with sulphur dioxide (SO_2) and ammonia (NH_3), they also give rise to the formation of additional particulate matter or so-called secondary particulate matter. Particulate matter and heavy metals are also released into the air as a result of wear of the road surface, brakes, tyres/wheels, rails and overhead lines (non-exhaust emissions). Passing vehicles resuspend the particulate matter.

Transport is still a major source of emission of harmful substances

Figure 2.4 illustrates the importance of the transport sector (passenger and freight transport) for the emission of nitrogen oxides, particulate matter, NMVOC and lead (Pb). Noise nuisance is also intimately linked to transport.

Figure 2.5 shows the evolution of (exhaust and non-exhaust) emissions of a number of air pollutants by transport (passenger and freight transport). The modes of transport considered are: road, rail (only diesel for exhaust emissions), inland navigation, inland maritime shipping, and aviation. For aviation, only emissions during take-off and landing are included, emissions during the flight are not considered. Inland maritime shipping covers the shipping traffic between Flemish ports. The emissions from international maritime shipping are not attributed to Flanders and not considered here. Likewise, the emissions resulting from the production of fuel are not considered here.

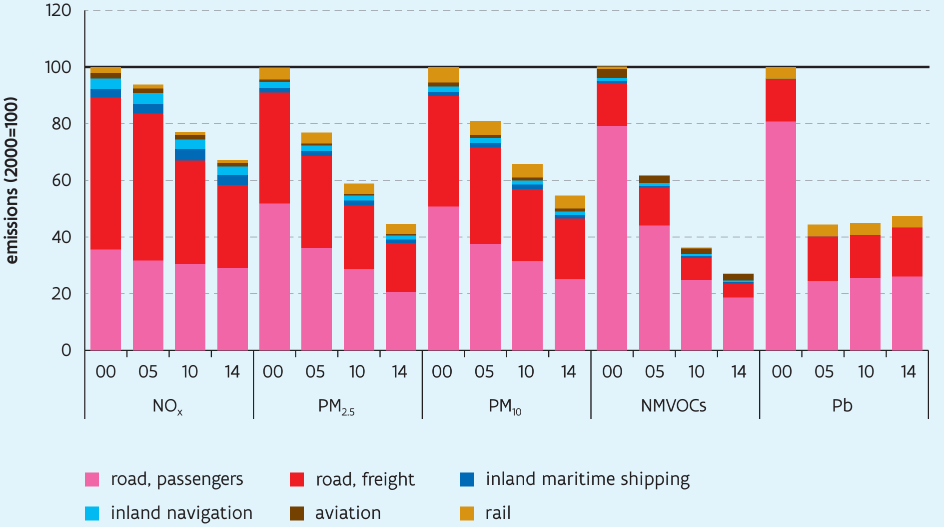
Figure 2.4 Share of the transport sector in environmental pressure (Flanders, 2014)



white bars: not allocable to a sector; * figures 2013; ** figures 2010 or earlier

Source: MIRA

Figure 2.5 Exhaust and non-exhaust emissions of air pollutants NO_x, $PM_{2.5}$, PM_{10}, NMVOC and Pb by the transport sector (Flanders, 2000-2014)



In addition to road traffic, rail and aviation both have a share of passenger transport and freight transport, but this share cannot be broken down for all pollutants and is therefore represented as a single share.

Source: VMM

NO_x emissions from passenger road traffic decreased only slightly

In 2014, more than half (55 %; 61 ktonnes) of nitrogen oxide emissions in Flanders originated from transport (**Figure 2.4**), and this share continues to increase. This is mainly attributable to road traffic (87 %). Passenger road traffic (passenger cars, motorcycles, buses and coaches) accounts for half of the share.

NO_x emissions from passenger road traffic decreased by only approximately one-fifth between 2000 and 2014, despite increasingly more stringent emission standards for vehicles. This is due, among other things, to the continued increase in the number of kilometres travelled in the last ten years. Another major factor was the significant dieselification of the car fleet, because diesel cars emit far more NO_x than do petrol cars. Finally, the small decline in NO_x emissions by passenger cars also results from the higher emissions from diesel cars in actual traffic than is legally permitted via the EURO standards. This is due in part to an obsolete test procedure that does not reflect driving behaviour in actual driving conditions and to the use of authorised modifications to the test vehicles, for example, optimisation of the vehicle's temperature during testing to reduce rolling resistance[20]. However, recent research[21] revealed that the mechanism whereby certain carmakers use specially designed software to distort the tests, the so-called Dieselgate, could possibly play a greater role. The difference between actual emissions and EURO standards has increased over the years. For EURO 3 diesel cars (from 2000) this was a factor of two, for EURO 6 diesel cars (from 2014) this increased to a factor of on average seven[20]. As a result, the NO_x emissions from a EURO 6 diesel car are only 40 % lower than those from a EURO 3 diesel car, whereas this should actually be 84 %. EURO 4 and EURO 5 diesel cars do not score better than EURO 3 diesel cars.

Significance of non-exhaust particulate matter emissions increases

Emissions of $PM_{2.5}$ (this is the fraction of particulate matter with an aerodynamic diameter less than 2.5 μm) by transport decreased by more than half between 2000 and 2014 (2.7 ktonnes in 2014), and accounted for 16 % of Flemish emissions in 2014. Transport is not the main source of $PM_{2.5}$, but because the $PM_{2.5}$ is emitted close to the ground and, moreover, often in densely populated locations, its impact is still significant. In 2014, road traffic still accounted for 85 % of the total $PM_{2.5}$ emissions by transport, with passenger road traffic making up almost half of the total (46 %). Rail transport, mainly with non-exhaust emissions, was responsible for 8 %. Road traffic recorded the greatest reduction, due to the EURO 5 standard which made it compulsory for diesel cars to be fitted with a built-in and closed particulate filter. Also De Lijn installed particulate filters and continued the greening of its bus fleet.

Wear of brakes, tyres, road surface, rails and overhead lines contributes to non-exhaust $PM_{2.5}$ emissions. These emissions are proportional to the number of kilometres travelled. After an increase between 2000 and 2007, they decreased in 2008-2009 due to the economic crisis, and then increased again, in line with economic recovery. It accounts for an increasingly larger share in the total $PM_{2.5}$ emissions by transport because thus far only a few measures have focused this fraction. Specifically for passenger road transport, non-exhaust emissions accounted for 16 % of the total $PM_{2.5}$ emissions in 2000, in 2014 this percentage had increased to 45 %.

Emissions of PM_{10} (particulate matter smaller than 10 μm) decreased less sharply than $PM_{2.5}$ emissions over the period from 2000 to 2014. The larger particles in the PM_{10} fraction are mainly non-exhaust emissions for which only few measures have been elaborated. In 2014, passenger road transport had a share of 62 % in non-exhaust emissions.

Particulate matter is not only emitted directly. Traffic also plays an important role in the formation of secondary particulate matter, mainly via the emission of NO_x and NMVOC.

Table 2.1 Overview of EU targets and WHO guidance values for air quality

	Averaging period	EU target[1]	WHO guidance values[2]
NO_2			
Protection of human health	year	limit value (2010): 40 µg/m^3	40 µg/m^3
O_3			
Protection of human health	highest daily 8-hour average	target value (2010): 120 µg/m^3 – max. 25 days per year, averaged over 3 years	100 µg/m^3
Protection of human health	highest daily 8-hour average	long-term target 120 µg/m^3	
$PM_{2.5}$			
Protection of human health	year	limit value (2015): 25 µg/m^3	10 µg/m^3
Protection of human health	year	indicative limit value (2020): 20 µg/m^3	
Protection of human health	1 day		25 µg/m^3 - max. 3 x per year

(1) EU (2008)[22]

(2) WHO (2006)[23]

As a result of the introduction of unleaded petrol, lead emissions fell sharply until 2005. The increasing road traffic, however, caused lead emissions to rise again. Today, lead emissions are caused mainly by wear of brakes and tyres.

NMVOC emitted mainly by petrol vehicles

Petrol cars are primarily responsible for the NMVOC emissions. The tighter EURO standards for vehicles resulted in a significant decrease in NMVOC emissions from transport since 2000. In 2014, emissions amounted to 5.1 ktonnes, or 7 % of the total Flemish emissions. Road traffic had a share of 87 % in total transport emissions, and passenger road transport a share of 69 %.

Traffic emissions: conclusions

Road traffic emissions are primarily responsible for the emissions from passenger transport. The level of the emissions is determined by the number of kilometres travelled, the renewal of the vehicle fleet and the composition of the vehicle fleet (e.g. dieselification). Despite the growing number of kilometres, NO_x, $PM_{2.5}$, PM_{10} and NMVOC emissions decreased between 2000 and 2014. This decrease was to be attributed mainly to the more stringent emission standards for new vehicles. It was greatest for NMVOC and lowest for NO_x. The increase in lead emissions after 2005 is to be attributed to the increasing road traffic.

Busy traffic affects air quality

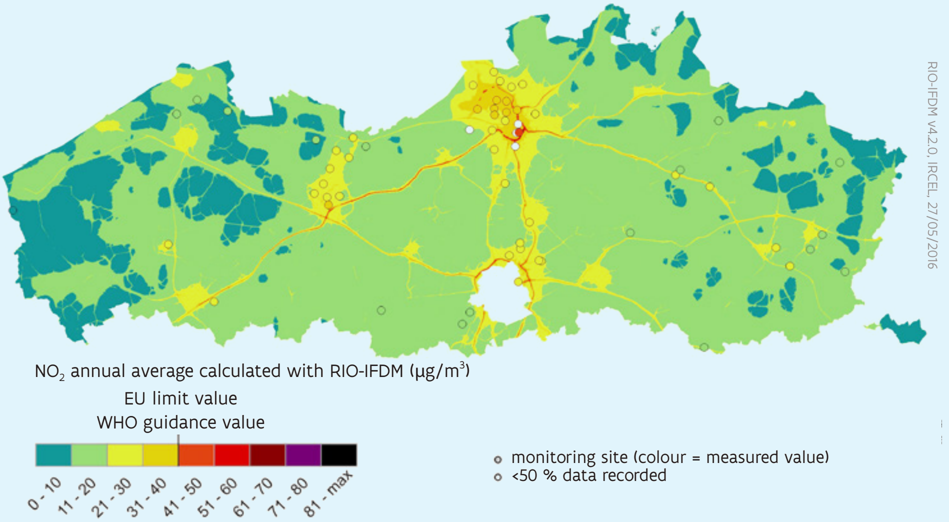
Not only transport contributes to the emission of harmful substances in Flanders. Households, industry and agriculture also have their respective shares. Moreover, the air quality in Flanders is determined not only by the emissions within Flanders itself. Also the pollutants emitted in the other regions and abroad contribute to the concentration of pollutants in Flanders. Certain pollutants are carried over long distances and the weather conditions also play a role in the spread and formation of pollutants. The air quality and the health impact in general, with specific attention for traffic-related pollutants, will be discussed below. The share of (Flemish) traffic in the measured concentrations can only be determined by modelling and is illustrated indicatively below for NO_2. **Table 2.1** provides an overview of the targets of the European Union (EU) and the guidance values of the World Health Organisation (WHO) for the pollutants discussed below.

Too high NO_2 concentrations at busy traffic locations and in street canyons

Nitrogen oxides (NO_x) consist of a mixture of nitrogen dioxide (NO_2) and nitrogen monoxide (NO). NO_2, in particular, is harmful to humans and ecosystems. It is an oxidising gas that can cause irritation of the airways. Short episodes of high concentrations, but also long-term exposure to low concentrations, are harmful. Locations with intense road traffic are characterised by higher NO_2 concentrations. The large proportion of diesel cars in the Flemish car fleet has an adverse effect on the NO_2 concentrations in the air because diesel cars emit far more NO_x than do petrol cars.

To protect public health, the EU imposed, as of 2010, a limit value of 40 µg/m^3 for the annual average NO_2 concentration from 2010, which corresponds with the WHO guidance value. The annual average NO_2 concentrations, averaged over all monitoring sites in Flanders, decreased slightly after 2003. The EU annual limit value, and therefore also the WHO guidance value, was exceeded in 2015 at one urban traffic-related monitoring site (out of a total of 42 monitoring sites), notably in Borgerhout on the street side of the Plantin en Moretuslei.

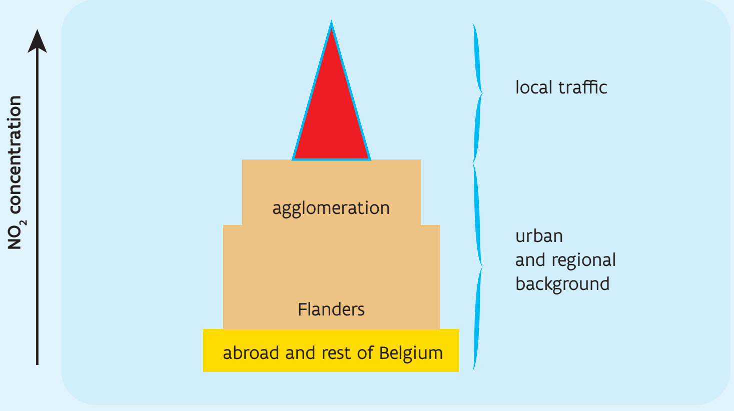
Figure 2.6 Modelled spatial distribution of the annual average NO_2 concentrations in air (Flanders, 2015)



The modelled values may locally differ from reality due to uncertainties in both the RIO interpolation technique and the emissions used, and also due the fact that the topography and roadside obstacles are not taken into account. In street canyons, the model may underestimate the concentrations.

Source: VMM/IRCEL

Figure 2.7 Modelled build-up of the NO_2 concentrations in a busy traffic street



Source: IRCEL/VITO[26]

Models are used to estimate NO_2 concentrations in locations where no monitoring is carried out, so as to obtain a picture of the NO_2 concentrations for the whole of Flanders. From these model calculations and from studies[24, 25], it appears that too high NO_2 concentrations occur in several traffic-intensive urban locations and in so-called street canyons in Flanders. Street canyons are narrow, densely built-up streets with much traffic, where the air pollution can spread less easily. The highest annual average concentrations occur in the cities and near busy road traffic locations (**Figure 2.6**). In a number of traffic intensive locations, the limit value of 40 µg/m³ is exceeded. To estimate the exposure of the population, modellings are carried out based on population densities (i.e. not based on activity profiles). According to this modelling, 0.3 % of the Flemish population (21,000 people) was exposed to annual average concentrations in excess of 40 µg/m³ in 2015. This is probably an underestimation of reality because these modellings do not take into account the street canyon effects.

Local NO_x emissions contribute significantly to local NO_2 concentrations. **Figure 2.7** indicatively illustrates the modelled concentration build-up at a monitoring site in a busy traffic street. This demonstrates that almost one-third of the concentration is determined by local emissions from the traffic in the street[26].

EU annual limit value for particulate matter achieved, but is it ambitious enough?

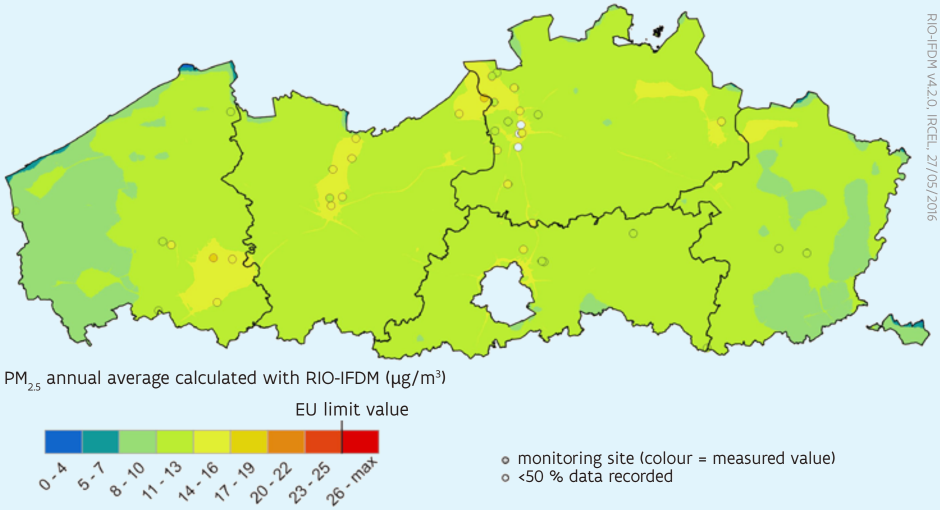
Both primary and secondary particulate matter contributes to the particulate matter concentration in the air. The size of the particles varies, but both larger and smaller particles cause health effects. A number of effects occur in the short term, for example, hospitalisation for heart problems, others are the result of long-term exposure, such as chronic bronchitis or lung cancer. For the protection of human health, the EU imposed, as of 2015, a limit value of 25 µg/m³ for the annual average $PM_{2.5}$ concentration, which provides a picture of the long-term exposure to particulate matter. There is also an indicative annual limit value of 20 µg/m³ by 2020.

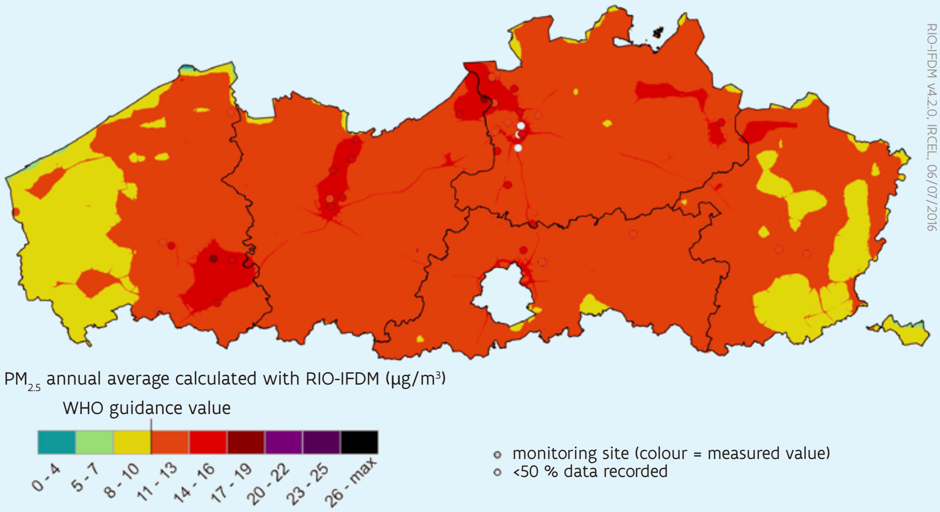
According to the WHO, there is no safe threshold value below which no harmful effects occur. Already in 2005, the WHO advised 10 µg/m³ for the annual average $PM_{2.5}$ concentration. In addition, they advised to limit short-term exposure: the daily average $PM_{2.5}$ concentration was not to exceed 25 µg/m³ with only three exceedances per year being allowed.

In 2015, Brunekreef et al.[27] concluded that the current European limit values are not ambitious enough. The ESCAPE study[28] in fact demonstrates that health effects also occur at $PM_{2.5}$ concentrations lower than 20 µg/m³ or even 15 µg/m³. In addition to the known effects (airways and cardiovascular disorders), the study points to a significant adverse effect of $PM_{2.5}$ on birth weight and head circumference at birth[29]. There are also indications that $PM_{2.5}$ plays a role in diabetes[30].

The first map of **Figure 2.8** shows that the EU annual limit value was not exceeded anywhere in 2015. The second map shows that nearly every inhabitant of Flanders (94 % based on population density) was still exposed to concentrations higher than the more stringent WHO guidance value. The highest annual average $PM_{2.5}$ concentrations occurred in Antwerp and Ghent and their respective port areas, in the south-east of the province of West Flanders, and in part of the Campines. The influence of traffic

Figure 2.8 Modelled spatial distribution of the annual average $PM_{2.5}$ concentration compared to EU limit value (above) and WHO guidance value (below) (Flanders, 2015)





The modelled values may locally differ from reality due to uncertainties in both the RIO interpolation technique and the emissions used, and also due the fact that the topography and roadside obstacles are not taken into account. In street canyons, the model may underestimate the concentrations.

Source: VMM/IRCEL

is noticeable, albeit less pronounced than for the more traffic-related pollutants such as NO_2 and black carbon. Some motorways have higher concentrations than the surrounding areas. Higher concentrations were also present in the northern part of the Brussels ring road. In 2015, the most western and eastern parts of Flanders had the lowest $PM_{2.5}$ concentrations. Also the WHO guidance value for short-term exposure is still far out of reach. In 2015, the whole Flemish population was exposed to concentrations that exceed this guidance value.

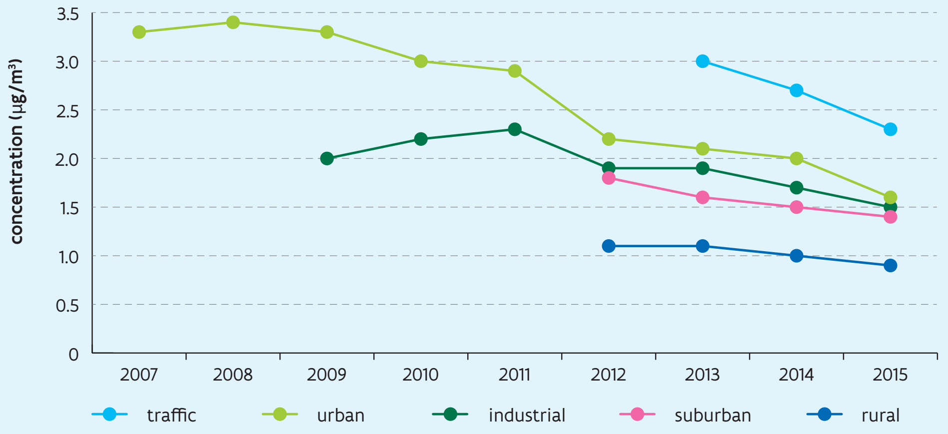
In 2012, the WHO explicitly made the link to traffic and classified diesel soot as carcinogenic[31]. The black carbon concentration is a measure of that soot. Black carbon is mainly present in the ultrafine fraction of particulate matter ($PM_{0.1}$, particles smaller than 0.1 µm). **Figure 2.9** clearly shows that the highest black carbon concentrations are measured in the traffic area type, followed by the urban area type. The rural area type has the lowest concentrations.

NO_x emissions from road traffic play a complex role in ozone contamination; long-term targets for ozone concentrates not yet reached

Nitrogen oxides, together with other pollutants such as NMVOC, also play a role as ozone precursors. These are substances, which in the presence of solar radiation on hot days, give rise to ozone formation. Ozone chemistry is a complex process that depends, among other things, on the weather conditions and the concentration ratios of the various pollutants in the air. For example, there is no linear relationship between the amount of emitted precursors and the amount of ozone being formed. Road transport emits a mixture of nitrogen oxides (NO_x); NO_2 forms ozone, NO breaks down ozone. Ozone breakdown by NO predominates in busy traffic locations whereby the ozone concentrations are locally lower. The amount of emitted NO_x and the ratio between NO_2 and NO is furthermore dependent on the vehicle type. Diesel cars emit more NO_x than do petrol cars and for the newer types of diesel cars the NO_2/NO ratio is higher than for the older types. The ozone chemistry depends on so many factors that it is not straightforward to establish a clear relationship between traffic emissions and the resultant ozone concentrations.

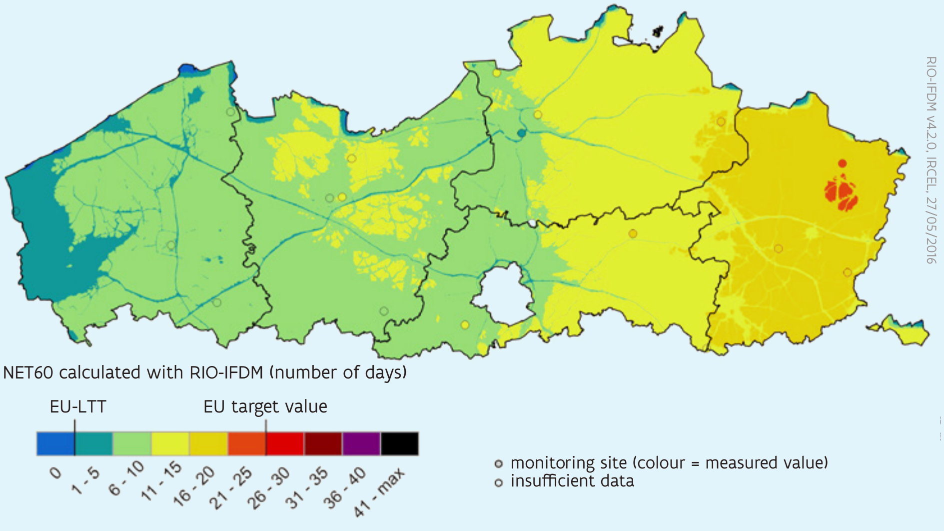
The ozone formed is harmful to humans, plants and materials. Ozone can cause acute health effects such as respiratory problems, (temporary) lung function reduction or inflammatory reactions in the lungs. As health target value, the EU stipulates that the maximum daily 8-hour mean is not to exceed a concentration of 120 µg/m^3 (= NET60ppb-max8h) on more than 25 days per calendar year as of 2010. To level out the impact of weather conditions (temperatures, number of sunshine hours) on the ozone chemistry, the number of exceedance days is averaged over 3 years. In 2015, the highest 3-year average (over 2013, 2014 and 2015) amounted to 15 exceedance days. This number of exceedance days is in line with the 3-year average values of the past seven years and well below the target value of 25 days. This is due to favourable weather conditions over several years in combination with reductions in the emissions of ozone precursors. An analysis of the combination of the number and extent of exceedances shows that the ozone peak excess decreased slightly between 1990 and 2015 in more or less comparable weather conditions. This decrease can be attributed to the emissions reduction policy for ozone precursors.

Figure 2.9 Annual average black carbon concentration by area type (Flanders, 2007-2015)



Source: VMM

Figure 2.10 Modelled spatial distribution of the number of ozone exceedance days (NET60ppb-max8h) (Flanders, 2015)



The modelled values may locally differ from reality due to uncertainties in both the RIO interpolation technique and the emissions used, and also due the fact that the topography and roadside obstacles are not taken into account. In street canyons, the model may underestimate the number of days.

Source: VMM/IRCEL

Figure 2.10 shows the modelled spatial distribution of the number of ozone exceedance days in Flanders in 2015. Motorways are represented as lines where fewer ozone exceedance days occur. In addition, a clear east-west gradient is visible, which is due primarily to differences in weather conditions.

However, in 2015, the EU long-term target (not a single exceedance day above 120 µg/m^3) was not reached at any of the monitoring sites in Flanders, and therefore neither was the more stringent WHO guidance value which sets the threshold at 100 µg/m^3.

To achieve a sustainable reduction in ozone concentrations in Flanders and to reach the long-term targets, significant and global reductions in the emission of ozone precursors are needed. To this end, emissions from various ozone precursors, originating from different sources (including road traffic) should decrease over a large area. In fact, ozone precursor pollution in the northern hemisphere significantly affects the ozone concentrations in Flanders.

Air quality: conclusions

The evolution of the air quality in Flanders is, on the whole, slightly positive, but traffic continues to play role in a number of bottleneck pollutants. Too high NO_2 concentrations occur in busy traffic locations and in street canyons. The role of NO_x emissions and therefore also the share of traffic in ozone pollution is a complex one, but the European long-term targets for ozone concentrations are not yet reached. The European targets for particulate matter are achieved, but the health-related WHO guidance values are still out of reach.

Health effects due to environmental disruptions

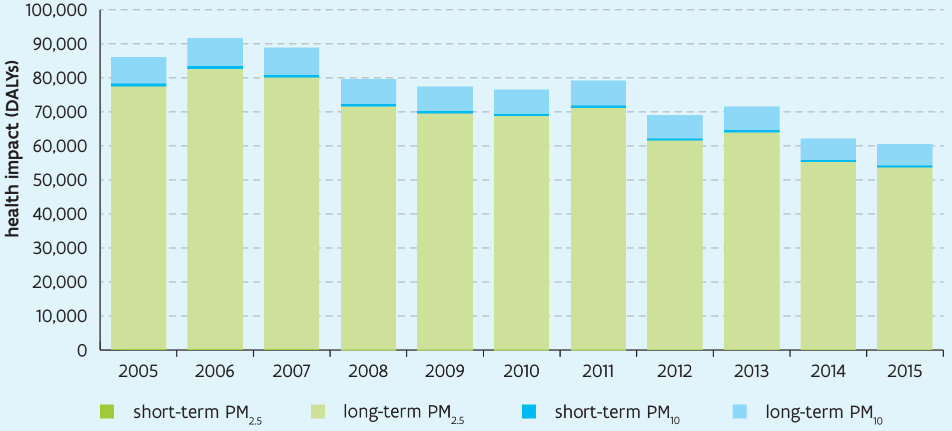
Environmental disruptions cost Flemish people on average one healthy life year

The indicator "potentially lost healthy life years", also called 'Disability Adjusted Life Years' or DALY, is used to describe the disease burden of a population as a result of environmental disruptions. Both the number of years lost due to premature death and the number of disease-years are calculated.

For Flanders, DALYs were calculated for 14 stressors: particulate matter, ozone, atmospheric benzene, carbon monoxide (CO), dioxins in food, electromagnetic radiation, transport noise, heat, lead, radon, moulds and moisture, UV, formaldehyde and passive smoking[32]. In case of lifelong exposure to the current pollution, every inhabitant in Flanders loses on average one healthy life year (or one DALY). For sensitive groups such as asthma patients, children or elderly people, the health impact is probably greater.

The two major stressors are particulate matter and noise nuisance. Traffic plays an important role in both cases. The current particulate matter concentration is responsible for 71 % of the total health impact by environmental disruptions, and noise nuisance for 7 %. The twelve remaining stressors account for just over one-fifth of the total environmental burden in Flanders. Of these stressors, traffic in particular contributes to emission of lead, CO, dioxins, benzene and formaldehyde, and also to the formation of ozone.

Figure 2.11 Lost healthy life years due to exposure to particulate matter (Flanders, 2005-2015)



In interpreting the results, allowance must be made for the fact that the uncertainty for the estimation of the DALYs remains relatively high. This is due to the uncertainty of the concentration response relations derived in epidemiological analyses.

Source: VITO based on VMM, IRCEL, SVR

Health impact from particulate matter determined mainly by exposure to $PM_{2.5}$

Figure 2.11 shows that, despite the increase in population, the health impact caused by particulate matter ($PM_{2.5}$ and PM_{10}) decreased by 30 % over the last ten years. This is the result of lower particulate matter concentrations due to the reduction in emissions of primary particulate matter and particulate matter precursors, both in Belgium and abroad. Although Flanders met all the EU limit values for protection of human health against particulate matter, on average one healthy life year per 100 inhabitants was still lost in 2015 due to exposure to particulate matter. This means that every inhabitant in Flanders loses on average nine healthy months in case of lifelong exposure to the current particulate matter concentrations.

Smaller $PM_{2.5}$ in particular can penetrate deep into the body and cause major health damage. The traffic-related and carcinogenic diesel soot belongs to the $PM_{2.5}$ fraction. Long-term exposure to $PM_{2.5}$ may lead to premature death and has the greatest share of the health impact of particulate matter (88 % in 2015). Long-term exposure to PM_{10}, which may lead, for example, to chronic bronchitis, is also important (10 % in 2015). Acute or short-term exposures, which may lead, for example, to hospitalisation due to heart problems, use of bronchodilators, or absenteeism, account for only 1 % of the health impact.

The costs associated with disease and premature death are not (fully) included in the price of the environmentally disrupting activity, but is (partly) borne by society. They are therefore 'external' health costs. Examples are the cost of chronic bronchitis and also the cost incurred by absenteeism at work[32]. The total external costs caused by particulate matter amount to approximately 4 billion euros (2015). One-third of these external costs (35 % in 2015) is due to acute exposure to particulate matter ($PM_{2.5}$ and PM_{10}), highlighting the importance of this exposure.

Lead exposure may cause mental retardation in young children or high blood pressure in adults. These effects result in lead being responsible for 2 % of the total health impact by environmental disruptions (DALYs)[32].

Respiratory complaints due to exposure to increased ozone concentrations

In addition to the more general DALY approach, the health damage caused by ozone is also calculated as the number of extra urgent hospital admissions for respiratory complaints due to increased ozone concentrations in persons aged 65 and over[33]. This provides a picture of the exposure to increased ozone concentrations throughout the year, and not only of the effect of ozone peak concentrations on hot summer days.

Since 2001, increased ozone concentrations have each year resulted in 600 to 800 extra urgent hospital admissions of persons aged 65 or over in Flanders (i.e. about 2.5 % of the total number of urgent hospital admissions in that age category). In 2003 and 2006, the extra number of urgent hospital admissions for high ozone peak concentrations amounted to 1,400 and 1,100 respectively.

The sensitivity to the health effects of ozone varies from person to person, but in all cases the effects depend on the dose received. The dose is determined by a combination of ozone concentration, exposure period, and inhalation rate. The last two factors can be mitigated by avoiding outdoor activities and physical exercise at increased ozone concentrations. These mitigations by themselves already have a beneficial impact on well-being. To ensure sustained lower doses, lower ozone concentrations are required, which can only be achieved through both a regional and international policy aimed at reducing the emission of ozone precursors.

Traffic is major source of noise nuisance

The Written Environmental Survey[34] shows that Flemish people experience traffic noise as the major source of nuisance. Increased exposure to traffic noise may lead to severe nuisance, serious sleep disturbance, and cardiovascular diseases. A large part of the population is exposed to traffic noise, caused, among other things, by the dense road network, the increasing number of kilometres driven, and the high population density.

For an assessment of the potential noise nuisance caused by traffic, it is calculated by modelling how many persons are exposed to which noise levels. This information is linked to the known relationships between exposure to different noise levels and experienced nuisance, producing an assessment of the extent to which noise nuisance may occur. These results are then supplemented with the results of nuisance surveys. The model calculations for 2015 suggest that 14 % of the population in Flanders is potentially severely annoyed by noise from road traffic. For aviation and rail traffic these figures are significantly lower: 5 and 1 % respectively[35]. The percentage of people highly annoyed by road traffic hardly changed between 2003 and 2015. The periodically repeated Written Environmental Survey, nonetheless, shows a decrease in the percentage of reported cases of severe nuisance caused by road traffic. The exact cause of these differences has not yet been identified, but may be the result of a combination of a changed sensitivity and lifestyle. Younger generations may be more tolerant to noise than estimated in the standardised nuisance functions. The number of people potentially severely annoyed by air traffic living within the 55 dB contour around the Brussels National Airport, decreased between 2007 and 2015 by 30 % as a result of the number of (night) flights and the use of quieter aircrafts. These people have only a small share in the total percentage of people potentially severely annoyed by air traffic. Also people at greater distances from the major airports and close to military airports may experience nuisance. For the reported nuisance by aviation away from the immediate vicinity of airports and for the percentage of people potentially severely annoyed by rail traffic noise, the fluctuations between 2003 and 2015 fall within the accuracy margin of the model.

SOLUTION DIRECTIONS

The persistent congestion, traffic safety and environmental problems are evidence that the current mobility system is reaching its limits. Moreover, the expected population growth, the reduction in family size, and an increase in individual activity may put the mobility system under increased pressure in the future[36].

The problems encountered on the road are to a large extent associated with the large number of trips and kilometres travelled by car. Car use is, however, deeply rooted in society and in everyone's behaviour. Therefore, drastic measures in combination with a number of social and technological developments are needed to bring these mobility problems under control. These measures may be aimed at:

- reducing the number of trips and/or reducing the distances involved (avoid);
- facilitating a shift to more environmentally friendly modes of transport (shift);
- cutting back energy consumption and reducing the environmental impact of means of transport (improve)[2, 37].

First of all, it should be considered whether all these trips are actually necessary. The efficiency of the transport system must be improved and the demand for transport handled intelligently, so that unnecessary trips are avoided and the utilisation rate increases. Secondly, as many trips as possible must be undertaken with a more environmentally friendly mode, for example, public transport or cycling instead of car use. Finally, each mode of transport must become more environmentally friendly[38].

Better spatial planning leads to fewer mobility problems

Spatial planning is of vital importance if mobility issues are to be tackled at source. One of the major instruments to influence travel distances is location policy. A better alignment between functions (living and working, but also school, shopping and recreation) in the form of greater spatial proximity can reduce travel distances and eliminate chained trips. Urban development around major public transport nodes and routes makes it easier for residents to orient their mobility behaviour towards other modes than the car. The individual characteristics of the built-up environment, such as density, functional interweaving and accessibility, on the distances travelled will, in most cases, probably have a small effect, but their combined effect can be quite large[39]. Better spatial planning may not only lead to environmental gains, but may also improve the accessibility of destinations[40]. The latter may in turn lead to more trips.

The organisation of cities may induce people to change their mobility behaviour[2]. Cities and municipalities can limit car traffic through targeted circulation plans, or by means of spatial measures such as low-traffic and no-traffic streets where soft modes of transport are given priority. A targeted parking policy can discourage car traffic in the city. Efficient public transport can transport visitors from peripheral parking areas to the city centre. In low emission zones (LEZ), certain vehicles can be banned because they emit too many harmful substances. All these measures locally reduce air pollution and noise nuisance and moreover often contribute to a higher living quality in the city.

Sustainable modes should have priority

Safe and comfortable pedestrian and cycling paths are necessary to promote these sustainable modes of transport. The emergence of the electric bicycles offers new opportunities to reduce the share of car use in commuting. Bicycle highways can significantly further enhance these opportunities. An extensive and efficient public transport network remains one of the cornerstones of the future mobility system. Public transport itself must also become more environmentally friendly. An efficient combination with other modes (e.g. bicycle sharing) can enhance the appeal of public transport[46].

Financial incentives can drive mobility behaviour

Tax measures can significantly affect the choice of the place of residence, the mobility behaviour, and the choice of a particular mode of transport, with positive or negative environmental effects[2]. The current tax regime for company cars promotes automobility; it encourages people to use their cars more intensively, also for private purposes[17]. A general tax deduction for commuting can stimulate car use and lead to greater distances travelled and to urban sprawl. However, much depends on how tax deductibility is applied, i.e. the way in which cars are taxed as compared to the other modes[37]. Properly designed tax measures do seem to succeed in promoting more environmentally friendly vehicles[41].

The mobility budget is an alternative to company cars. Employees receive a given budget which they can spend on the most suitable means of transport at any given time. The mobility budget should encourage employees to adopt multimodal mobility behaviour by using several modes for a single trip or using different modes for different trips[42]. It is meaningful only if it is combined with other measures such as road pricing[43].

By having users pay for the use of the infrastructure it is possible to influence the price and therefore also the demand for transport[2]. Pricing can alter the behaviour of drivers[44]. Such pricing (e.g. kilometre-based charges) can induce people to reduce the number or length of trips, to shift the time of the trips, or to consider the use of environmentally friendly vehicles and/or a change of mode. Therefore, it remains important that external costs of transport are correctly reflected in the pricing[37].

Technological improvements will not solve all problems

Driven by EU legislation, carmakers have succeeded, through a variety of technological measures, in making their cars more economical and more environmentally friendly. Partly as a result thereof, emissions to air have decreased, but further efforts still need to be made for certain pollutants. A very profound technological change is the transition from the internal combustion engine to the electric motor, which does not produce exhaust emissions and is also significantly quieter. However, the switch to electric cars will not solve all problems. Emissions to air, for example, due to wear of the tyres, will continue to exist. Electric vehicles take up just as much space and contribute to congestion just as much as conventional vehicles. Because fuel costs per kilometre are lower, they could even contribute more to congestion. Moreover, part of the environmental pressure may shift to the location where the electricity and the battery are produced.

The introduction of autonomous or self-driving cars is approaching. Yet it is difficult to predict when they will effectively hit the market, especially given the uncertainty regarding their regulation[45]. To the extent that they are cooperative vehicles, i.e. vehicles that communicate with each other and with roadside systems, they can produce capacity gains. However, a higher road capacity and the comfort of self-steering vehicles can in turn result in higher traffic volumes and greater distances travelled. Commuters who use their daily train journey to catch up on some reading or work could do so even more comfortably in a self-driving car[45, 46]. New technologies in the field of ICT offer a wide array of possibilities. Smart transport systems can help reduce fuel consumption and congestion[2]. Alternative forms of transport, such as Uber which is accessible via a mobile app, are becoming increasingly popular. An important question is how these new technologies will affect transport patterns. They can make the transport system more efficient, but this may in turn lead to an increased demand for mobility.

New socio-economic developments offer new prospects

Car sharing can be an environmentally friendly alternative to car ownership because the cost structure and the cost transparency induces people to consider, for each trip, whether use of the car is the most cost-effective option. With car ownership the fixed costs (purchase, insurance, taxes) are incurred at the time of the purchase, so that there is less incentive to consider other options for a particular trip. Moreover, car sharing allows the most appropriate car type to be chosen as soon as there is a sufficient number of available shared cars, whereas car owners will also use their family car, for example, when the number of passengers is limited to one or two. Finally, cars used for car sharing can be more environmentally friendly than privately owned cars. However, there is also the risk with car sharing that a number of trips by cycling or public transport are replaced by trips using the shared car or that trips are done that otherwise would not have been done[47].

Another development that raises high expectations is 'Mobility as a Service' (MaaS). This stands for a package of services and modes that are provided as a bundle to users. Today, people often opt either for car, bicycle or public transport and therefore a choice between public and private, whereas MaaS can facilitate the combination of different modes of transport. The transport service provided by transport companies will be more customised to the specific expectations of a varied group of users. Developing custom-made services contrasts with conventional public transport. However, because technological innovations make it possible to link conventional public transport to more flexible, demand-oriented services, the trend towards MaaS also holds opportunities for pubic transport[46].

Social developments such as teleworking, e-shopping and e-learning offer prospects for limiting the number of trips and the distances involved. Not only can they contribute to reducing the number of trips related to a particular mobility motive (e.g. commuting, shopping), but they often also reduce time pressure. However, the environmental benefit of such developments is not always guaranteed. In the case of teleworking, for example, the environmental gain resulting from avoided trips may be partly cancelled out by the higher energy consumption for private residential heating[48]. For e-shopping, it is important whether home delivery replaces a trip that would otherwise be done using the car or the bicycle, whether home delivery is done in an environmentally friendly manner, whether orders are often returned, etc. The efficiency of deliveries as a result of e-commerce, could be increased by working with a fine-meshed system of pick-up points whereby parcel services no longer deliver at home but pick-up point (either manned or not) at walking distance from the recipient.

The government plays a key role

Many of the above-described social developments and technological improvements offer prospects to improve the functioning of the mobility system and to reduce its environmental impact. It is, however, not obvious to optimally exploit this potential. Rebound effects are never far away and not all technological and social developments automatically lead to an improvement of the (environmental) performance of the system as a whole.

The government, therefore, must play a key role and ensure that the various transport services are interconnected and can operate together. It must ensure that the necessary infrastructure is in place and price signals are consistent. The government can help shape the mobility system of the future through regulation and financing. By creating the necessary regulatory and operational framework, it can ensure that innovative technologies and business models fully break through and contribute to a more sustainable mobility system[38].

The importance of individual choices

Despite the government's key role and the social and technological developments, part of the solution has to come from the people themselves. Perhaps not all trips are equally necessary or perhaps they can be organised more efficiently. Sustainable trips may enhance one's own well-being and that of others. A part of short distance car trips could possibly also be replaced by walking or cycling – with positive effects for one's own health[49] –, whilst public transport could more often be an option for longer distances. Such day-to-day decisions can, however, to a large extent be driven by earlier and much more fundamental choices. Perhaps the most decisive choice is that of the place of residence and the place of work. Once the choice of a place of residence has been made, it will not easily be reconsidered. Reconsidering the choice for a place of work may be feasible, for example by switching jobs with workers performing similar work, to shorten the common commuting distance. Also the choice to receive part of your wages in the form of a company car or purchase your own car, can for many years determine the mobility behaviour and the associated environmental impact.

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SYSTEM BALANCE
2017

_3 Food System

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INTRODUCTION

Food is a basic need and is also of great social and cultural significance. Food supply has therefore always been of strategic importance for societies. A sufficiently large autonomous food production, low food prices and a fair income for farmers were important objectives of the European Common Agricultural Policy (CAP) that was created after the Second World War. Under impulse of the CAP and the gradual liberalisation from the end of the twentieth century, the Western European and therefore also the Flemish food production and supply evolved into a large and complex system. An extensive, internationalised network, sometimes over long distances, of suppliers, farmers, food companies, carriers, merchants and catering actors guarantees, the whole year through, a wide and varied offer of affordable food, not only for local consumers but also for exports. Agriculture-related products accounted for around 10 % of total Belgian imports and exports in 2013. The Flemish share in Belgian agricultural trade is estimated at around 80 %, showing that also the Flemish agro-business complex is particularly open[1]. A high degree of specialisation in the food chains allows labour, capital and expensive resources to be dealt with in an efficient manner. This allows to remain competitive in a global market of bulk products and also provides opportunities to reduce a number of environmental impacts per unit of output.

Not only agricultural policy and the economic actors within the food chains shape and maintain the food system, also the practices of other policy areas, consumers, credit providers, education, research, and interest groups all play an important role. Thus, the high expectations of consumers, such as a permanent wide offer at low prices, call for an extensive and cost-efficient production and distribution structure, whilst credit providers usually apply a financing model that induces investments, production increases and large-scale operations[2].

While the current food system is successful in terms of sufficient and affordable food supply, it is nevertheless reaching its limits. Food-related disorders such as obesity and cardiovascular diseases have increased significantly, land is becoming increasingly scarce, and the profitability of agricultural sectors is under pressure. There is also tension on the environmental level. The high consumption of animal products causes a great burden on the environment, also outside Flanders, and the intensive agriculture is highly dependent on external inputs such as fertilisers, water, imported animal feed, pesticides, veterinary medicines and fossil fuels. Also the other sectors in the food chain, such as food industry and retail, are greatly dependent on the use of, among other things, energy and water. And although the environmental impact per output unit of these sectors has considerably decreased in Flanders, the total environmental impact of agriculture remains high, especially at the local level, due to the high production volumes.

This chapter zooms in on two of the environmental challenges facing the Flemish food system, notably climate change due to greenhouse gas emissions, and eutrophication due to nitrogen losses. The chapter starts with a description of a number of major driving forces behind the environmental pressure from the food system. It then considers the greenhouse gas emissions and nitrogen losses on the consumption and production side, and concludes with three broad solution directions, which, in combination with each other, can provide inspiration for the transition to a more sustainable food system. While these solution directions are approached primarily from an environmental perspective, they can also address a number of other societal challenges facing the food system.

SOCIETAL DEVELOPMENTS AND ACTIVITIES

What does our consumption pattern look like?

Consumer enjoys a wide range of food products at low prices

Today's food system provides us with a wide and varied range of food products the whole year through. Consumers enjoy a high degree of purchasing comfort thanks to a vast network of points of sale, and low food prices. The share of food in the total family budget in Belgium fell from 50 % just after the Second World War to less than 15 % in 2014[3]. To this should be added the expenditure for eating out (5 % in 2014)[4].

However, the current dominant model of food production has also numerous adverse effects on humans, animals, nature and environment, here and elsewhere in the world, and a significant portion of the damage and the costs is not reflected in the price of our food. Moreover, the numerous links in many food chains have increasingly alienated consumers from the production of their food. This reduces the feeling of co-responsibility towards farmers and the ecosystems in which the food is produced[5].

Meat consumption is high

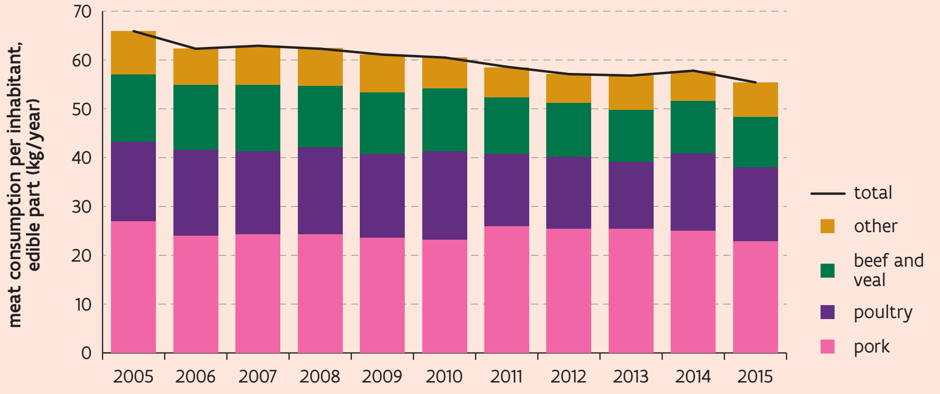
Increasing income and lower food prices have led to an increase in the consumption of animal products worldwide[6]. Although it is difficult to unambiguously compare the environmental impact of individual products, it is clear that the production of meat, dairy products and eggs leads to an increase in greenhouse gas emissions and nitrogen losses, and to higher land and water consumption as compared with vegetable products[7].

In 2011, animal products accounted for about 60 % of the proteins in Belgian food[8]. The largest portion came from meat and milk (products) (each almost a quarter of the total protein intake). By comparison: the world average share of animal proteins in the total protein intake is 40 %[8]. According to the Food Consumption Survey, in 2014 the average Belgian citizen ate 145 g meat, fish, eggs and vegetable substitutes per day. According to the recommendations of the Flemish Institute for Health Promotion and Disease Prevention (VIGeZ), a daily intake of 100 g of these food products is sufficient to fulfil the protein need of the body (from the age of 12). Especially the meat consumption is too high: in 2014 the average Belgian citizen ate 111 g meat per day, whereas VIGeZ recommends to eat no more than 100 g of meat maximum four times a week. That amounts to an average of 57 g/day. 89 % of the population exceeded this recommended maximum quantity. The study concludes that Belgians do not yet make the best choices regarding food products that contain biologically high-quality proteins[9].

... but decreasing?

In the meantime, the consumption of animal products does appear to exhibit a downward trend. According to the supply balances of Statistics Belgium, meat consumption in Belgium decreased by 16 % between 2005 and 2015. This is a decrease by on average 1.1 kg per inhabitant per year (**Figure 3.1**). A significant decrease is recorded for beef in particular. Also the consumption of eggs decreased, whereas the consumption of milk products remained relatively stable. A decrease in meat consumption was, however, not observed in the Food Consumption Survey. This study, which is based on surveys instead of macroeconomic calculations, did not find any significant difference between the meat consumption in 2014 and that in 2004[9].

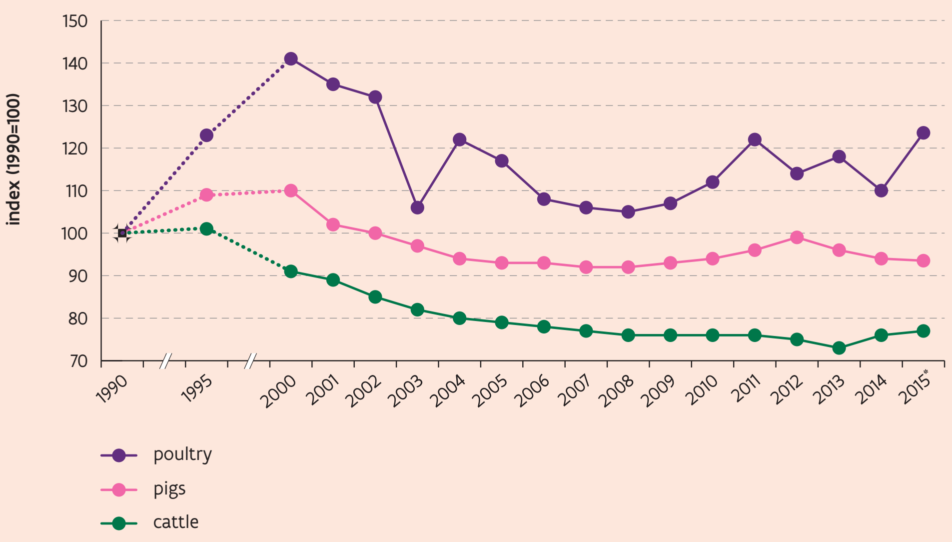
Figure 3.1 Evolution of meat consumption (Belgium, 2005-2015)



Calculated based on production, imports and exports; extraction factors (kg meat per kg carcass weight) according to Global Footprint Network, National Footprint Accounts 2008 edition. The average daily meat consumption in 2014 (158 g/day) is higher than that reported in the Food Consumption Survey (111 g/day)[9]. This is not illogical because the Food Consumption Survey reports the quantities of meat as they are consumed, i.e. possibly prepared, and because the calculations of Statistics Belgium do not take into account losses in retail and in households. The Netherlands Environmental Assessment Agency estimates these losses at 20 %[11].

Source: Algemene Directie Statistiek - Statistics Belgium

Figure 3.2 Evolution of the livestock population by animal category (Flanders, 1990-2015)



* provisional figures

Source: MIRA based on Algemene Directie Statistiek - Statistics Belgium

A decrease in meat consumption appears, in any case, to be in line with the results of a survey held among 1,000 Flemish inhabitants, commissioned by EVA, a not-for-profit organisation. This survey shows that the number of Flemish consumers that occasionally choose not to eat meat or fish doubled in three years' time, from 5 % in 2013 to over 10 % in 2016. Around one in six of the Flemish population eats vegetarian at least three times a week. The main reasons why the respondents eat less meat are health, followed by concern about the environment and the climate, animal welfare, and the pleasure of discovering new tastes. Barriers are lack of interest, followed by fear of the taste and of the price tag[12].

What patterns are visible in agricultural production?

Trend towards increasingly fewer yet bigger Flemish farms continues

The early European Common Agriculture Policy enabled the modernisation and the increase in efficiency of the agricultural sector. As a result, agricultural products increasingly became bulk products. Through price support, farmers were assured of a fair income. At the end of the twentieth century, a liberalisation process was started and the price support policy phased out. Farmers more and more began to directly compete with each other on the world market. For bulk products, price is the most distinctive characteristic, which is why cost leadership – producing the same product as much as possible in the cheapest possible way – is the dominant strategy for competitiveness in the European, and also the Flemish, agricultural sector. This strategy leads to a continuous process of specialisation, upscaling and intensification, based on technology and high use of external inputs such as fertilisers, water, imported animal feed, pesticides, veterinary medicines and fossil fuels[5].

The typical evolution towards fewer but bigger farms is also noticeable in Flanders. In 2015 there were almost three times fewer farms than in 1980, whereas the average size of farms almost tripled[10]. In the specialised animal husbandry sector, which in 2015 represented over half of the farms[3], the average size of the livestock per farm increased considerably: in 2015 an average Flemish cattle and pig farm had 60 % and 80 % more animals respectively than in 2000[10]. The evolution of the total livestock population presents a more nuanced picture, with differences between animal categories. From 1990 to 2015, the number of cattle and pigs decreased by 23 % and 6.5 % respectively and the number of poultry by 24 % (**Figure 3.2**). In 2015, Flanders had around 1.3 million cattle, 6 million pigs and 32.1 million poultry. Explanations for the decrease in the livestock population between 1990 and 2008 are efficiency improvements (dairy cattle), unfavourable market trends (beef) and in general also the inhibitory effect of increasingly stringent manure legislation on the rearing of animals. The pig and poultry populations again increased from 2009, under impulse of the expansion facilities after proven manure processing provided for in the third Manure Action Plan (MAP3). After 2012, the pig population decreased again. From 2014 there is again an increase in the cattle population. The complete abolition of the milk quota effective from April 1 2015 and the high milk price at that time probably played a role in this.

The total agricultural area used in Flanders for the cultivation of agricultural crops, including horticultural crops and temporary fallow, has decreased slightly over the last 15 years (-4 % compared to 2000). There were shifts between crops over the years. Permanent grassland, for example, often had to make way for more profitable crops: between 1990 and 2015 the area of permanent grassland decreased by 14 % to the benefit of temporary grassland, maize and industrial crops. Approximately two-thirds of the Flemish agricultural area is reserved for livestock farming (grassland and arable farming for animal feed production).

Intensive farming is not equally efficient in all respects

In specialised intensive farming, costs are kept low by treating expensive production factors such as labour, land and animal feed, as efficiently as possible. This is reflected in high labour productivity and a high yield per hectare or per kilogram animal feed. This yield increase caused a decrease in the land use per unit of output. Also for greenhouse gases, for example, intensive agriculture produces lower emissions per unit of output. In developing countries, for example, the production of one kilogram of milk from grazing cattle causes greenhouse gas emissions of 2.7 kg CO_2-eq. For mixed systems in Europe, based on grassland and animal feed, this is only 1.7 kg CO_2-eq per kg of milk[13]. Despite the relatively high eco-efficiency for some parameters, the total environmental pressure from Flemish agriculture is considerable, certainly at the local level. This is due to the high production volumes in relation to the small surface area of Flanders, and to the nature of the production (much livestock production).

Moreover, the emphasis on increasing labour and land productivity may incite farmers to make excessive use of proportionately cheaper inputs such as fertilisers, pesticides and energy[7] or subsidised resources such as machinery and stables. Also for impacts that are not sufficiently regulated and/or do not carry an explicit price tag, such as local biodiversity and animal welfare, farmers lack incentives to produce more effectively[14].

Specialised and intensive production is also physically and economically vulnerable. Large numbers and densities of animals and crops, for example, result in greater disease susceptibility, promoting the use of veterinary medicines and pesticides. Economic factors include high vulnerability to volatile input prices, uncertain product prices on liberalised world markets, and the disappearance of large export markets due to geopolitical problems. This economic vulnerability is visible in the reduced and volatile margins of Flemish agriculture. Boerenbond calculated that direct costs of 100 euros generated a turnover of 146 euros in 2006. In 2016 this turnover was only 122 euros[15].

Low margins provide less room for more sustainable production

Low margins are not only a threat to the viability of a farm, but also reduce the opportunities for farmers to invest in innovations that contribute to more sustainable operations. Margins depend on total costs and sales prices. Partly as a result of more stringent requirements with regard to public health, environment and animal welfare, and the rising prices of numerous inputs, agriculture is facing increasing costs. These costs can often not be simply passed on to the buyers in the food chain. A first major cause of this weak negotiation position of farmers is the fact that the system induces them to increase their production. In the dominant model, which is aimed at production at the lowest possible cost, farmers are under pressure to invest in the latest technologies and to use them to the maximum, resulting in an increasing production[16, 17]. Even farmers who cannot keep up with the technological treadmill, try to continue with their (obsolete) production resources for as long as possible. As a result, the collective production exceeds what is strictly profitable. In combination with the low price elasticity of the demand for food, this leads to a downward pressure on prices.

In addition, market concentration in certain sectors of the food chain creates an unequal bargaining power, thus contributing to a downward pressure on prices that farmers receive for their products[7]. In Belgium, the food retail sector in particular is highly concentrated: three major players together hold a market share of almost 70 %[18].

ENVIRONMENTAL DISRUPTIONS

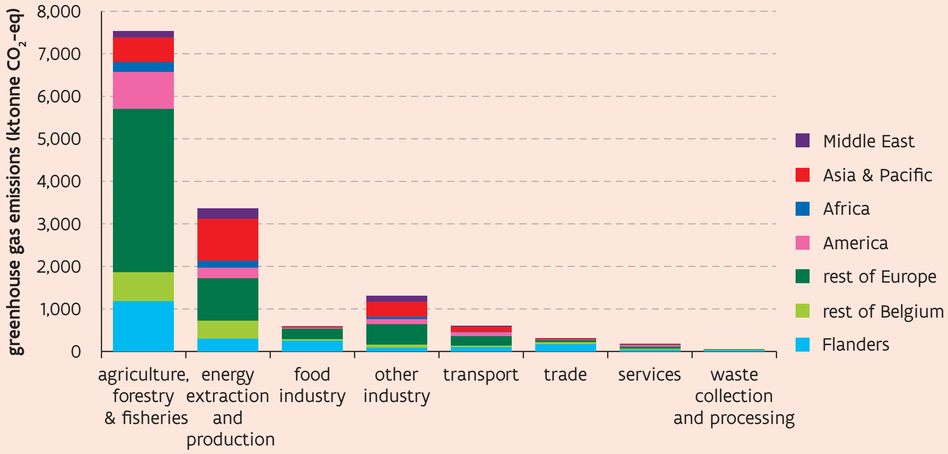
Greenhouse gas emissions

Carbon footprint of food consumption originates mainly outside of Flanders

The carbon footprint of Flemish households are the greenhouse gas emissions linked to the goods and services purchased by households. It takes into account not only the emissions that occur during the use of these products, but also the emissions that occur as a result of their production and distribution. The production and distribution of food products purchased by Flemish households, excluding food products in catering, in 2010 caused greenhouse gas emissions of 2.2 tonnes CO_2-eq per inhabitant (**Figure 3.3**) and thus accounts for about one-sixth of the total carbon footprint of Flemish households. By comparison: to limit the average global temperature rise to 2 °C, global greenhouse gas emissions would need to be reduced to an average of 2 tonnes CO_2-eq per capita per year by 2050. Over half of the greenhouse gas emissions linked to Flemish food consumption originate during the production of meat, dairy products and fish.

Today's regional policy objectives for greenhouse gas emissions address only emissions that originate within the territory of a country or region and therefore ignore any responsibility for emissions that are caused outside the territory as a result of consumption. These emissions are, however, significant: over two-thirds of the greenhouse gas emissions linked to the total Flemish consumption originate outside Flanders[20]. For the production of food products consumed by households, this is 85 %, of which 9 % in Wallonia and Brussels, and 42 % in the rest of Europe (**Figure 3.3**). These consumption-related emissions outside Flanders are more than a third higher than the greenhouse gas emissions from agriculture and the food industry in Flanders itself (**Figure 3.5**). From a global perspective, the reduction in greenhouse gas emissions within the worldwide production chain of food products consumed in Flanders is therefore at least as important as a reduction in the territorial greenhouse gas emissions from the Flemish food production. This is a shared responsibility, the more so because the 'costs' in terms of greenhouse gas emissions and the 'benefits' in terms of gross domestic product (GDP) are not equally distributed: 41 % of the added value linked to Flemish food consumption is created in Flanders, and therefore contributes to the Flemish GDP (**Figure 3.4**), although only 15 % of the greenhouse gas emissions is generated here.

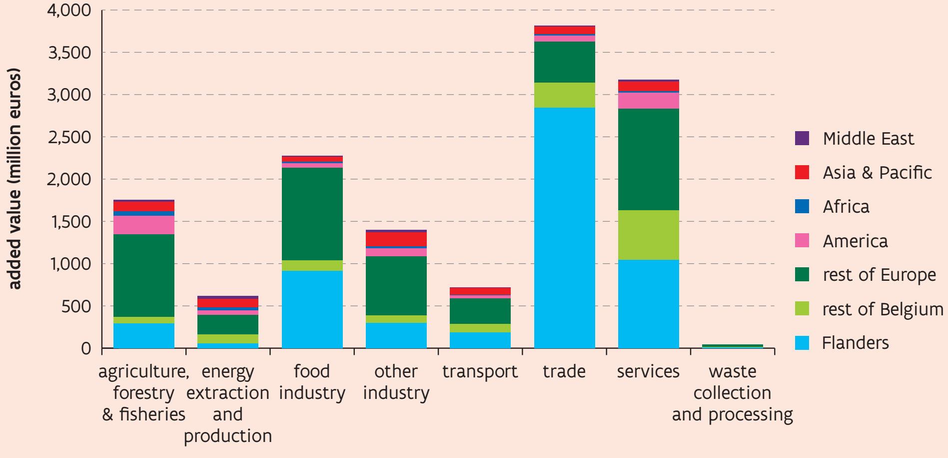
Figure 3.3 Greenhouse gas emissions caused by the production and distribution of food products purchased by Flemish households (carbon footprint of food), broken down by emitting sector and by geographical origin (2010)



Excluding emissions linked to storage and preparation of food at home, and excluding emissions linked to purchases in catering.

Source: Vercalsteren et al. (2017) commissioned by MIRA[20]

Figure 3.4 Added value created by the production and distribution of food products purchased by Flemish households, broken down by sector and by geographical origin (2010)



Source: Vercalsteren et al. (2017) commissioned by MIRA[20]

Agriculture and energy sector make largest contribution to carbon footprint of food consumption

More than half of the greenhouse gas emissions linked to the consumption of food products occurs in agriculture, forestry and fisheries, and one quarter during energy extraction and production (**Figure 3.3**). Three sub-sectors account for almost two-thirds of the emissions: animal husbandry (31 %), electricity production (17 %) and arable farming (16 %). More than three-quarters of animal husbandry emissions are generated within Europe. For electricity production this is almost two-thirds. In Flanders, the largest contributions are made by animal husbandry (6 %), electricity production and food industry (2 % each), and horticulture (1.4 %).

The distribution of the added value linked to the foodstuffs bought by Flemish households, yields a different picture (**Figure 3.4**). Two-thirds of this added value is created in trade, the services sector and the food industry, whereas the aggregate share of these sectors in greenhouse gas emissions is less than 10 %. In the Flemish chain, too, the largest added value is created in these sectors.

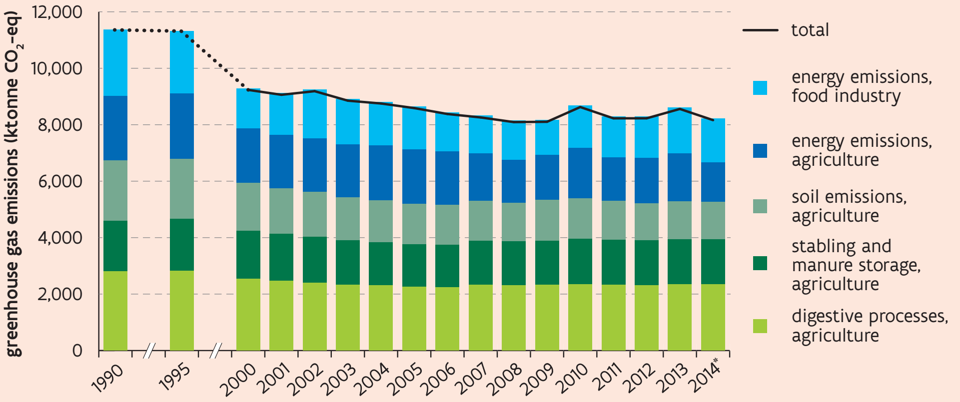
Emissions from biological processes are the biggest challenge for Flemish agriculture

Agriculture and food industry have a combined share of 11 % in total Flemish greenhouse gas emissions, or 8,224 ktonnes CO_2-eq in 2014, three-quarters of which originate from agriculture (**Figure 3.5**). More than two-thirds of these 8,224 ktonnes is linked to production for export[20].

Agriculture and food industry have very different emission profiles. Agriculture is an outsider compared to other sectors because biological, non-energy processes are the major source of greenhouse gas emissions. Not CO_2 (emissions due to the use of fossil fuels for heating, propulsion, use of tractors, etc.), but methane (CH_4) and nitrous oxide (N_2O) originating from digestion in ruminants (CH_4), production and storage of manure (CH_4 and N_2O) and soils (N_2O) are the major emissions here. Emissions from the food industry, by contrast, are purely of energy origin.

Already serious efforts have been made to reduce the greenhouse gas emissions from agriculture and the food industry. Between 1990 and 2008 this resulted in an absolute emissions reduction of 28 %, to be attributed to digestive processes (-18 %), manure storage and use (-13 %), soil processes (-35 %) and energy consumption (-37 %). From 2009, however, the emissions have stagnated, for non-energy greenhouse gases in particular. This was caused by a slight increase in the livestock population from 2009. Variations in the average winter temperature such as the cold winters of 2010 and 2013 and the mild winter of 2014 could explain the fluctuations in the energy greenhouse gas emissions.

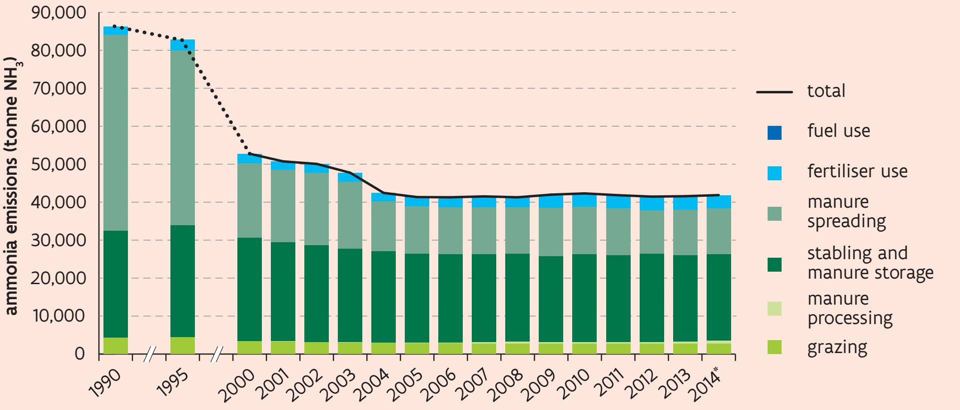
Figure 3.5 Evolution of greenhouse gas emissions from agriculture (arable farming, horticulture and animal husbandry) and food industry, broken down by emission source (Flanders, 1990-2014)



* provisional figures

Source: MIRA based on VMM, and VITO Energy Balance

Figure 3.6 Evolution of ammonia emissions (NH_3) from agriculture (arable farming, horticulture and animal husbandry), broken down by emission source (Flanders, 1990-2014)



* provisional figures

Source: MIRA based on VMM

Agriculture experiences effects of climate change

The agricultural and food sector contributes to climate change, but at the same time experiences its effects. What is certain is that climate change will create additional uncertainty and complexity in the medium and long term (50-100 years). In Flanders, climate change is expected to manifest itself primarily in a marked temperature rise with an increase in frequency of extremely hot summer days and in high precipitation variability, with an increase mainly in winter precipitation. Under a high climate change scenario, harvest losses of up to 30 % are likely due to drought stress for shallow-rooted summer crops such as sugar beet. Potential effects in the field of animal production are higher wind chill temperatures, leading to production losses, new diseases, lower energy demand for heating and higher energy demand for cooling[21]. Expectations on a larger geographical scale include changes in food quality, increase in (as yet unknown) diseases, heat stress in cattle, drought stress in plants, and strong variations in yield and associated price volatility[22].

... but can also contribute their buffering

Preserving or increasing the area of permanent grassland in Flanders may be relevant in the fight against climate change. In fact, a significant amount of carbon can be stored under grassland. Carbon build-up will be greater if the grassland is kept in the same plot over a long period of time and if the turf is renewed only if necessary, preferably by means of superficial soil tillage. A literature study conducted by ILVO on behalf of Boerenbond reports an average carbon storage of 0.5-1.0 tonne C ha^{-1} $year^{-1}$ for the conversion of arable land to grassland[23]. The grass was kept undisturbed on the same plot for a period of 10 years or longer. Moderately intensive grassland management whereby the grass stalks and roots are given sufficient opportunity to develop, leads to the highest carbon build-up. During the conversion from grassland to arable land, carbon is lost and this loss proceeds at least twice as fast as the carbon build-up during the conversion from arable land to grassland[23]. In 2015, grassland accounted for about one-third of the Flemish agricultural area, of which 23 % (50,000 ha) was designated as temporary grassland and 77 % (169,000 ha) as permanent grassland[10]. The area of permanent grassland has been declining since 1990 (-55,944 ha or -26 %) to the benefit of temporary grassland, maize and industrial crops.

Nitrogen losses in agriculture

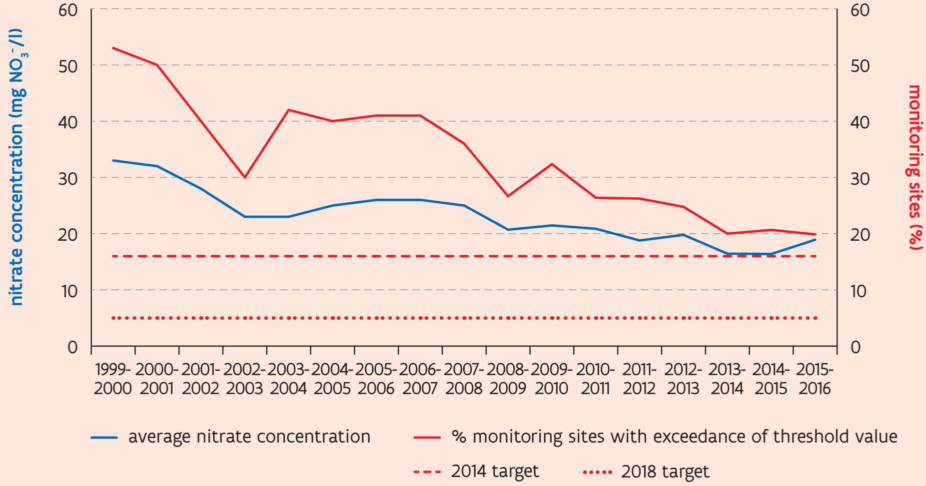
Agriculture is responsible for half of the nitrogen losses to the environment

Food production is a major cause of nitrogen losses to the environment. A calculation of the nitrogen flows in Flanders[24] shows that agriculture accounts for half of the total nitrogen losses[25], via volatilisation of ammonia from manure and stables, leaching of nitrate from soils, volatilisation of nitrous oxide due to rumen fermentation, and denitrification in the soil. Households, trade & services and transport together account for around one-third of the total nitrogen losses. These are primarily emissions of nitrogen oxides that are produced during the burning of fossil fuels.

Despite tightened manure policy, ammonia emissions stagnate

In 2014, agriculture accounted for 94 % of the total ammonia emissions in Flanders. Almost two-thirds of these emissions originate from livestock farming, mainly as a result of stabling and manure storage and to a lesser extent grazing and manure processing. The remaining emissions come from the use of fertilisers and animal manure on the land (**Figure 3.6**). Pig farming accounts for over half of the emissions from stabling and manure storage, cattle farming for about one-third.

Figure 3.7 Evolution of average nitrate concentration and percentage of monitoring sites with exceedance of the threshold value, located in surface water agricultural area (Flanders, 1999-2016)



The MAP4 targets (2014 target) and MAP5 targets (2018 target) are indicated by a red dotted line.

Source: MIRA based on VMM

In the 1990s, the agriculture sector achieved a large reduction in ammonia emissions. Reduction in livestock, lower nitrogen content of the cattle feed, low-emission application of animal manure on fields and meadows, construction of low-emission stables, and increasing manure processing reduced ammonia emissions also after 2000 (**Figure 3.6**). During the last decade, however, these emissions have stagnated, because a slight increase in the livestock no longer sets off the positive effect of low-emission stables and manure processing.

In addition to ammonia emissions, nitrogen losses to air also occur in the form of nitrogen oxides. The shares of agriculture and the food industry in Flemish nitrogen oxide emissions (9 and 1.4 % respectively) are much smaller than those for ammonia. The major sources of nitrogen oxides in agriculture are the use of manure and fossil fuels. In the food industry, fuel use is the only source.

Nitrate concentration in surface and groundwater of agricultural area decreases too slowly

Too high nitrate concentration in surface and groundwater can pose a threat to drinking water production and may lead to excessive algae growth. Manure policy from the beginning of the 1990s and its further tightening, resulted in a reduction in the average nitrate concentration of surface water in agricultural area by 42 % in winter year 2015-2016 with respect to 1999-2000 (**Figure 3.7**). Also the number of monitoring sites where the threshold value of 50 mg nitrate per litre (MAP4, 2011-2015) is exceeded, has more than halved. In the last two winters, however, little further improvement is visible. The target of MAP4 (maximum 16 % standard exceedances in 2014) has not been reached to date[26]. The target of the fifth Manure Action Plan (MAP5, 2015-2018), i.e. 5 % standard exceedances in 2018, is not expected to be reached either without additional efforts. Moreover, there are substantial local differences: the situation does not improve everywhere and to the same extent. Especially regions with concentrations of intensive specialised animal husbandry (such as, for example, South-West Flanders (pig farming) and the Northern Campines (poultry and beef cattle) remain problematic.

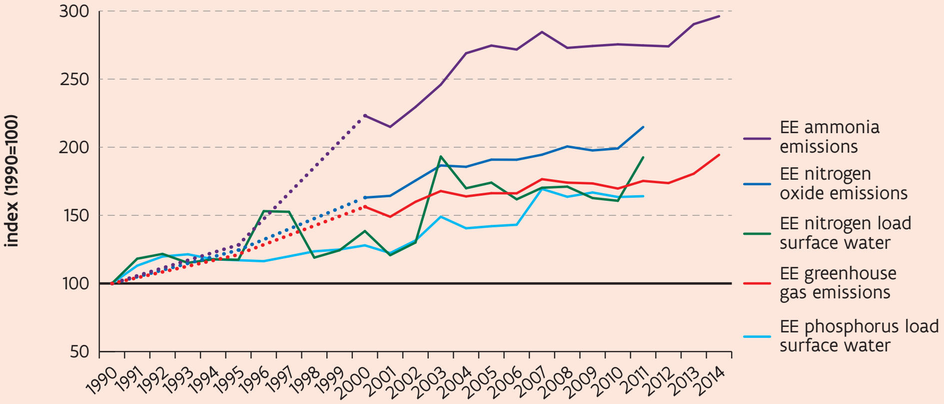
For nitrate concentration of groundwater in agricultural areas, a similar story applies. Despite a gradual decrease in the percentage of monitoring sites with exceedances, the standard is not reached in nearly one-third of the sampled wells. Here, too, exceedances are greatly influenced by local factors such as crop-specific limits on fertiliser use.

Nitrogen losses are harmful to nature

Ammonia and nitrogen oxide emissions give rise to nitrogen deposition on the soil. This can disturb the biodiversity because nitrophilic plants suppress less nitrophilic plants. The impact of nitrogen deposition on Flemish biodiversity is great: model calculations show that in 2013 the critical load for eutrophication was exceeded on 83 % of the surface of terrestrial ecosystems. This critical load is the deposition per surface unit for a specific ecosystem above which, based on available knowledge, a decrease in biodiversity occurs in the long term. Nitrogen deposition in Flanders is mainly caused by emissions that occur outside Flemish territory and by agriculture (mainly animal husbandry), with contributions of 47 % and 39 % respectively, in 2013.

Also the sharp decrease in nitrogen deposition since the 1990s has levelled off in recent years. The share of agriculture in this evolution is difficult to determine because around half of the nitrogen depositions in Flanders originate from cross-border emissions. What is clear, however, is that local emission sources lead to a very unequal distribution of nitrogen deposition across Flanders. Furthermore, ammonia, which mainly originates from agriculture, precipitates faster and therefore closer to the source than

Figure 3.8 Eco-efficiency (EE) of agriculture for a number of environmental parameters (Flanders, 1990-2014)



Eco-efficiency (EE) is defined here as the ratio between the end production value at constant prices (2005=100) and the environmental indicator (emission of greenhouse gases, ammonia, nitrogen oxides, nitrogen and phosphorus loading). Trend lines between 1990-1995 and 1995-2000 were visualised through linear interpolation.

Source: MIRA based on AMS, LNE and VMM nitrogen oxides, which originate from transport and industry, among other sources. The nitrogen deposition is highest in agriculture-intensive areas in West Flanders, the north of Antwerp and, to a lesser extent, the north of East Flanders. Also in the north of Limburg, deposition has increased, due to the vicinity of Dutch Limburg and the German Ruhr region with high emissions from industry. This uneven distribution poses a barrier to achieving the conservation objectives in some Natura 2000 areas. In 2013, the critical nitrogen deposition was exceeded in 51 % of the Natura 2000 areas in Flanders[27].

SOLUTION DIRECTIONS

Environmental challenges require structural innovations within the entire food system

The current food system tackles environmental challenges mainly by improving the eco-efficiency of production processes. Based on predominantly technical innovation, the use of resources and the amount of emissions and residual flows per unit of output is reduced. This approach has certainly been successful: in the 1990s, the eco-efficiency of Flemish agriculture increased markedly and substantial absolute reductions were achieved for most emissions.

Over the last decade, however, the eco-efficiency has stagnated for a number of key parameters (**Figure 3.8**) and the total environmental pressure from Flemish agriculture remains considerable, especially at the local level. This shows that optimising production alone will not suffice to achieve the great reductions that are needed within the framework of the nature and environmental quality objectives, for example Natura 2000, the Nitrate Directive and Water Framework Directive. In addition, certain eco-efficiency improvements require a high investment cost that is becoming more difficult to bear for farmers in the current business model.

Moreover, the environmental pressure from the food system comprises not only the environmental pressure from food production in Flanders, but also the environmental pressure that is linked to the food consumed in Flanders. The footprint of Flemish food consumption on the environment is high, and the largest portion of it is generated by activities outside of Flanders[20, 28]. A reduction in the environmental pressure from Flemish food production has little impact on this.

The nature, scope, geographical range and urgency of the environmental challenges therefore require more structural innovations throughout the entire food system, in which an essential role is to be played not only by the production chain but also by all other actors within the system (commerce, consumers, public authorities, knowledge institutions, investors, education, interest groups, civil society organisations, etc.).

Working on all fronts simultaneously

By analogy with the Netherlands Environmental Assessment Agency[14], we suggest three broad solution directions for an ecologically more sustainable food system: eating differently, producing and earning differently, and marketing, sharing/distributing and connecting differently. To achieve a sufficiently great environmental gain, while at the same time minimising shifting to other regions or from one environmental compartment to another, as well as any undesired socio-economic effects, we have to work on three fronts simultaneously.

It is, for example, not enough to address only the environmental impact of local production, as this involves a risk of shifting. If, for instance, less local meat production is not accompanied by eating less meat, more meat will be imported. This import could possibly be produced under less stringent environment and social standards. Conversely, more environmentally friendly consumption patterns do not necessarily imply a reduction in environmental impact of local production, as long as the food system incentivises farmers to increase their production. Thus, the decreasing meat consumption in Belgium has thus far not been reflected in a decrease in meat production and the associated local environmental impact, because exports have increased[29]. The same effect is observed in food waste: reduced demand as a result of less food waste by the Flemish consumer will in the current system be offset by an increase in exports.

Moreover, the solution directions are dependent on each other. A breakthrough in the production of more sustainable food will only be possible if demand is high enough and if the consumer is prepared to pay a price that covers the actual costs of a sustainable food production.

Solution direction 1: Eating differently

Lower consumption of animal products

Eating fewer animal products has the largest potential to improve the ecological sustainability of the food system[30]. A nutrition pattern where meat, dairy products and eggs are (partly) replaced by environment-friendly alternative protein sources provides significant environmental benefits, including a much smaller ecological footprint, less and improved direct and indirect land use, lower water consumption and fewer greenhouse gas and nitrogen emissions[14, 31, 32]. Thus, a halving of the consumption of meat and dairy products in Europe – assuming unchanged exports – can lead to a reduction in nitrogen losses by 40 %, lower greenhouse gas emissions (-25 to 40 %) and lower land use (-23 %)[33].

Wasting less food prevents unnecessary environmental pressure

Less waste of edible food by consumers and in the distribution sector prevents unnecessary use of raw materials, other resources and agricultural land and unnecessary emissions during food production[31, 34]. Each Flemish consumer, on average, throws away between 18 and 26 kg of food per year, which corresponds to 4 to 6 % of the total quantity of purchased food[35] and approximately 4 % of the carbon footprint of the purchased food[20]. Assuming an average daily food consumption of 1.2 kg, beverages not included, 264,000 to 381,000 people can be fed with this wasted food[35].

Alternative protein sources can replace animal products

In addition to known alternatives, namely vegetable protein sources such as soya and other legumes, there are products that have only recently come into existence, such as cultured meat, or that are starting to emerge, such as insects, algae and seaweeds and novel protein foods, a term that designates various protein sources such as by-products of the starch and oil industry, by-products of ethanol production and proteins from existing crops and from new protein sources that have not been used before[34]. The Netherlands Food Centre assessed a number of alternative protein sources for criteria of sustainability, nutrients and food safety. Legumes appear to be the most obvious healthy and sustainable meat substitutes. Seaweeds, algae and insects could also prove to be valuable alternatives, but their suitability has to be evaluated on a case-by-case basis[36]. For the large-scale application of novel protein foods, much research remains to be done on such aspects as optimal reuse of secondary flows and competition in the area of land use for other crops or applications (for example biofuel). To play their role as sustainable meat substitutes, it must be examined whether there is a technical potential for them in Flanders, whether they can be developed and produced profitably, and whether they are ecologically sustainable[37]. The future for cultured meat is unclear. Barriers in the short term include the high cost price, technological issues, and lack of clarity in the area of consumer acceptance, for example with regard to the different texture[34]. It should be added, however, that efforts are being stepped up to address these problems, as became apparent recently from the second international, scientific congress on cultured meat. Entrepreneurs and consumers are also beginning to show interest[38].

Latching on to new trends

Consumers are increasingly concerned about issues like health, environmental problems, climate change and animal welfare[3, 5]. This translates, for example, in the significant increase in the number of Flemish consumers that occasionally choose not to eat meat or fish (from 5 % in 2013 to over 10 % in 2016)[12]. These trends can be used to embed the new eating pattern into an eating culture that is oriented more towards things like frugality, seasonality, knowing what you eat, good food and personally getting to know the farmer as producer[39].

There is, however, often a large gap between what consumers think and do[3]. Nutrition practices such as buying food, are routines that are embedded in a wider spatial, economic and sociocultural context[31, 40, 41]. And that is also why they cannot easily be changed. Standards and attitudes[14, 39] (quality requirements, environmental awareness, etc.), material factors[31, 42] (price, information on packaging, etc.), time-related factors[31] (available time, work patterns, etc.) and spatial factors (importance of home meals versus eating out, etc.)[31] together shape nutritional practices and sometimes also counteract each other. Thus, for example, one may want to eat less meat for health reasons but have insufficient access to healthy alternatives or feel confused due to the amount of product information, notably on food labels[31]. For sustainable nutritional practices to take hold on a large scale and permanently, the food chain and policy need to consistently address all these factors. Existing routines must be broken by offering consumers a new 'choice architecture'[41, 43], whereby the alternative is at least as attractive (it should, for example, be quick to prepare or be available outside the home).

Solution direction 2: Producing and earning differently

More efficient and more circular production within the boundaries of the environmental space

The largest eco-efficiency improvements in the Flemish food system are to be achieved in the non-OECD regions of provenance of food import[14]. However, gains are also to be made in Flemish intensive agriculture. The efficiency of nitrogen and phosphorus conversion throughout the Flemish food chain, for example, is only 12 % and 9 % respectively[24, 25]. A surplus of these nutrients is therefore contained in residual and waste flows such as animal manure, organic-biological waste and household waste water. Reuse of nitrogen and phosphorus from these flows can reduce emissions to water, air and soil. An example is the integration of aquaculture and hydroponics (aquaponics), resulting in optimal use of nutrients, water, heat and energy[44]. The use of residual flows from agriculture in other sectors is still limited in Flanders[45], but research is under way[47, 48]. Residual flows from the food or biofuel industry are already used as an alternative for soya proteins in feed. In Belgium, already more than half of the raw materials for compound feed comes from such flows[3].

While there are still opportunities for more efficient and more circular production, such improvements will, as already mentioned, not be sufficient to bring the environmental impact of agriculture quickly enough within the boundaries of the environmental space in Flanders. Consequently, measures will also have to be taken at the level of production volumes, and here the government has a role to play.

Producing more carefully and closing cycles at the local level

The Netherlands Environmental Assessment Agency defines more careful production in agriculture as production that is aimed at improving the quality of the local environment and nature and increasing animal welfare[14]. This may involve, for example, animal husbandry where more space is created for animals, or production models where cycles are closed at the local level wherever possible. In the second case, the Flemish Department of Agriculture and Fisheries distinguishes circular agriculture and multi-actor multifunctional agriculture[45].

In the circular model, which is closely linked to the concept of agro-ecology, farmers try to close cycles on the farm or at the local level wherever possible. Central here is the combination of vegetable and animal production whereby (residual) products from animal production are used for vegetable production and vice versa. The focus here is on food production. In the multi-actor multifunctional production model, cycles are closed on the level of the nearby (urban) environment. Farmers not only produce food but also fulfil other functions such as recreation or the 'provision' of biodiversity, for which they cooperate with various actors (citizens, NGOs, local authorities, etc.)[45].

Organic farming, too, is a method of more careful production. Despite the growth figures, Flemish biological agriculture remains a small player in the (European) market[49]. With a share of 0.8 % in the total agricultural area, organic farming in Flanders remains far below the European average (EU-28) of 5.9 % in 2014. There is nevertheless room for faster growth, as the demand for organic products in Flanders significantly exceeds domestic production. Key conditions for accelerated production growth include ensuring the continuity of organic farms and sufficient access to agricultural land.

The environmental benefits of more careful production show a mixed picture. There is often less local environmental impact (for example less leaching of nutrients and pesticides per hectare, and higher local biodiversity), but per unit of output there is often higher land use (for example due to lower productivity of crops or with free-range animals) and some emissions may be higher (for example as a result of the longer lifespan of the animals and therefore the increased need for feed production, or more ammonia emissions with free range than in an indoor system)[14, 39].

Business models with higher added value needed for farmers

More sustainable operations often lead to higher costs for farmers and are moreover often accompanied by decreased yields. A key requirement for success is therefore that the environmental performance is reflected in the farmer's income. Possible options in this respect are business models that do not unilaterally focus on low costs, but also, for example, on the unique character and the quality of the products (organic products, regional products, etc.), or on services around the product (diversification through recreation, education, reuse of residual flows, provision of ecosystem services in relation to climate efforts such as carbon storage in grasslands, protection against erosion by planting hedges and trees, or contribution of the sector to the supply of green energy, etc.). As we will see below, the likelihood of success for business models with higher added value depends to a large extent on other actors in the food system.

Environmental impact throughout the food chain must be reduced

Not only agriculture but also other sectors contribute to the environmental impact of the Flemish food system. For example, greenhouse gas emissions from the extraction of fossil fuels and electricity production account for one quarter of the carbon footprint of foods purchased by Flemish households[20]. These fuels and electricity are used primarily by the food industry and other industrial sectors, and also by trade & services and the transport sector. To this should be added the emissions from the actual use of fossil fuels by those sectors, which represent almost one-fifth of the carbon footprint. Reducing the energy consumption by these sectors and the switch to environmentally friendly energy sources could therefore have significant effect on the climate impact of food.

Solution direction 3: Marketing, sharing/distributing and connecting differently

Environmental and social costs to be incorporated into the price of food

More sustainable operations in agriculture often result in higher costs that need to be offset by higher sales prices or other income. However, due to the current low prices of food from the conventional production chains, the prices for more sustainably produced food cannot be much higher. Too great a price difference in fact reduces the willingness to pay by the consumer. To further upscale more sustainable food production, environmental and social costs will therefore have to be reflected in food prices.

This also gives rise to tension between various societal concerns. On the one hand, higher food prices are needed to make food production more sustainable, but on the other hand, food supply at sufficiently low prices is desirable from a societal perspective because it contributes to stability. However, it should be noted that the share of food in household expenditure has dropped significantly since 1950[3].

Cooperation within the chain

Higher food prices for consumers do not always translate into higher margins for farmers. Market concentration in retail, for example, makes it difficult for farmers to obtain a good price. Conversely, the dominant position of retail also enables the sector to push agriculture in a more sustainable direction. Vredeseilanden examined which initiatives already exist in Belgium and how the potential can be further developed. A number of supermarkets have already undertaken efforts to make food chains more sustainable and to improve the marketing of sustainable products, for example by relegating less sustainable products to less prominent shelf space or by offering only the sustainable alternative. However, these initiatives often remain modest, not in the least because the financial margins are limited due to the price pressure from consumers. To take this process to the next level, more sustainable partnerships throughout the food chain are necessary, as well as more active steering by and support from the government[50].

Marketing and connecting differently

Farmers can also sell their products directly, through other farmers or in a partnership, to consumers. Examples of such short-chain sales are farm shops, farmers' markets, automatic vending machines, self-picking farms, Community Supported Agriculture (CSA), food subscriptions and food teams. Although the environmental impact of such short chains is not always lower, they can be instrumental in creating more mutual understanding and respect between producer and consumer whereby the latter may be more prepared to pay a fair price. Despite the 1,500 or so points of sale in Flanders, the short chain remains a niche. In 2016, on-farm sales and sales at farmers' markets had a share of 0.8 % in total consumer expenditure on fresh food[3].

All noses in the same direction

The transition to a more sustainable food system will have to be achieved through mutually reinforcing changes in the production and distribution chains and in individual consumer behaviour. Paredis et al. (2009) provided a number of levers to promote the transitions to more sustainable systems[51]. Firstly, it is important to guide the actions and decisions of individual actors with a broad but supported long-term vision that is incorporated into policy processes such as 'Vision 2050'. The development of such a long-term vision requires a consultation model that involves not only the traditional societal stakeholders, but also civil society, progressive regime and niche actors and all relevant policy areas (agriculture, environment, public health, economy, taxation, etc.).

Secondly, a long-term vision must be translated into regular policy in a stable and consistent manner. Policy integration whereby overarching objectives are embedded into different policy areas or whereby policy areas integrate each other's objectives into their own policy, is an important lever in this respect. In practice, this should be reflected in the choices made, for example, in environmental legislation with respect to food production, in the allocation of budgets for agricultural research, agricultural education, products that are promoted to consumers, advice and educational programmes on healthy food, etc. Certain policy instruments are potentially very powerful levers. Thus, a significant tightening of the European environmental legislation on food production would not only make conventional agriculture more sustainable, but it would also reduce the price difference with the even more sustainable products, thereby increasing the market opportunities for the latter. However, also other policy instruments such as taxes, awareness raising, and education can have a big impact, provided they work in the same direction.

A third lever to accelerate the transition to a more sustainable food system is the creation of space for experimentation, for example via projects whereby innovations can be tested exempt from inhibitory rules, or via subsidy systems, such as projects around innovative rural development as part of the European Common Agricultural Policy (CAP).

Networks, too, are of vital importance to set up and further upscale innovative experiments. There are already many food-related networks, including (inter)sectoral networks such as Flanders Food and the Belgian agrofood supply chain initiative, and networks at the urban level such as in Ghent and Bruges. Just as policy instruments, networks also have a powerful impact when they join forces. In some instances, this is already happening. The Citizens for the Foodture project of Vredeseilanden and Fairtrade Belgium, for example, is supported by Boerenbond, FEVIA, Comeos, Gezinsbond, Test-Aankoop and The Shift. However, the government too can assist in optimising and aligning networks through a long-term vision on a sustainable food system.

The transition to a more sustainable food system does not stand or fall with the government alone. In fact, it acts on structures and practices that are deeply embedded in society, and therefore requires the commitment from all stakeholders involved. The government does, however, have a key role and can, for example, take the initiative to have all noses pointing in the same direction, as on the occasion of the reform of the CAP planned for 2020.

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The Flanders Environment Agency plays a vital role in integrated water management. It measures and monitors the quantity and quality of water, manages water systems, collects a levy on water pollution and groundwater extraction, advises on environmental permits and ensures the planning and supervision of the treatment infrastructure. The VMM acts as the regulator for drinking water. Furthermore, the VMM monitors ambient air quality, draws up the air emissions register and makes policy proposals. It also publishes the Flanders Environment Report (MIRA).

The task established by decree[1] of the Flanders Environment Report (MIRA) is threefold:
- a description, analysis and evaluation of the current state of the environment;
- an evaluation of the environmental policy conducted to date;
- a description of the expected environmental developments in case of an unchanged policy and a changed policy according to a number of scenarios that are thought relevant.

Moreover, broad publicity must be given to the environment reports. MIRA provides the scientific foundation for environmental policy planning in Flanders. More information about the Flanders environmental reporting and the MIRA publications at www.environmentflanders.be.

[1] DABM, decree concerning general provisions on environment policy of 5 April 1995, BS 3 June 1995.

Colophon
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System Balance 2017

Environmental challenges for the energy, mobility and food systems in Flanders

Societal systems are more and more reaching their limits: we face the tremendous challenge of meeting both our present and future needs within the capacity of our planet. The use of a system lens allows us to better grasp the complexity of the environmental issues and to clearly present the necessary changes.

The System Balance 2017 investigates to what extent these three important societal systems are, or are not, environmentally balanced and what system changes are needed. The urgency, scope and geographical range of the environmental challenges in fact require structural innovations in the different system components and from the stakeholders involved.

This MIRA publication fits in with MIRA's mission, which is to provide an analysis of the state of the environment, and its form and content make it complementary to the individual indicators at www.milieurapport.be. The further focus on systems in the indicator reporting should therefore enable us to further develop the basic knowledge for system change, and the policy-related monitoring thereof.

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