SUMMARY

In the autumn of 2018, the MIRA department is planning to publish a new environmental outlook, which will consist of three building blocks: i) environmental indicators, ii) horizon scanning (incl. megatrends) and iii) solutions that may contribute to an (ecologically) more sustainable energy, mobility and food system. As part of this planned new environmental outlook. this report aims on the one hand to identify and evaluate the application potential, environmental impact and feasibility of possible solutions that may contribute to a more sustainable energy system in Flanders in the long term (horizon 2050) and, on the other, to map out barriers and leverage options that will have to be eliminated or promoted on our path towards a sustainable energy system.

To ensure the further reduction of the (ecological) sustainability impact of the energy system, energy consumption will have to be limited where possible by changing behaviour (e.g. use of public transport or bicycles rather than cars), remaining energy consumption will have to be as efficient as possible (e.g. buying efficient household appliances) and the energy produced will have to be renewable as much as possible with respect for people and the environment (e.g. generating power with solar panels). Furthermore, the growing share of variable renewable power generation (wind and solar energy) means that a better balance between power generation and energy consumption is required (e.g. encouraging electricity consumption during times when renewable electricity is in large supply). These various options to make the Flemish energy system more sustainable are called 'solution pathways' in this document. Each of these four solution pathways – 'saving energy by changing behaviour', 'saving energy through energy efficiency', 'making energy supply and demand more sustainable' and 'adjusting the energy demand to suit the supply' – covers various possible solutions for the different subsystems of the Flemish energy system. A 'possible solution' therefore is a change within a certain subsystem, which could mean an improvement to at least one dimension of the ecological sustainability impact (or environmental impact). We consider 'sustainability impact' to include both the ecological sustainability impact (or environmental impact) and the social and economic 'feasibility' of the various solutions. For the environmental impact, we mainly focus on the direct impact caused by energy end-use in Flanders, where the emission of greenhouse gases and air pollutants (NO_x, SO_2, polycyclic aromatic hydrocarbons or PAHs, dioxins, particulate matter and heavy metals) plays the most important role. Where relevant, other environmental impacts (e.g. in case of nuclear energy or the use of raw materials for batteries) will also be stated. The feasibility is estimated based on the social affordability (consideration of costs and benefits to society) and acceptance of the solution in question.

Composition of the report

The structure of the report is based on a funnel model, starting with a 'longlist' of possible solutions and gradually making choices regarding feasible and desirable solutions (from the perspective of application potential and environmental impact). Finally, for these desirable solutions we will map out the barriers and leverage options that respectively still hamper broad application thereof or could lead to accelerated application. During the execution of this assignment, we could also count on contributions from various stakeholders and energy experts, who were involved at various times during the execution of the study assignment by organising structural discussions (see Annex 1).

Chapter 1 contains a brief description of the Flemish energy system based on the key figures, the objectives of this report and the methodology and structure followed.

Chapter 2 of the report contains an extensive list of possible solutions that may contribute to a more sustainable future energy system in Flanders. These possible solutions are systematically discussed within the structure of the four solution pathways (see above), for each of the following sectors:

- Built environment
- Transport
- Industry
- Agriculture
- Central power generation
- Production of sustainable biomass
- Refineries
- Infrastructure
- Central adjustment of the energy demand to suit the supply

For each of the possible solutions identified within these sectors and solution pathways, a general analysis was prepared of the following aspects (see Annex 2):

- Level of application in the current energy system
- Level of policy-based support (e.g. imposed targets, policy ambitions, subsidies, investment support, etc.)
- Technological maturity and future expectations
- A list of possibly relevant sustainability impacts and initial considerations regarding the feasibility of the various possible solutions

Chapter 3 presents the application potential, the sustainability impact and the feasibility of the various possible solutions. Under 'application potential' we will provide an estimate of the possible level of application of the possible solutions until 2050. Unless otherwise stated, this estimate is mainly based on the study 'Roadmap towards a low-carbon Belgium by 2050'[7] ('Roadmap Study' for short) from 2013 and the extensive sectoral analyses[8] that were carried out as part of this study. The estimate of the application potential is based on the 'core' scenario from the Roadmap Study, which relies on a balanced mix of behavioural and technological solutions to achieve an 80% reduction in greenhouse gas emissions in Belgium by 2050. If we deviate from the assumptions made in this study (usually because better potential estimates have been made since then), we will clearly indicate the sources used.

[7] http://www.klimaat.be/2050/files/2513/8625/2687/Low_Carbon_Scenarios_for_BE_2050_-_Final_Report.pdf
[8] http://www.klimaat.be/2050/nl-be/analyse-van-scenarios/sectoriele-analyses/

			SUSTAINABILITY POTENTIAL				
			ENVIRONMENTAL IMPACT POTENTIAL			SOCIOECONOMIC FEASIBILITY	
			Greenhouse gas reduction 2050	Air pollutant reduction	Other environmental effects	Costs/affordability	Social
E-savings through behavioural change	a	built environment	8 Mt compared to reference scenario (Belgium), *4.5 Mt (Flanders based on 56% of households)*	generally positive	slightly positive	not calculated	slightly negative
	b	transport	12 Mt compared to reference scenario (Belgium). *7 Mt (Flanders based on 58.4% of vehicle kilometres)*	generally positive	generally positive	not calculated	slightly positive
	c	industrial fabric	included on other cards (chemical sector, iron and steel sector, E-efficiency of other industry, refineries, carbon capture and storage or utilisation, production of sustainable biomass). No estimate of change in demand for products (produced in Flanders).				
E-savings through E-efficiency	a	built environment	6 Mt residential, 3 Mt tertiary compared to reference scenario (Belgium) *3.4 Mt residential (Flanders based on 56% of households), 1.7 Mt tertiary (Flanders based on 58% of tertiary sector added value)*	generally positive	slightly negative	slightly negative	slightly positive
Making E-supply and demand more sustainable	a	built environment	8 Mt compared to reference scenario (Belgium), *4.5 Mt (Flanders based on 56% of households)*	slightly positive	slightly negative	CAPEX for air heat pump: €9000–12600; ground heat pump: €14000 per household in 2010	slightly negative
	b	transport	15.73 Mt compared to reference scenario (Belgium), *9.2 Mt (Flanders based on 58.4% of vehicle kilometres)*	generally positive	generally positive		neutral
	c	photovoltaic systems	5.2 Mt (Flanders)	slightly positive	slightly negative	in 2030: CAPEX €800/kW, OPEX €46/MWh	slightly positive
	d	sustainable biomass	5.6 Mt in non-ETS sectors	slightly negative to slightly positive depending on biomass & technology used	slightly negative	slightly negative depending on biomass & technology used	neutral
	e	wind energy - offshore	6.8 - 9.0 Mt compared to gas-fired power station (Belgium), *4.4 to 5.9 Mt (Flanders based on 65% electricity consumption in Fl. compared to Belgium)*	neutral compared to gas-fired power station	generally positive	in 2030: CAPEX €1800-2300/kW, OPEX €63/MWh	generally positive
	f	wind energy - onshore	2.9 - 3.3 Mt compared to gas-fired power station	neutral compared to gas-fired power station	generally positive	in 2030: CAPEX €1050/kW, OPEX €24/MWh	neutral
	g	partial postponement of phasing out of nuclear energy	TEMPORARILY (until 2035), *2.8 Mt in Flanders (based on keeping Doel 4 and Tihange 3 open, capacity of each about 1 GW)*	neutral	generally negative	€1000/kW	negative
	h	carbon capture and storage or utilisation	depending on process: CO2 to methanol 420 kt/yr, CO/CO2 to ethanol 360 kt/yr, CO2 to algae 36 kt/yr, carbonation of 96 kt/yr captured plus 184 kt avoided	more research required	depends on process, utilisation preferably as close as possible to CO2 source	depends on process, income from CO2 emission rights will generally be decisive	generally positive for utilisation / generally negative for storage
	i	refineries	62% reduction in the sector and outside sector *(at the same production level as in 2014 this represents a reduction of 2.9 Mt)*	62% reduction in the sector and outside sector	positive	generally positive	neutral
Adjustment of E-demand to E-supply	a	built environment	generally positive by promoting integration of renewable E	generally positive by promoting integration of renewable E	generally positive by promoting integration of renewable E	neutral	neutral
	b	electricity transmission	generally positive	generally positive	possibly negative	neutral	possibly negative
	c	distribution of electricity	generally positive by promoting integration of renewable E	generally positive by promoting integration of renewable E	neutral	neutral	possibly negative
	d	heat networks and geothermal energy	generally positive	generally positive unless for biomass	possible questions regarding sustainability of biomass	high CAPEX, OPEX depending on heat source used	slightly negative
	e	storage of electricity	generally positive by promoting integration of renewable E	generally positive by promoting integration of renewable E	slightly negative	slightly negative	neutral
	f	power to gas	179 g CO2/kWh compared to combustion of natural gas	neutral to generally positive regarding combustion of natural gas and use in transport sector	neutral	generally negative	neutral
Outside category INDUSTRY	a	chemistry	4.7 Mt (energy + process)	process-specific	process-specific	CO2 prices of €150-200/t required for deep decarbonisation (CCS or CCU, use of hydrogen, green chemistry)	possibly negative, sector subject to international competition
	b	iron and steel sector	3.2 Mt	slightly to generally positive	more research required	CO2 prices of €150-200/t required for deep decarbonisation (CCS or CCU, use of hydrogen, green chemistry)	possibly negative, sector subject to international competition
	c	other industry	3.3 Mt	generally positive, except for use of biomass	neutral	depends on the situation, electrification requires high gas price	generally positive

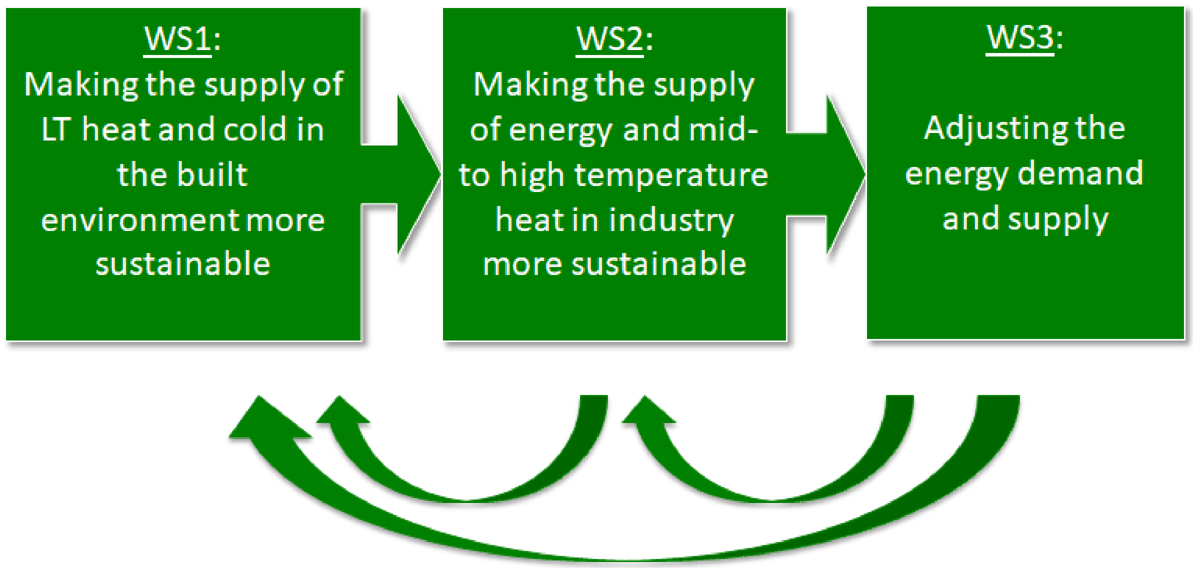
5-10 Mt CO2 in Flanders
2-5 Mt CO2 in Flanders
< 2 Mt CO2 in Flanders
generally positive

Under ‘environmental impact’ we will provide an estimate of the impact of the application potential on the emission of greenhouse gases[9], air pollutants and any other environmental impacts. The summary tables included in the report also provide general information about other possible environmental impacts and social acceptance. Under ‘feasibility’ we will provide an estimate of the social affordability of the possible solutions and the extent to which the possible solutions may or may not lead to social resistance. The estimates regarding the application potential, sustainability impact and socioeconomic feasibility of the various possible solutions were assessed by energy experts and representatives of different relevant sectors during a workshop for experts (see Annex 3 for the results of the workshop). The above table summarises the estimated application potentials and sustainability impacts for the various solutions.

Finally, **Chapter 4** of this report describes which barriers and leverage options may have an effect on the transition towards a sustainable energy system by 2050 and how they may affect it. An image of the future is used as an end point (objective) here, following which roadmaps are outlined for the various solutions and innovations described in Chapter 3, indicating which barriers will have to be overcome, which leverage options are required and which actors play a role in them. In order to arrive at sufficiently detailed analyses and recommendations, it was agreed with the client to organise three workshops. For this, the Flemish energy system had to be split into three subdomains, but without losing sight of the relationships between these domains. A slight deviation was applied here to the subdivision into the various solution pathways used in the previous chapters:

- making the supply of low-temperature heat and cold in the built environment more sustainable: this subdomain groups all the solutions regarding the supply of heat and cold, which are described for the built environment (sections 3.1.1, 3.1.2 and 3.1.3) and heat networks (section 3.5.1);
- making the supply of energy more sustainable, supplemented by the provision of high-temperature heat in industry: this subdomain groups all the solutions regarding wind energy (sections 3.4.1 and 3.4.2), photovoltaic energy (section 3.1.4), phasing-out of nuclear energy (section 3.4.3) and sustainable biomass (section 3.4.5). The industrial demand for high-temperature heat was considered generically based on the overall demand (not subdivided into specific subsectors);
- adjusting the energy demand to suit the supply: this subdomain groups all the solutions discussed for the built environment (section 3.1.5) and regarding the central adjustment of the energy demand to suit the supply (section 3.6).

[9] Regarding the calculated impact on greenhouse gas emissions, we would like to point out that we have calculated the impact of individual measures here. As we are not taking into account any scenarios that describe the interrelationship between the various measures, the calculation provides a distorted image, so the impacts cannot simply be added up to determine the overall greenhouse gas reduction potential for Flanders. For example: the calculation of the greenhouse gas reduction potential through the use of innovative heating technology in the built environment is performed in relation to the reference scenario described in the Roadmap Study. In combination with further improved energy efficiency (through renovation and new developments) in the built environment, the remaining potential for reducing greenhouse gas emissions through innovative heating technology (in view of the lower remaining demand for heat) will obviously be less. The greenhouse gas reductions described here should therefore be interpreted more as an indication of the possible significance of the various measures.



Furthermore, the possible interactions between the subdomains were taken into account while planning the workshops (see above figure): since electrification of LT heat supply is part of workshop 1, the output of workshop 1 was used as partial input for workshop 2, and since the estimates regarding the use of fluctuating renewable energy sources is part of workshop 2, the output of workshop 2 was used as partial input for workshop 3.

Findings from the workshops and conclusions

A guiding vision was prepared for each subdomain based on existing vision documents or policy intentions. For each workshop, this vision was based on the overarching principles included in the background section below.

Regarding the subdomain '**making the supply of low-temperature heat and cold in the built environment more sustainable**', most of the suggested barriers and leverage options clearly turned out to relate to the short term (until 2020). The situation is therefore highly urgent.

Saving energy is the cornerstone of the transition process 'making the supply of LT heat and cold in the built environment more sustainable'. The consulted experts mainly referred to the applicable Renovation Pact and the actions undertaken as part of this pact. They mostly pointed out the huge challenge of tackling the renovation rate of existing buildings, which in recent years has varied between 0.5% and 1%. In order to take on this transition challenge, the workshop participants believe that this rate should at least be doubled. Various ideas to improve ways to 'take matters out of the hands' of house owners were suggested, e.g. making use of the 'housing pass' – a concept currently being developed as part of the Renovation Pact – to define a suitable energy renovation process for every house (taking into account the current policy visions at various levels – see above). When selling the house, an obligation to perform certain steps of this renovation process within a suitable period of time (e.g. 5 years) can be imposed on the new owners. The concept of 'taking matters out of people's hands' could also include the actions of a 'third party' that coordinates and implements the entire renovation process on behalf of the house owner. A more radical idea would be to adjust the cadastral income to the energy performance of the house, also taking into consideration the location of the house. A better energy performance could then be awarded by lowering the cadastral income. This could create a major incentive for households to invest in energy savings.

At the United Nations summit on 25 September 2015, the 193 Member States of the United Nations (UN) adopted a new programme with 17 goals for sustainable development ('Sustainable Development Goals' or SDGs). These relate to the environment, climate, social progress and economic growth. Especially SDG 7, 11, 12 and 13 are of a guiding interest to the energy system:
7 = "Affordable and clean energy"
11 = "Sustainable cities and communities"
12 = "Responsible production and consumption"
13 = "Climate action"

SDGs 7, 11 and 12 relate to minimising the general sustainability impact of the energy system. Examples are environmental impacts such as the emission of air pollutants (NO_x, SO_2, polycyclic aromatic hydrocarbons (PAHs), dioxins, particulate matter and heavy metals), water pollution, use of space, consumption of raw materials (and associated impacts, like in the case of batteries) and other environmental impacts (such as in the case of nuclear energy). All of this should be realised in an affordable and socially feasible manner. In the Interfederal Energy Pact, this is formulated as pursuing a 'triple optimum':

- *Environmental efficiency: a low-carbon society, reducing the environmental effects on the entire life cycle (natural resources, pollutants, waste, etc.) and controlling emissions of other pollutants.*
- *Economic efficiency: the potential to create new local activities, the effect of this strategy on the production costs of companies and competitiveness in general (supply security, adjustment to climate change, innovation, etc.).*
- *Social efficiency: controlling the costs of this transition to distribute the costs and profits fairly and proportionally between the current and future generations, ensuring that every citizen is supported during the transition (solidarity mechanism).*

The remaining demand for low-temperature heat should then be covered by sustainable heat sources. In principle there are three options: heat networks (fed by residual heat or sustainable sources, such as biomass or geothermal energy), the 'all-electric' solution (heat pumps) or individual heating based on biomass or green gas. The large-scale rollout of heat networks is facing various barriers for the various parties involved, varying from the residents (private buyers) to the heat producers and financiers. This explains why the consulted experts see a lot of potential in the role of a 'heat broker'. This heat broker would actively go looking for possible heat sources that could be connected to a heat network (e.g. residual heat from the industry) and would try to link these sources to possible buyers, to get all the parties involved to join in the discussion on this basis in order to look for solutions that are acceptable to everyone. The 'all-electric' solution mainly applies to newly built houses or existing houses with thorough energy-related renovations, for which the construction of a heat network does not appear to be feasible. Finally, for buildings that cannot be connected to a heat network and for which there is no option to implement an 'all-electric' solution, solutions such as heat supply based on green gas or sustainable biomass should be considered. Policy measures based on a clear vision are also required here, e.g. regarding the modifications to the gas network (in the locations where this is necessary) for the use of green gas, or the phasing-out of unsustainable forms of heating based on biomass (e.g. outdated wood-burning appliances).

For the authorities (at all policy levels) an important role is envisaged in order to create the right market environment and boost entrepreneurship to ensure that the required technological solutions are implemented on time. There was particular emphasis placed on the importance of initiating the required modifications to the institutional environment, mainly in the field of vision forming, coordination between various policy levels and ensuring that the required data become available. After all, the long investment cycles for energy infrastructure require far-reaching policy measures and policy planning for the period until 2030 and 2050. Here a long-term vision on making LT heat in the built environment more sustainable (horizons 2030 and 2050) should prioritise clear choices, including those relating to[10]:

- Which sustainable energy networks are desirable and feasible specifically for various Flemish neighbourhood types.
- Which strategic heat sources will the focus be on, at the expense of other heat sources.
- What level of energy renovation is targeted for existing buildings (see also the Renovation Pact).
- In which locations and with what programme may property still be developed.

Such a vision cannot simply be imposed from the top down. In the transition towards a sustainable LT heat and cold supply in the built environment, a key role is to be played by local authorities. Local authorities are in the best position to judge the local social, environmental and economic aspects. Based on this consideration, the subsidiarity principle appears to be beneficial to local authorities, which may for example be given responsibility for working out local heat zoning plans (based on a local consideration framework in line with the overarching long-term vision). Major cities should take on a pioneering role when working out these local zoning plans; smaller municipalities and cities may require support due to their limited administrative capacity.

The consulted experts viewed the availability and public character of data on heat consumption, investment costs for new sustainable heat sources and the depreciation of infrastructure (e.g. gas distribution networks) as key barriers against the development of a long-term policy vision. They also stated, for example, that the available EPC data on existing buildings provide an incomplete picture of the actual energy consumption in these buildings. A sound policy cannot be formulated until the data now managed by various actors, including the distribution network managers (which have lots of data on heat demand) and knowledge institutes (including VITO, which prepares the Energy Balance for Flanders), is made available and aligned.

Apart from vision forming, the pricing of energy carriers also plays a key overarching role. Making green heat economically more attractive by making the use of fossil fuels more expensive was viewed as a crucial step towards creating a larger market share for green heat. In this regard, a lot is expected of the proposal to introduce a CO_2 tax for the non-ETS sectors, which is currently being discussed on a federal level (within the more general framework of a sustainable tax shift). In this regard, enough attention should also be paid to the impact of this tax shift on households or companies that, for technical or financial reasons, are having difficulty switching to a green alternative (e.g. companies with a high demand for heat that cannot yet be covered by heat pumps, or families in energy poverty).

[10] Study assignment – Towards a greener supply of heat for households in Flanders, September 2017, Kelvin solutions on behalf of BBL.

In terms of **making the supply of energy more sustainable**, there is a high level of consensus about the application potential and desired sustainability impact of renewable energy in Flanders. On a European level (Paris Agreement) it was agreed that by 2050 greenhouse gas emissions are to be reduced by 80 to 95% compared to 1990. The EU step-by-step plan towards a low-carbon economy stipulates that all Member States of the European Union should make a solidary contribution to achieving this goal. The EU step-by-step plan also states that a more or less fully CO_2-free electricity supply in 2050 is a necessity as part of the European long-term climate targets. Depending on the scenario, renewable energy sources should provide 64% to 97% of electricity in 2050. It is important, however, to note here that the lowest percentage (64%) is based on a significant contribution to EU electricity production by nuclear energy and carbon capture and storage. Because of the existing law on phasing-out nuclear energy, its adoption in the coalition agreement and in the Energy Pact, nuclear energy is not considered to be a desirable solution for the energy system in Flanders in 2050. CCS in electricity production was generally not considered to be a desirable solution either, due to the technical and financial issues with demonstration projects and the uncertainty regarding storage options abroad. Since we are assuming that these technologies will not play a role in the Flemish energy system in 2050, the percentages of renewable energy to be achieved in Flanders will have to be in the higher range (approximately >80%). The Federal Planning Bureau is taking into account an electricity demand of 125 to 145 TWh in 2050 in Belgium (an increase of 40% to 60% compared to 90 TWh in 2010). When converted to Flanders (with an electricity consumption of 55 TWh in 2010) this would mean an increase in electricity demand to 77-88 TWh in 2050. Taking into account the European scenarios (and assuming that 80% to 97% of electricity production in Flanders will be based on renewable energy sources, with Flanders not being a structural net importer of electricity), 62 to a max. of 85 TWh of renewable electricity would have to be produced in 2050.

This suggested vision for 2050 was generally accepted as a feasible but still ambitious target. Supporting of renewable energy production was considered to be a reasonably mature policy domain where the necessary policy instruments have already been shaped, especially during the past decade. Continued application and refinement of these policy instruments is required to create the right market environment and boost entrepreneurship to ensure that the required technological solutions are implemented on time. The majority also share the view that most technologies are already available and only few radical new breakthroughs are to be expected; it is therefore mainly important to create a large market for the existing renewable solutions.

The participants view a binding target imposed at EU level (currently for 2030, but to be maintained until 2050) as a strong legitimisation and incentive for the Flemish policy to be implemented. According to the consulted experts, the policy to phase out nuclear energy will play a key role in the medium term: choosing to phase out nuclear energy during the period 2022-2025 sends a clear signal to the market about the necessity for sustainable alternatives; postponing the phasing-out of nuclear energy creates uncertainty and delays.

Regarding the application of specific technologies, a great deal is expected of the development of offshore wind farms in the Belgian part of the North Sea and beyond. In the long term, much is expected of the development of a modular grid or ‘power socket at sea’. This means that wind farms in the North Sea will be connected to a high-voltage station that can be built on a platform at sea. In the long term, this modular grid will then be connected to an international platform using direct-current connections, which allow greater amounts of power to be transported over longer distances. The overall potential for wind energy in the North Sea is 150-250 GW. Through these connections, it will also be possible to store wind energy in dedicated infrastructure (e.g. ‘energy atolls’) or convert it into hydrogen during periods of surplus supply.

This new grid in the North Sea could therefore even guarantee supply when there is no wind. In the long term, an 'energy hub' could even be constructed in the North Sea, which would not only offer space for offshore farms, but also for cultivation of algae, wave energy plants, floating PV platforms, etc.

As far as onshore wind energy is concerned, a continuous evolution towards greater efficiency is expected (based on material improvements, greater mast heights and rotor diameters) without spectacular cost reductions. In policy terms, the biggest gains were expected from the Flemish government's 'fast-lane' initiative, which determines for various ambition levels the best locations for the installation of wind turbines in order to limit nuisance. Here an assessment is made of the impact if certain currently applicable spatial preconditions were to be modified. This makes a discussion possible about which spatial restrictions should or should not apply in order to achieve the desired ambition and limit nuisance at the same time. Furthermore, the workshop participants believed that local policies could play a key role in actively supporting local wind energy projects. So far, however, local authorities appear to make up the largest group of opponents against onshore wind turbines. Mayors and aldermen sometimes take up an extremely unfavourable position regarding local wind farms, even if they signed the Covenant of Mayors during their period in office, committing themselves to a climate-neutral municipality.

In the field of PV, a lot is also expected from ongoing policy initiatives that aim to improve the use of its considerable technical potential. The solar chart initiative, for example, received a positive response. New policy initiatives, such as remote net metering[11], solar sharing or replacing roofs containing asbestos with PV roofs are considered to be necessary to make investments in PV systems accessible to a larger target audience. One topic that plays a role in the short term is the lack of clarity regarding the revision of the regulations for prosumers (scrapping the system whereby the meter runs down when power is fed to the grid in exchange for as yet undetermined compensation), which might have a negative effect on the profitability of PV installations (in order to achieve the goal of rational network usage). On the horizon is the application of 'building-integrated PV', a technology that can significantly increase the surface area available for PV applications (integration in windows, walls, roof tiles, etc.).

Regarding the use of biomass, the workshop participants mainly see long-term potential in the production of green gas and green liquid transport fuels. Flanders itself has only a limited supply of sustainably produced biomass, mainly in the form of residual and waste streams. It would be best to use these residual and waste streams in the most valuable way (within the context of a strategy of rational waste processing), whereby the cascade principle should be taken into account: initially using the material in the most valuable way by recycling it before using it as a source of energy. In terms of the energy-related applications of biomass, it was also stated that their potential currently still remains underused due to the relatively low prices of fossil alternatives. The workshop participants also believed that the energy-related application of biomass currently suffers from an image problem (with all the applications being heaped together), even though the actual environmental impact of the combustion of biomass depends greatly on the type of biomass and the technology used.

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[11] In case of remote net metering, solar panels are installed on someone else's property (e.g. schools, car park buildings, churches, etc.) and the power generated is set off on the investor's electricity bill. This means that the production of the PV installation (in kWh) is proportionally divided among the investors and subtracted from the amount of electricity consumed by the investor.

Increasing the sustainability of industrial energy consumption in Flanders is surrounded by major uncertainties.
On the one hand, there is the uncertainty around the development of industry in Flanders. According to some, our economy will evolve into a niche economy that focuses on high-performance, market-oriented production. In this vision, the most energy-intensive part of current industrial production could move to other regions in the world. In that scenario, the energy demand of the industry in Flanders could change fundamentally, both in qualitative and quantitative terms. On the other hand, others believe that the contrast between a niche economy and a basic economy is a false one. If the basic industry were to leave, this would also put pressure on the production of high-quality goods, which is linked to it, and drag the entire economy into a downward spiral. By the same token, the production of high-quality products also anchors the basic industry in our region. Representatives of the energy-intensive industry also point out that moving industrial production to other regions would not be a solution for the global climate issue – on the contrary even, since production in those regions is often less energy-efficient. It should also be noted in a general sense that Flanders has industrial activities that could play a key role in the transition towards a low-carbon economy (e.g. production of insulating materials and lightweight materials in the chemical sector, recycling of (car) batteries in the non-ferrous industry, etc.). Innovation also offers these companies competitive advantages, creates jobs and increases export potential. This means that there is definitely potential for using the process of making the energy system more sustainable as an opportunity for the further expansion and/or reorientation of these industrial activities.

There are also still major areas of uncertainty and ambiguity in terms of making the Flemish industrial demand for energy more sustainable in 2050. Important European trade associations (such as CEFIC for chemistry, EUROFER for the steel industry, CEPI for the paper industry, etc.) have already prepared roadmaps listing the options for contributing to a low-carbon economy in 2050. But at the same time, industry in Flanders has presented less concrete plans for a low-carbon sector compared to other sectors. There is no concrete guiding vision for a sustainable (low-carbon) industry in Flanders yet. This is partially due to the fact that the required technology is often not yet available or still too expensive. Furthermore, Flemish industrial activity is relatively energy-intensive from an international perspective and largely based on fossil energy. That is why the required energy transition towards a low-carbon energy supply will result in major changes especially in Flanders.

The subdomain '**adjusting the energy demand to suit the supply**' is considered to be a domain in full development. Even though local voltage quality issues are already occurring, the current level of penetration of variable renewable energy sources, such as solar and wind energy, is not yet such that the large-scale application of solutions to adjust the energy demand to suit the supply would already be necessary. This kind of large-scale application is not expected until the period 2030-2050. Most technological solutions are already known and can already be applied on a commercial scale (the first niche markets already exist), but getting the entire subdomain into an acceleration phase requires further boosting of the 'business engine'. As the domain is in full development and is therefore confronted by many uncertainties, it would be impossible to predict in advance exactly which business activities will or would have to develop.

In a general sense, the consulted experts pointed out that each possible application will only develop if a positive business case for entrepreneurs can be attached to it. For most of the possible innovations, this is not yet the case (= general barrier, so we will not mention it separately each time for all possible innovations). It was also pointed out in a general sense that the development of the market for balancing solutions is also related to developments on the energy market (= general leverage option). For example:

a rising carbon price on the European ETS market could make the integration of renewable energy generation (and adjustment of the production processes to suit the supply) attractive on a business level. Finally, it is also important for the government to obtain a clear picture of the social added value of various innovations (what social benefits do they provide and at what price) in order to promote entrepreneurship through targeted initiatives based on this estimate if required. Subsidies for storage technologies are obviously a general leverage option to promote the market absorption of these technologies. However, if it is decided to switch to support mechanisms for storage, it is highly important to carefully investigate the social 'return on investment', who manages the storage capacity and how the interaction with the grid is carried out.

As general leverage options for the development of balancing solutions, the rollout of digital meters and the EU 'clean energy package' were mentioned. In early 2019, there will start the mandatory rollout of digital electricity and gas meters for newly built houses, mandatory meter replacement and thorough renovation, new and existing local production, budget meters and on demand. Full replacement of existing meters will be achieved once the digital meters have reached a certain critical level of penetration; all Flemish households are expected to have digital meters by 2035.

In terms of the local adjustment of electricity and/or heat demand to suit the amount of electricity supplied, the consulted experts mainly see options in the short term for smartly controlling energy systems at the level of individual households or SMEs. These require a more limited investment, so these applications are much closer to the market. For solar panels, for example, passive systems can be developed (e.g. undersizing of the inverter), which could facilitate faster integration into the grid. In contrast to battery storage, where mainly economic limitations still prevent a large-scale rollout, increasing the number of smart control systems is often a matter of regulation. Once the share of electric vehicles gets large enough (this is expected in the medium term, 2025-2030) smart charging and 'vehicle2grid' technology offer interesting opportunities to use car batteries for adjusting the energy demand to suit the supply as well. A current drawback of the 'vehicle2grid' application is that the frequent switching between charging and discharging cycles negatively affects the lifespan of the battery. However, the consulted experts believe it is highly likely that a solution will be found for this in the future. For apartment buildings, neighbourhoods or urban districts, the consulted experts viewed the application of microgrids as an interesting route. The energy demand from the residents of the apartment building would then be adjusted as much as possible to suit local production within the building itself (e.g. PV panels on the roof, a combined heat and power plant or heat pump with a heat buffer in the basement), minimising the load on the connection to the distribution grid. In order to make this happen, however, net metering of the PV production will have to be made possible[12].

Regarding the further expansion of active demand control at a system level (shifting the energy demand over time depending on the price of electricity on the market), the consulted experts could see expansion of this demand control in the energy system to a residential level, where aggregators are expected to develop commercial activities as new market parties. In the near future, energy suppliers are also expected to include dynamic (time-dependent) tariffs in their product range. One of the crucial questions is whether the average residential consumer will be able/willing to participate in this emerging flexibility market and will shift their demand over time. Pilot projects have shown that the installation of the required smart

[12] Net metering of PV production means that the total yield of the PV installation (expressed in kWh) of the collective housing facility is subtracted from the electricity consumed by the residents of the housing facility in proportion to their share in the investment for the installation.

control systems for appliances is not always straightforward and limits the potential for cost reductions on bills. In the long term it is expected to become more interesting for residential customers to participate in the flexibility market as well, once the electrification of heat supply (based on heat pumps) and transport (electrically driven vehicles) is more widely implemented. According to the consulted experts, it is not inconceivable that in the future existing or new players on the energy market will develop business models based on the concept of the all-inclusive provision of energy services for households, SMEs or apartment buildings. Such an 'all-inclusive model' is based on guaranteeing certain energy services to the customer (e.g. sufficient heat comfort, sufficient electricity for specified uses, etc.), which are supplied based on an optimum combination of demand control, energy storage and local energy generation, which the party providing the all-inclusive service takes care of on site. The customer pays a monthly fee for the energy services and no longer has to invest in the required infrastructure as a result.

In the long term, when renewable energy sources are expected to represent a considerable percentage of the energy supply, 'power-to-gas' applications will become more important. As a storage medium, hydrogen could complement batteries; injecting hydrogen into the gas network allows it to be used as seasonal storage. In order to facilitate this application, however, the gas network should be modified for hydrogen mixing. Some consulted experts believe that the phasing-out of the gas network in Flanders should be considered over a period of 100 years rather than using 2050 as the horizon. This would mean that green gas would continue to play a role in the Flemish energy system for a prolonged transition period. Not only can hydrogen produced through electrolysis be used for energy storage, it can also be used as a raw material for oil refineries, for example, or for refining biogas to increase its quality to that of natural gas. The promotion of hydrogen produced in a 'green' manner (e.g. similar to the system for green power certification) could leverage the rollout of electrolysis. 'Power-to-methane' will only be used in case of surplus hydrogen production. The consulted experts do not expect such a surplus to occur before 2050, so the opportunities for 'power-to-methane' inside the horizon of this reflection are rather limited.

Conclusions

Based on the estimates regarding the sustainability and feasibility of possible solutions for the Flemish energy system, the following transition pathways would appear to be the most desirable ones for the various subdomains:

- Saving energy is the cornerstone of the transition process '**making the supply of low temperature heat and cold in the built environment more sustainable**'. The consulted experts mostly pointed out the huge challenge of tackling the renovation rate of existing buildings, which in recent years has varied between 0.5% and 1%. In order to take on this transition challenge, the consulted experts believe that this rate should at least be doubled. The remaining demand for low-temperature heat should then be covered by sustainable heat sources. In principle there are three options: heat networks (fed by residual heat or sustainable sources, such as biomass or geothermal energy), the 'all-electric' solution (heat pumps) or individual heating based on biomass or green gas. Vision forming and strategic policy implementation (with a key role for local authorities) should answer the question of which sustainable energy networks are desirable and feasible specifically for various Flemish neighbourhood types.
- In terms of **making the supply of energy more sustainable** there is a high level of consensus about the application potential and desired sustainability impact of renewable energy in Flanders. Because of the existing law on phasing-out nuclear energy, its adoption in the coalition agreement and in the Energy Pact, nuclear energy is not considered to be a desirable solution for the energy system in Flanders in

2050. CCS in electricity production was generally not considered to be a desirable solution either, due to the technical and financial issues with demonstration projects and the uncertainty regarding storage options abroad. Taking into account the European scenarios (and assuming that 80% to 97% of electricity production in Flanders will be based on renewable energy sources, with Flanders not being a structural net importer of electricity), 62 to a max. of 85 TWh of renewable electricity would have to be produced in 2050. This suggested vision for 2050 was generally accepted as a feasible but still ambitious target. Supporting of renewable energy production was considered to be a reasonably mature policy domain where the necessary policy instruments have already been shaped, especially during the past decade. The majority also share the view that most technologies are already available and only few radical new breakthroughs are to be expected; it is therefore mainly important to create a large market for the existing renewable solutions.

- In terms of **making the Flemish industrial demand for energy more sustainable** in 2050, there are still major areas of uncertainty and ambiguity, regarding both the nature and scale of the industrial activities and how the remaining demand for energy will be met. Important European trade associations have already prepared roadmaps listing the options for contributing to a low-carbon economy in 2050. But at the same time, industry in Flanders has presented less concrete plans for a low-carbon sector compared to other sectors. There is no concrete guiding vision for a sustainable (low-carbon) industry in Flanders yet.
- In terms of **adjusting the energy demand to suit the supply**, the consulted experts mainly pointed out that the possible solutions should be considered ‘enablers’ of a sustainable energy system, because they do not have a positive environmental impact as such, only indirectly by promoting the integration of renewable energy. Batteries were viewed as a good ‘enabler’, whilst their environmental impact during production and extraction of raw materials remains a focal point. ‘Curtailment’ or smart controlling of local production is an option to make more local production feasible without the major investments associated with network expansions. In the long term, when renewable energy sources are expected to represent a considerable percentage of the energy supply, ‘power-to-gas’ applications could become more important. According to the consulted experts, most technological solutions are already known and can be applied on a commercial scale (the first niche markets already exist), but getting the entire subdomain into an acceleration phase requires further boosting of the ‘business engine’. As the domain is in full development and is therefore confronted by many uncertainties, it would be impossible to predict in advance exactly which business activities will or would have to develop.