ENERGY
NATIONAL INVESTMENT PACT
FINAL REPORT

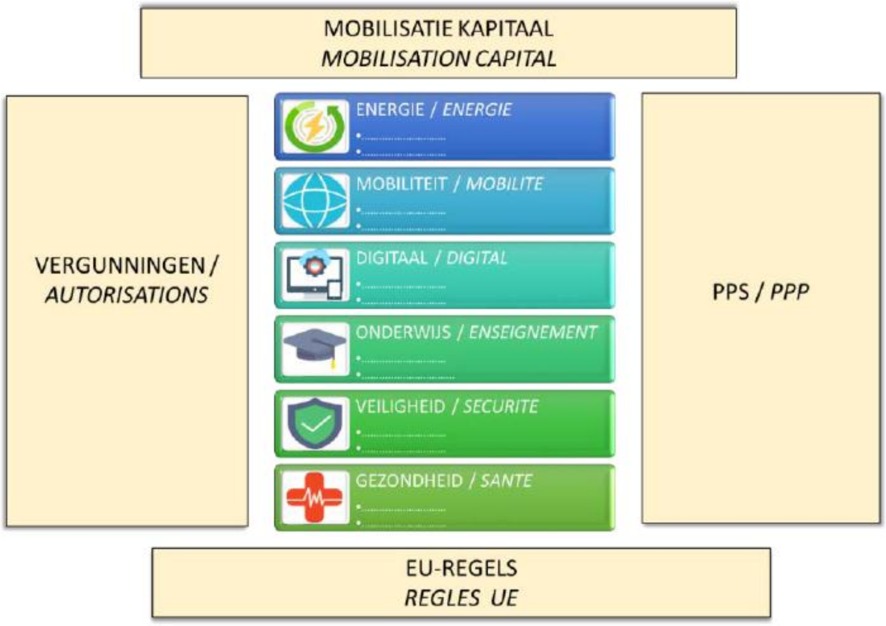
Version: 04-05-2018

1 CONTEXT

On March 30th 2017, Prime Minister Charles Michel launched the “National Pact for Strategic Investments”. The objective of the initiative is to support economic growth, job creation and to sustain our model of social protection. Its ambition is to accelerate and reinforce the investment in key sectors of our country up to 2030.

A strategic committee was created to formulate recommendations aimed at guiding and strengthening the investment strategy in Belgium. The Committee identified six strategic domains: energy, mobility, digital, education, security and healthcare; as well as four macro-economic issues: mobilisation of capital, public private partnerships (PPP), EU-rules and authorisations. This ‘reflection framework’ (pictured below) was the basis for subsequent works.

Figure 1: Strategic domains and macro-economic issues



Working groups were set up to analyse each of the sectoral issues. This paper presents the conclusions of the working group dedicated to energy. The purpose was to define a general and forward-looking vision of the domain and to translate it into concrete recommendations regarding investments. Several enablers – necessary conditions to trigger investment – were also identified.

2 DOCUMENTS' STRUCTURE

After presenting the **methodology** (chapter 3) used for the selection of the proposed projects, the different **trends and needs for insuring the energy transition** will be described (chapter 4). Indeed, energy transition involves numerous evolutions within the current energy system. Most of the required changes will require new investments.

Finally, the document will focus on a small number of **projects that were selected** by the Energy Group (cf. below) and that it supports as investments in the framework of the strategic investment pact (chapter 5). Those themes are discussed in more detail in the annex.

3 METHODOLOGY

The present document presents the work performed by the Energy group under the presidency of Michèle Sioen. To accompany her in the work, Prof Johan Albrecht (UGent), prof. Tine Baelmans (KUL) and prof. S. Furfari (ULB) were invited as member of the Energy group.

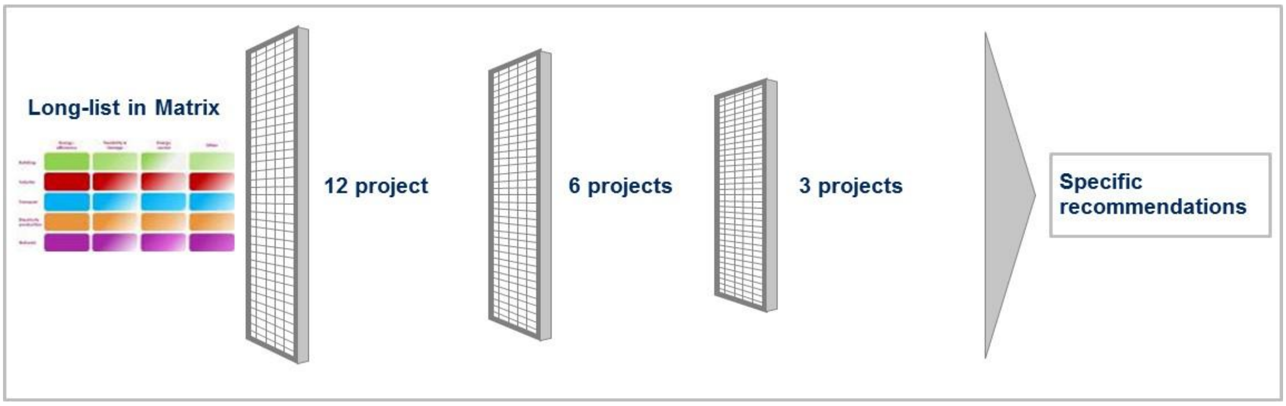
The energy system needs to strongly evolve to meet societal challenges such as security of supply or CO_2 emissions. Based on the foreseen and expected solutions to meet those challenges, a matrix of required changes was developed and discussed within the Energy group. In parallel, one to one meetings were organised with the stakeholders in view of sharing experience and collect opinions[1].

After a first discussion on the matrix with the Energy group, 12 projects were selected for further discussion amongst which 6 required more attention. In parallel, the Energy group also wished to draw the attention on various investments that:

- are already foreseen as they are decided and that a financial close is already – for some - set;
- could emerge if:
  - on one hand a clear vision exists on where Belgium is going to and
  - on the other hand the required measures (such as legislation) are taken in line with the vision.

The Energy group will come back on those investments later in this document.

Figure 2: Selection process



Source: McKinsey

[1] ORES, Resa, BASF, SCK°CEN, Febeg, essenscia, Deme, Cogen Vlaanderen, engie, Eandis, Fluxys, Agoria, EDF Luminus, FPB, Greenpeace, IEW, BBL, CREG, Belesco, Blauwe Cluster were met

The selected projects were then discussed with a group of representatives from BASF, Febiac, Total, Ores, Imec, SCK CEN, Febeg, Siemens, essenscia, DEME, Cogen Vlaanderen, engie, GSV, Elia, Eandis, Synergrid, Fluxys, Agoria et EDF Luminus. The group provided orientation on the projects' selection. The Energy group with the Academics then concluded on the final 3 projects to be further investigated.

Once the 3 projects were more detailed, the group formulated final specific demand to complement the projects that will be presented as **energy projects for the strategic investment pact**.

During the selection process, criteria with regards to the impacts of the proposed projects were looked at. Those criteria have to do with their impact on:

- the transition,
- the Belgian economy,
- the employment,
- the export opportunities,
- the Belgian know-how / the unique selling proposition,
- the urgency,
- the energy independency.

4 INVESTMENTS IN THE CONTEXT OF THE ENERGY TRANSITION

4.1 The matrix

4.1.1 ENERGY TRANSITION

The energy transition will require deep changes in the **way we consume and produce energy**. The challenges we faced today are due to multiple societal evolution starting with the need to evolve towards a low carbon economy.

Next to decarbonisation, the market has been liberalised meaning that the market actors will invest in function of their interest and compete against one another. Their decision will be based on the expected business case of projects and the risk linked to these projects. **Therefore, having a stable and positive framework for investment is crucial to allow private investments to occur**. This means that two essential requirements need to be fulfilled: 1) having a clear, stable, mobilizing vision (accompanied by a legislation in line with this vision), and 2) in the particular case of Belgium, having a good coordination between the different authorities for the implementation of the vision as energy competences are spread between authorities.

4.1.2 MATRIX: SUMMARY OF REQUIRED CHANGES

The below matrix summaries the main foreseen changes linked to the transition.

Figure 3: Transition matrix

	Energy-efficiency	Flexibility & Storage	Energy vector	Other
Building	• Insulation • Rational use of energy (e.g. sensor, automation, heat recovery, …) • EE appliances	• Smart meters / energy management system • Elect. / heat / cold storage • Power-to-X at home?	• Oil, gas, biogas, electr., cogen., H2, NH3? • Geothermal / PV / sol. heat / link windmill • Heat network • E.V. charge	• Shared / collective PV, district battery, district heating system, …
Industry	• EE of existing process • Adapt process / product design • Waste heat valorisation	• Demand side management • Energy storage (heat, cold, battery, …)	• Gas / biogas / elect. / biomass / H2 / NH3?	• Reducing process emissions (e.g. by switching to other inputs (CO2, H2, biomass, …) and processes
Transport	• EE cars & trucks • Better match transport means vs move needs • Light vehicles development	• E.V. charge (at the right moment)	• Moving from diesel and gasoline towards biofuels, gas, biogas, electricity, H2, NH3 (?)	• Spatial planning (compact) • Share economy • Alternative mobility (bike, ..) • Quality of public transports • Traffic management • Multimodal applications
Electricity production	• Improvement of energy conversion (heat → electricity / wind, PV)	• Power-to-X • Nuclear flexibility • Pumped storage (eg. Coo, atoll, …) • Battery • Other	• Mix: gas, biogas, biomass, nuke, windmill, PV, geothermal, tidal, wave, …	• Sufficiency of the electricity production means in Belgium to ensure SoS
Network	• Decrease of network loss • Optimal choice between strengthening of net capacity versus other (storage, flexibility, …)	• Smart network • Storage on the net (distributor, suppliers, community, …)	• Development of alternative fuel charging points (E.V., gas car, …)	• North Sea Infrastructure development

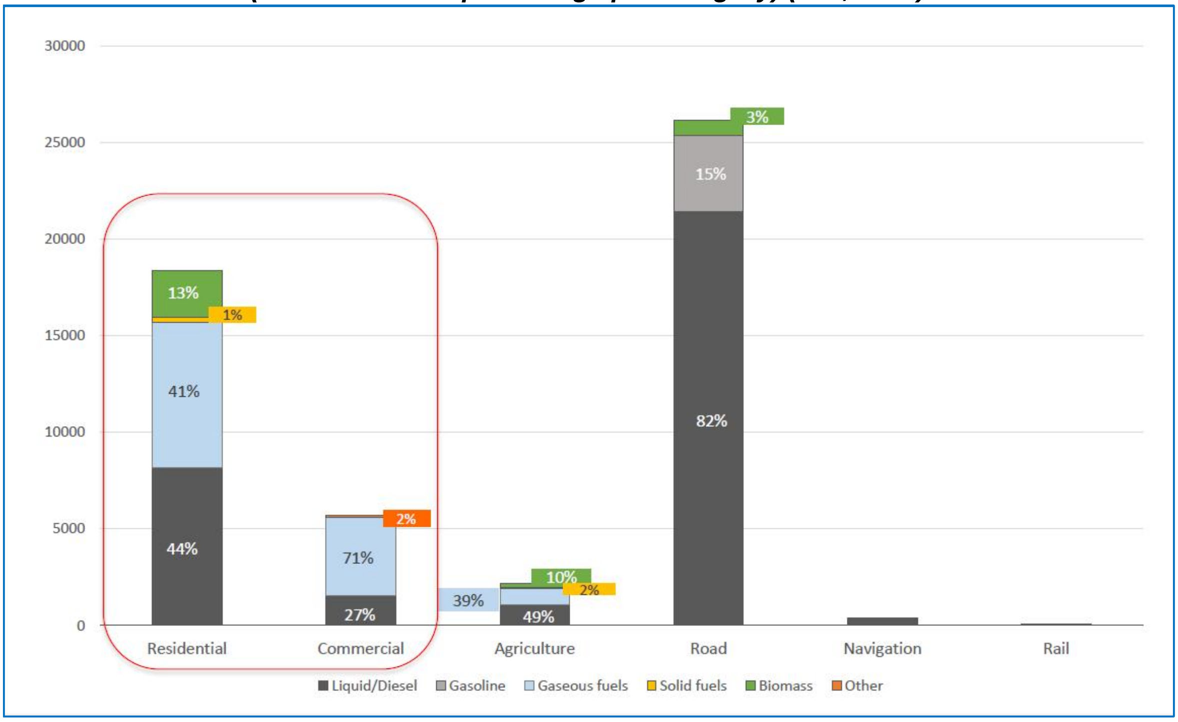
The energy working group went through the different boxes and provided an opinion on the different elements of them. In the following chapter, we discuss briefly the different elements in the matrix and present the selection of projects made by the Energy group which are relevant for the investment pact.

4.2 The matrix: sector per sector

4.2.1 BUILDING

Globally speaking our buildings stocks is old (80% of residential buildings has been built before 1981). The majority of these old buildings is not properly insulated. As a consequence, buildings are an important source of energy use and CO_2 emission as showed hereunder.

Figure 4: 2015 CO2 emissions in buildings, agriculture and transport, per energy vector (in ktCO2 and in percentage per category) (NIR, 2017)



Source: www.climatechange.be/2050 / / Belgian National Debate on carbon pricing – workshop on the Buildings sector 24.11.2017 (slide 6)

Efficient and smart buildings

EU directives provide a strict framework with regards to energy efficiency norm for new buildings. The challenge comes from the existing buildings' stocks: how to push renovation on an energy efficient way as buildings play a key role in the energy transition.

Insulation has a huge impact on energy use but one should also strive to efficient and smart – remaining- energy consumption with:

- best use of building's orientation (natural light, ...), bioclimatisation (if applicable);
- efficient heating and cooling system (heat pumps, cogeneration, …) with the most appropriate "fuel" (gas, biogas, electricity, …);
- energy optimisation system (automation, sensors, heat recovery, heat and/or cool storage, demand management, …) including ventilation system;
- distributed (local) electricity or heat production means (PV, sun heating system, geothermal, …);
- relighting;
- heat network (if applicable);
- cables ready for connection of electrical vehicle charging point.
- permanent, detailed energy use monitoring with feedback loops to users and owners

Evaluation based on different reports estimate investment requirements for the whole Belgian building stocks at **€ 325 bio**. In order to mobilize the required financial means for private residential or tertiary building renovation, regulation should be further developed. Feasibility studies (with regards to energy opportunities) should be encouraged, a financial incentive should be considered (e.g. withholding tax, donation tax or succession tax in function of the energy efficiency of a building), CO_2 price should be considered (playing a role in the business case of renovation investments), …

With regards to the buildings' sector, **the Energy group chooses to support, in the framework of the strategic investment pact, the transformation (renovation) of the public buildings to energy efficient and smart buildings**. According to a first set of estimations, this would require approximately **€ 33 bio investments**.

Relighting

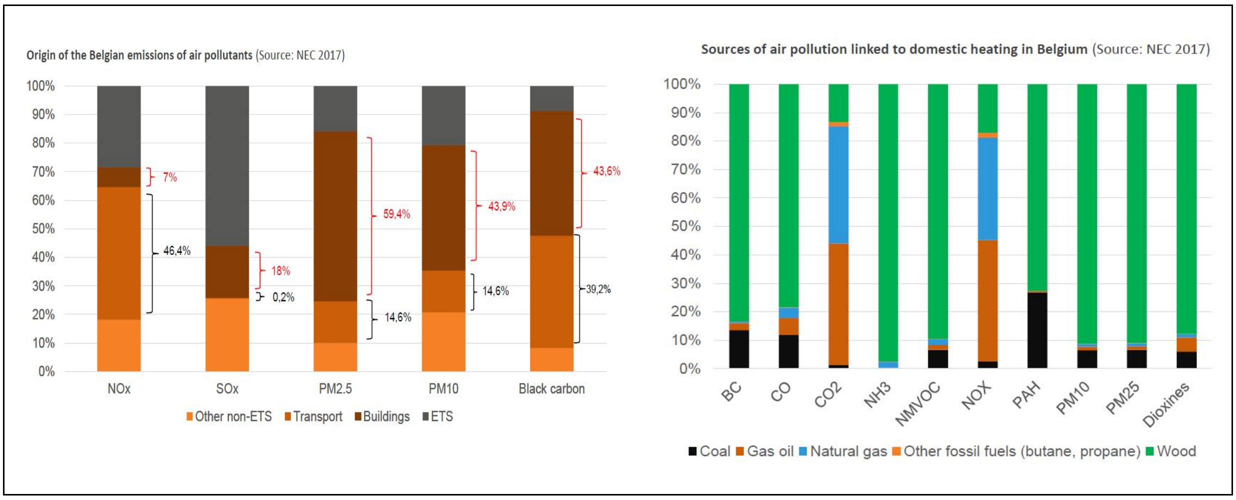
Relighting could have an important impact with often quick return on investment. It should then be combined with less attractive investments to globally improve the business cases of a set of needed investments in buildings. This approach could help financially to realise "less" interesting investments.

Public relighting, going from classical lightning to LED lightning with strong energy consumption reduction, is under the responsibility of DSO (distribution system operator). As for smart meters, investments programs have been adopted. The estimated value of public relighting programs is € **115 mio**.

Biomass

In the promotion of renewable energy, one should specially pay attention to the use and promotion of **biomass** as it produces air pollution as described hereunder. Regulation should ensure that biomass heating systems are marginal as to avoid air pollution worsening due to heating in buildings.

Figure 5: Belgian air pollution origin & impact of wood for domestic heating



Source: NEC 2017, www.climatechange.be/2050 / Belgian National Debate on carbon pricing – workshop on the Transport sector 07.12.2017

Smart meters and local energy community

With more and more intermittent renewable production, the consumer will be asked to be more flexible with regards to the time of its electrical consumption in order to facilitate the match between production and consumption of electricity. The consumer will also be able to store its energy (as electricity in battery, as heat in water tanks or building mass, …). To be able to materialize its new behaviour needs[2], smart meters will be deployed at household level. The evolution will go even further with local energy communities. These will gather a range of producers, consumers and prosumers into an energy community that together tries to better match their offer and demand of both electricity and heat. The rules concerning smart meter exploitation needs to be better defined keeping in mind its possible impact on the possible advantages in local energy communities and the energy system as a whole.

4.2.2 INDUSTRY

In order to decarbonise, industry invests in being more and more efficient in its energy use as well as in switching from one energy vector to another for their industrial processes. The heterogeneity of the industrial sector makes it difficult to draw a general conclusion. One should recall that investment decisions at industrial level are driven by positive business cases that are often induced by subsidy policy and tax regulations.

As for the household, the industry's flexibility with respect to electricity production and consumption should be facilitated on a voluntary basis. Some industries have real potential while others do not, depending of their process requirements.

Voluntary agreement

Governments have so far supported the voluntary agreements which demand additional investments in energy efficiency (/ own renewable energy production) up to some payback time in exchange for a tax reduction having a positive impact on industry's competitiveness. Governments should further support voluntary agreement as it is the case today. Also in this case, a monitoring system and related dashboard, measuring real effects needs to be considered.

Research, development and demonstration

Supporting research, development and demonstration projects can certainly help industry investigating possibilities offered by new transformation or new products.

Improving energy efficiency of production processes is limited as for all processes to the underlying laws of thermodynamics. Therefore new areas, new ways of producing should be envisaged such as the use of clean hydrogen, eventually produced by renewable energy or CO_2 as feedstock for industry (CCU: Carbon Capture & Use). A clear policy in this area should be adopted. This would also include a vision on the development in time of e.g. hydrogen transport network, or on a better valorisation of rest heat of some industrial processes and on cogeneration.

Such research should lead to commercial solutions. Depending on whether Belgium is taking a leading research and development position, new business can be created in Belgium.

SME

SME should be specifically supported as energy efficiency and smart use of energy is not considered as their core business. There is a real guidance need in this area, e.g. by promoting energy audits.

[2] As well as for other reasons / objectives

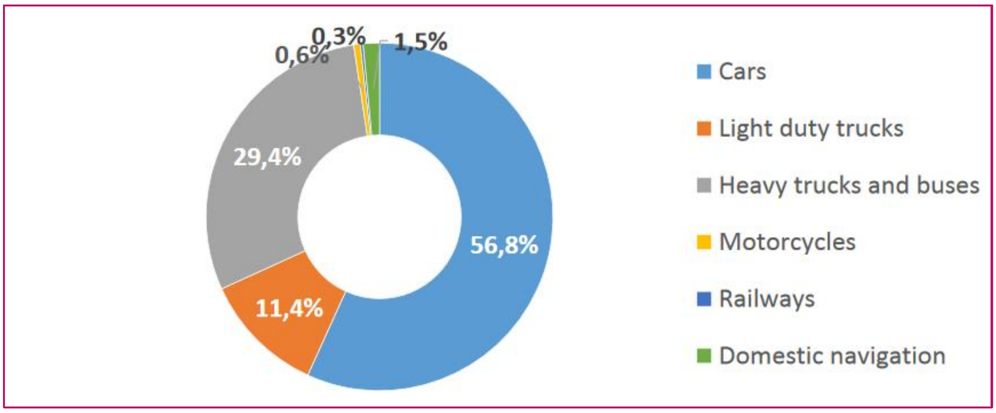
4.2.3 TRANSPORT

Transport vehicles (cars, trucks, busses, light vehicles, …) will have to strongly decrease their emissions: greenhouse gas as well as air pollutants. In 2015, CO_2 emissions in the transport sector accounted for 37% of non-ETS emissions with:

- 21% for cars;
- 15% for light and heavy vehicles and buses.

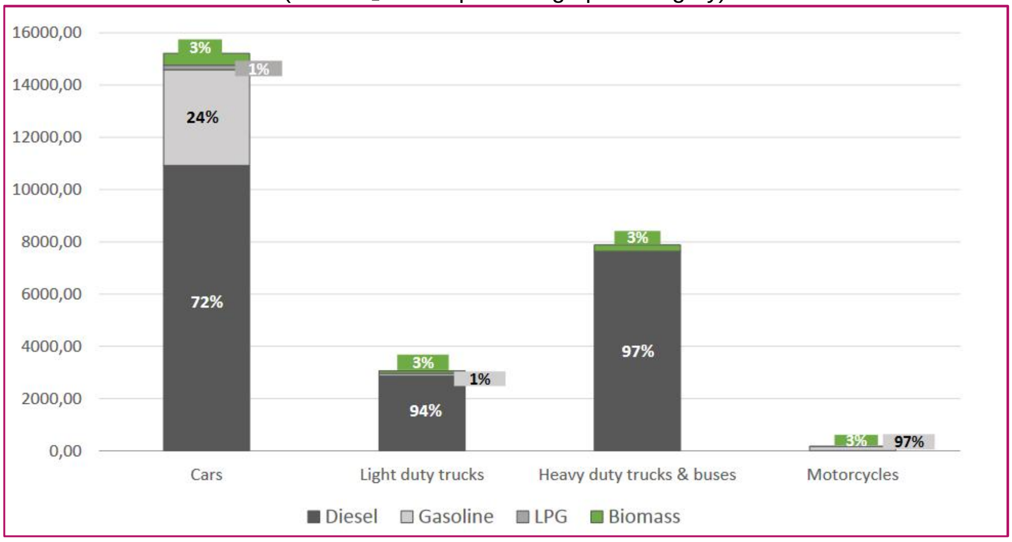
Between 1990 and 2015, CO_2 emissions in the transport have increased with 29%, i.e., +1.2% per year on average versus -2.9% per year on average required between 2015 and 2050 to reach zero emissions[3].

Figure 6: Distribution of 2015 CO_2 emissions in transport



Source: NIR 2017, www.climatechange.be/2050 / Belgian National Debate on carbon pricing – workshop on the Transport sector 07.12.2017

Figure 7: 2015 CO_2 emissions in road transport per energy source
(in $ktCO_2$ and in percentage per category)



Source: NIR 2017, www.climatechange.be/2050 / Belgian National Debate on carbon pricing – workshop on the Transport sector 07.12.2017

Within the transport sector, the fuel issue is the most predominant. How fast vehicles are going to switch to electricity, H_2, gas, … is a key factor influencing CO_2 emissions. These "new fuels" require filling infrastructures. In the case of electricity, personal electrical vehicles can be charged at home or at work. An inhibiting factor for the development of these "new fuels" often seems to

[3] Workshop on the transport sector; Dec 2017 – Belgian National Debate on Carbon Pricing

point at a chicken-and-egg problem: consumers don't buy electrical, gas or H_2 vehicles because of the lack of filling stations versus, no investments in filling stations for a new technology is performed as there are too few vehicles. The cost of the vehicles plays also an important role.

In that matter, **the Energy group chooses to support, in the framework of the strategic investment pact, a push for additional CNG (compressed natural gas) filling stations.** The project focuses on these stations for trucks. Although the transition to CNG will not significantly contribute to CO_2 emission reduction, it will drastically improve the small particle emissions by truck. Providing additional push to stations would allow a better penetration of filling stations and therefore remove a barrier to the deployment of CNG vehicles. A good coverage would then have a real impact on air pollution into the cities. Indeed, the project can also be viewed in the implementation of urban distribution centres using CNG trucks to feed the city. This latter would allow a sharp decrease of air pollutants in the city due to trucks. Pushing additional refilling stations means additional investment of **€ 100 mio**. A similar investment could be even more interesting for H_2 as its coverage is even smaller at present. However, with regards to H_2, the group expects its possible deployment on large scale only after the horizon time of the investment pact (2030) given the high cost for H_2 production in an energy system with an expected relatively "low" amount of renewable energy (< 50%) until then.

The Energy group voluntary chooses not to consider financial support when buying CNG or other alternative fuels vehicles. It would be out of the scope of the pact to support buying vehicles (as this relates to fiscal measures).

Electric vehicles and charging points should not be neglected. Those vehicles are now perfectly suited for urban mobility and as battery improves, the range of possibilities for electrical vehicles would cover more and more transport's needs. Investments in this domain will happen anyway and vehicles deployment issues are currently more of financial nature (cost of vehicles).

Policies dealing with spatial planning, shared economy, the development of light vehicles, alternative mobility, … (cf. matrix), have not been investigated in the Energy group as they refer more to mobility and transport issues.

4.2.4 ELECTRICITY PRODUCTION

Electricity production is among the areas where deployment of renewable energy has been the fastest. The development of renewable in the electricity production has brought lots of challenges due to e.g. the need for subsidies in a market that is liberalised, the intermittency of the electricity production and the required back-up capacity, the apparition of prosumer (producer and customer) at household level, …

The renewable production has put pressure on the business cases of the existing gas power plants that saw its operating hours diminish drastically. The producers claim they are losing money. In this context, the 30 March government's decision confirms the support to a capacity remuneration mechanism (CRM). This will lead to an investment in gas power plants. An investment in 9 gas power plants (3,6 GW in total) is estimated at **€ 2,9 bio**. If nuclear phasing out would finally not be maintained completely, required upgrade investment for 2 to 3 nuclear reactors is estimated to around **€ 1,4 to 3 bio**. The investment in gas power plant would then "only" be of **€ 1,3 bio** with the extension of 2 nuclear reactors.

In parallel, support (financial or other) will still be provided to renewable. In the next 5 years (up to 2023), this translates in investments for **€ 2,7 bio**. This trend will go on after 2023. Required support should be correctly designed to avoid any over subsidisation. The NIMBY (not in my backyard) syndrome is clearly a barrier to further development of some type of renewable as windmills. Demonstration projects, sensibilisation and information should be further enhanced to elevate this barrier. Furthermore regulation could certainly be adapted to facilitate investments.

On an ad hoc basis, the governments could support specific fields in electricity production (windmill, geothermal installations, …). With its current knowledge of the cases, the Energy working group did not identify additional specific needs that could lead to a stronger Belgian positioning in renewable energy.

4.2.5 NETWORKS

As we are striving to a low carbon economy based on a relatively large amount of renewable energy, the use of electricity will be more and more important: electric heating (heat pump, …), electrical vehicles, electric heating in some industrial processes. At the same time, the electricity production will be more and more dependent on weather conditions (wind, sun, …) and therefore have variable production in time.

The consequences of those elements (more important role of electricity, more local electricity production and variability of the production) require changes in our consumption pattern which will require e.g. smart meters, smart network, reinforcement of local network, …

At national level, importation and exportation of electricity through interconnection are a key element for ensuring security of supply. Elia, the electricity transport system operator has plans to expand interconnection up to 6500 MW in 2021-22. In order to deal with the increased penetration of renewables and to promote further integration of national electricity markets, Elia is currently conducting the largest investment plan in its history. In the period 2018-2022, about **€ 2.3 bio** will be invested. Elia is currently also making its 2021-2030 investment plan that has to be approved by the national regulator CREG.

The Energy working group believes that network development should fit the energy vision of the government and should be considered seriously as an enabler of the energy transition.

As said earlier, at longer term, the question of a dedicated hydrogen network can be raised.

In the medium term, gas will go on playing an important role. Investment by Fluxys is foreseen at about **€ 670 mio** the period 2017-2026.

Investment for electricity and gas distribution is estimated at **€ 1 bio** per year during the next 10 years.

4.2.6 FOCUS ON BIOGAS AND STORAGE

Biogas has a lot of advantage as its chemical composition is the same as natural gas and therefore emits very few air pollutants. It is considered as neutral with regards to CO_2 as it originates from a renewable energy source (forest, agriculture or livestock). Studies are being performed to analyse the biogas potential in our country. As a potential exists, investment in biogas stations should be facilitated (not necessary financially). Potential investments are currently hard to predict.

At some moments, too much electricity will be produced in comparison with the demand. This energy can be stored in very different ways: pumped storage, atoll, battery, conversion into heat, power-to-X, …

Pumped-storage exists already in Coo and Plate Taille. Extension is possible for Coo. New locations are currently under investigation. An **atoll** in the North Sea could also be developed for electricity storage. This atoll would be part of an island that would be multi-purposes island: energy storage, windmill, solar panels, aquaculture / fish farming, tourism, … An atoll can also be useful in the context of coastal protection. In both cases, the current business case is not guaranteed. Moreover, in the case of the atoll the North Sea marine special planning from the federal government should foresee place for such an island. Neither in the case of pumped-storage nor in the case of the atoll, the Energy group asks for subsidies but believes that the regulatory framework should be rendered more supportive.

Batteries will play a very important role in the future (e.g. within electrical vehicle, as private household battery or as battery directly on the distribution net). With Umicore, Belgium has an important niche player which provides lots of elements required for battery manufacturing on one side and that recycles the different battery components. Currently, Umicore is looking for a location for a development centre for Li-ion battery component processes. Belgium should try to attract this centre at its territory. Key elements are linked to cost (employment, energy, investments), field location, skills, … It is up to the different promotion agencies in our country to try to attract the future Umicore development centre. The investments for a development centre are around **€ 150 mio** and would generate long term employment. In addition, Belgium has also a number of other players in the battery / electric vehicle value chains.

Power-to-X is another way to store electricity. Converting electricity via electrolyse into hydrogen could provide proper fuel for car and trucks as well as interesting feedstock for industry. The Energy group expects the hydrogen economy starting only after 2030 which is too late in the framework of the current exercise. However, one should consider supporting demonstration projects to facilitate our industry to position itself in the hydrogen economy in Belgium and to set its first milestones within this respect.

4.2.7 FOCUS ON NUCLEAR PHASE-OUT

Nuclear power plants produce electricity … but generate spent nuclear fuel. Elements of those spent fuels are radioactive with for some of them very long time activity (up to 300.000 years without treatment and 10.000 years with treatment). The current solution consists of spent nuclear fuel disposal under specific geological layer under stringent security conditions. However, there is a solution that consists of transmuting the spent fuel and to bring its radioactive life time to around 300 years. To do so, one needs to construct a demonstration reactor. **The Energy group chooses to support, in the framework of the strategic investment pact, the building of the demonstration reactor MYRRHA.** The investment required for the MYRRHA project up to 2030 is **€ 375 mio**. Global project costs **€ 1.65 bio**.

At the same time, as nuclear power plants are shut down in Belgium and around the world, those nuclear power plants will have to be dismantled. With some experience with the dismantling project of BR3, an experimental reactor in Belgium, Belgian companies have experience and are ready to play an active role in the dismantling of nuclear power plants. **The Energy group chooses to support, in the framework of the strategic investment pact, a range of industries in Belgium active in the decommissioning of nuclear power plants.** As foreseen today, investment identified in order to support a positioning of Belgian companies in this field is around **€ 50 mio**.

5 FOCUS ON THREE THEMES

Three projects were identified from different boxes of the matrix by the Energy group as worth being supported in the strategic investment pact. They are going to be quickly described hereunder. The annex provides more details on each of those three projects.

5.1 Efficient and smart public buildings

The building stock in Belgium is old and far from energy efficient. There is a broad consensus among stakeholders that investments in this area are urgently needed. Two main benefits would result from this. Firstly, it could significantly reduce CO_2 emissions, as buildings account for about a third of Belgian CO_2 emissions in the non-ETs sectors. Secondly, this would also generate positive socio-economic effect, as renovation is a very labour intensive activity.

The project focuses on making public buildings energy efficient and smart. This means that buildings should not only be properly insulated, but that they also should have ICT tools which monitor and optimise energy usage and allow the building to interact in a smart way with the environment (e.g. consuming electricity when prices are low, and vice versa). Total required investments for public building are estimated at about **33 bio**. Investment needs for the complete building stock (including residential buildings) are even an order of magnitude higher, around 325 bio.

Project is further detailed in annex A.1 “Public buildings renovation project”.

5.2 Decommissioning and spent fuel management

The energy group believes the government should supports industries in Belgium to better position themselves in the dismantling of nuclear power plant business. To do so Agoria, the federation for new technologies, is developing a cluster with relevant industries in the domain (cluster ABCD for **A**dvanced **B**elgian **C**luster on **D**ecommissioning). Agoria has performed a first identification of potential investment projects helping those industries to position themselves in the growing market of decommissioning. Total investment projects are estimated at **€ 50 mio**. In order to ensure quality of the project as well as the interest of the projects, a selection committee will have to be set up.

With regards to MYRRHA, the nuclear demonstration reactor for transmutation, the government has already taken financial engagement on the long term. However, one needs now to engage in the first phase[4]. Covering phase 1 financing via the strategic investment pact would launch the building the accelerator. A signal now would positively position Belgium in the nuclear research as well as medical R&D and radioisotopes provider. Phase 1 budget is **€ 375 mio**.

Both projects are further detailed in annex A.2 “Decommissioning and Transmuting spent nuclear fuel project “.

[4] After the finalisation of this report, the federal government announced – begin September - their support to the realization of MYRRHA for more than € 0,5 bio

5.3 CNG filling station

In Belgium, transport is the most important polluter for fine particulates (PM 2.5 and PM 10) and black carbon. It also plays a role in CO_2 emissions. Gas fuel for transport can help reducing air pollution. One of the challenges of new fuel deployment has to do with the chicken-or-egg issue.

To ensure the right density of gas filling stations supporting an ambitious shift of diesel and gasoil towards CNG (or LNG) vehicles, one suggests to organise tenders for the development of additional gas filling station. Tendering structure as well as density requirements should be carefully thought. Tenders should allow investment for **€ 100 mio**.

The project is further detailed in annex A.3 "CNG project".

5.4 Investment versus financing

The current document evaluates required investments for the above introduced projects. Those investments should not be mixed with financing needs. Depending on the used tools and the type of investment, leverage can be found more or less easily. So € 33 bio for efficient and smart buildings does not require a financing of € 33 bio but of much less. The detailed documents on the projects will investigate, if applicable, possible financing structure and needs. ¢

ANNEX: IN-DEPTH DISCUSSION OF THREE THEMES

A.1 PUBLIC BUILDINGS RENOVATION PROJECT

1 INTRODUCTION

The Energy Group under presidency of Michèle Sioen has included investment in energy efficient and smart public buildings as one of the three priorities to be taken up in the context of the national plan for strategic investments. This note provides detailed information about the rationale behind this project, the investment needs and ways the project could be financed and implemented.

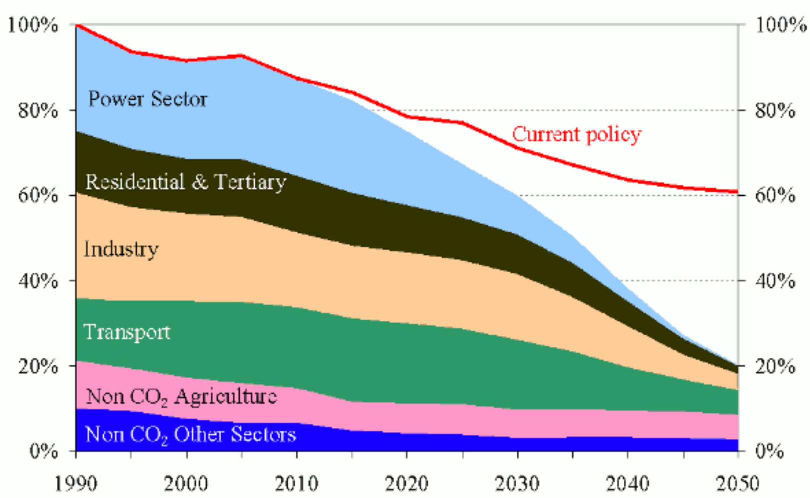
Chapter 2 introduces the importance of buildings renovation in the context of climate related challenges. Chapter 3 explains our understanding of what a smart and energy efficient buildings entails. Chapter 4 presents estimations of investment costs along with economic impact of the project and various options to finance the renovations. Chapter 5 discusses a number of implementation options that could strongly facilitate the realisation of this project. Chapter 6 concludes the note.

2 THE IMPORTANCE OF BUILDING RENOVATION

2.1 CO_2 emissions

The European Commission has published a roadmap[5] on how long-term climate objectives can be achieved. This roadmap suggests that the EU should cut its emissions with 80% by 2050. It also presents an indicative sectorial distribution. It is noteworthy that for the building sector a 90% reduction is envisaged, among the highest of all sectors. This is because major reductions are feasible with technologies that already exist today, and hence a high reduction rate can be achieved in a cost effective way.

Figure 1 EU roadmap for decarbonisation towards 2050



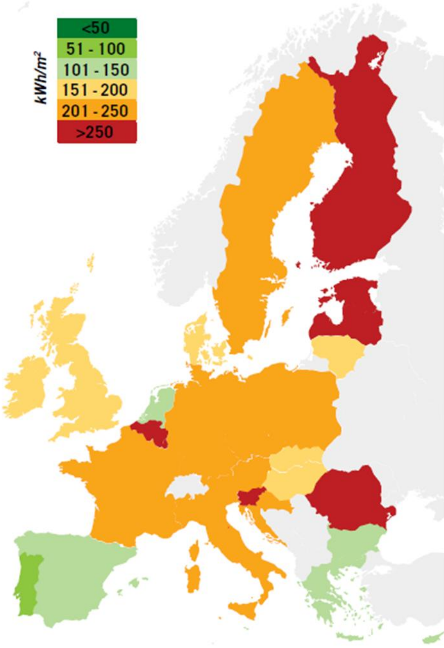
Source: European Commission (2011). A Roadmap for moving to a competitive low carbon economy in 2050

Buildings constitute together with transport, agriculture and a certain share of industry the sectors that are not regulated under the EU Emission Trading System. This part of the economy is therefore often referred to as the 'non-ETS' part. For Belgium, the non-ETS sectors have a CO_2 reduction target of 35% by 2030, compared to 2005 levels. As buildings constitute about 30% of non-ETS emissions, a proper renovation strategy will be instrumental in achieving this target.

Unfortunately, Belgium is not starting from a good position. As can be seen in Figure 2, the Belgian building stock is less energy efficient than the stock in the neighbouring countries. One of the primary reasons for this is that the stock is rather old.

[5] https://ec.europa.eu/clima/policies/strategies/2050_en

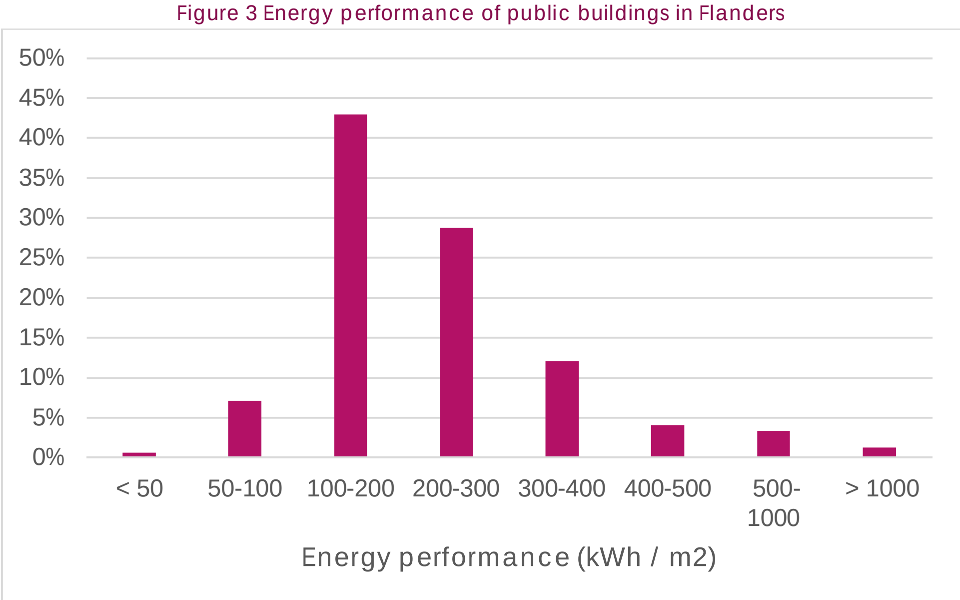
Figure 2 Final energy consumption under normal climate circumstances (kWh/m2 for residential and non-residential buildings)



Source: BPIE (2017). Is Europe ready for the smart buildings revolution?

Figure 3 provides more detailed information for public buildings in Flanders. It shows the distribution of public buildings over energy performance categories. As can be seen, very little buildings currently reach the threshold of less than 50 kWh/m2, even though with current technologies this is (in most cases) achievable. Somewhat more buildings achieve the 100 kWh/m2 threshold, but the very large majority of buildings perform worse. This means that nearly all public buildings will need at least some form of renovation to comply with the objective of having all public building energy neutral.

Figure 3 Energy performance of public buildings in Flanders



Source: Analysis of Prof. Griet Verbeeck (UHasselt) on data extracted in June 2017 from the Flemish' Energy Performance Certificate' database provided by the Flemish Energy Agency.

2.2 Policy context

Over the past years, the policy framework promoting the reduction of CO_2 emissions from buildings has been strengthened. At the EU level, the Energy Performance of Buildings Directive (EPBD) has promoted market functioning by better informing potential buyers about the energy consumption of a building, and includes stringent energy efficiency requirements for new buildings. Recently, a reform of the EBPD has been agreed, entailing among others a clear path towards a decarbonised building stock in 2050 and mechanisms to promote public and private finance[6]. The new EPBD also aims to promote the uptake of smart technologies, and introduces a 'smart readiness' indicator for buildings. The Energy Efficiency Directive (EED) provides an economy wide framework around energy efficiency with targets for reducing energy consumption. Very relevant for public buildings is the obligation in this Directive to renovate each year 3% of the surface of central governments (in Belgium, this relates the buildings of the federal and regional governments).

At Belgian level, one of the most important policy elements is the recently agreed interfederal energy pact. This pact sets out a long-term strategy shared by the different federal and regional governments, with objectives and measures that will steer the energy transition in this country. Among others, the pact sates that by 2040, all public buildings should be energy neutral. For privately owned buildings, ambitious targets are put forward as well, to be realised by 2050.

This project focusing on renovation of public building is therefore fully aligned with the (inter)national policy context. By including this project in the national plan for strategic investments, the Energy Group aims to further accelerate renovation of public buildings and make sure that the urgently needed investments are planned and executed in a timely and well considered manner.

3 A VISION FOR AN ENERGY EFFICIENT AND SMART BUILDING STOCK

When the term 'energy efficient building' is mentioned, many automatically connect this to a house which is properly insulated. Indeed, adding a thick insulation layer along the envelope (walls, roof, soil, with as limited interruptions as possible in order to avoid thermal bridges) for a certain class of buildings as well as using high performance glass and making the building more air tight, are the very basic starting point, and by itself already a major investment cost. However, making a building future proof goes well beyond this. Buildings need to become smart in the sense that they optimize their energy usage (see illustration of this in Figure 4). Examples include installing movement sensors so that rooms are only lit when necessary, or proper ventilation with heat recovery that reacts to air quality measurements (and hence intervenes only when necessary).

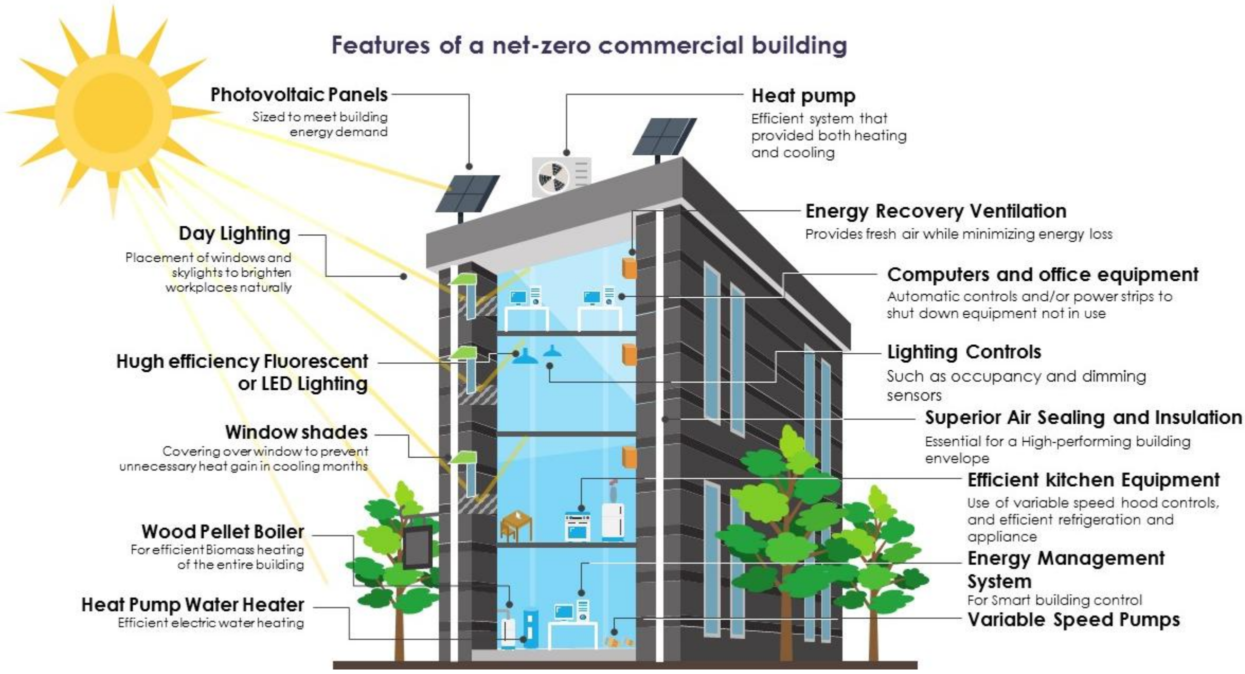
More on a general note, collecting all kinds of data (temperature, air quality, pressure, energy consumption, …) allows to optimise energy consumption, by heating / lighting / ventilating spaces only where and when necessary (to the extent this can be fully controlled externally). Large scale data collection also allows to detect anomalies in energy use, which then can be traced back to either improper habits of the occupants, or to structural problems with the buildings itself (e.g. an area which has not been properly insulated during construction).

[6] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

Apart from limiting energy use, buildings need also to make a switch to clean energy vectors, in order to support further decarbonisation. Different solutions exist to this end (solar panels, heat pump, sun collectors, biogas, geothermal ...) which have to be judged on their merit on a case by case basis.

Also very important is the interaction of the building with the environment. A particular point of attention here is the role of buildings in balancing the intermittence of renewable energy sources like wind and sun. With a smart meter, homes can consume or store electricity when it is abundant, and vice versa when there is scarcity. An important role to play in this respect will be for electric vehicles and for heat pumps in combination with thermal storage such as water tanks and building mass. With smart charging infrastructure, they can charge during the day (when there is a lot of wind and sun) or during the night, and batteries can discharge on moments with scarcity (e.g. a cold winter evening).

Figure 4 Illustration of a 'smart' building



Source: Mckinsey

All of this means that buildings owners should embrace the various smart technologies that can help to reduce their energy consumption much more than what would be possible without. This image of a smart building contrasts sharply with the situation of the current (public) building stock, where often the settings of the heating and cooling installations are not properly adjusted to the needs, and even heating and cooling at the same time in a building is found to be no exception. Thus, a crucial role is in the (optimal) control of the energy systems within buildings. It should be noted that in this context the minimal energy use goal needs to be well balanced with the (often conflicting) minimization of thermal discomfort, where the latter is influencing the productivity in offices and as such might have an important economic impact too.

4 PUBLIC BUILDING RENOVATION PROJECT

4.1 Project

The project aims at promoting the renovation of public buildings, in order to make them smart, energy efficient, and to reduce their CO_2 emissions in line with the long term climate objectives. Evidently, all types of building will need to be renovated, including residential buildings as well as private non-residential buildings (offices, stores, …). But in the context of the strategic investment pact, it was chosen to focus on public buildings, as government here has direct control over the investments. However, a number of figures and other information presented in this document are also relevant for investments to be undertaken by the private sector.

4.2 Investment costs

4.2.1 PUBLIC BUILDINGS

Data on the Belgian public building stock is poorly available. In most databases, public buildings are classified under the tertiary sector, with no subdivision between public and private stock. A good overview of the overall state of these buildings seems to be lacking. To the best of our knowledge, no estimations have been made so far on the investment volumes that would be needed to make the Belgian public building stock contributing in a realistic way to the climate objectives.

In order to overcome this, we deploy a two-step methodology. Firstly, we calculate the total surface (m^2) of the public building stock, by estimating the share of public building in different types of tertiary building (offices, schools, health care, …). Secondly, we deploy a proxy for investment cost per m^2. Here we base ourselves on an in-depth European study that evaluates the cost of bringing primary energy consumption of buildings close to zero (nZEB level)[7]. For buildings in France and Germany (which have comparable climates), this figure lies between 600 and 700 euro/m^2 for schools and offices. We therefore employ an average of 650 euro/m^2.

Combining this with the surface to be renovated, we arrive at a total investment figure of approximately 33 billion euros. If we assume that this needs to be realised by 2040 (as indicated in the interfederal energy pact), this implies a yearly investment of more than 1,6 billion euro in public buildings. For federal public buildings (offices, courts, prisons, …), total investment cost is estimated at about 3 billion euro (or 155 million euro per year if spread over 20 years).

Note that there are many uncertainties surrounding these figures. Depending on the methodology, estimates can be lower or higher. Some authors, such as Cityinvest, indicate that cost can go up to more than 1000 euro/m^2 and even more for deep renovation, which results in investment costs for public buildings in the order of 50 billion euro.

In any case, public entities need to be aware of the investment challenge that they will be facing in the years to come so that they can prepare accordingly. Therefore, a proper

[7] http://www.entranze.eu/files/downloads/D3_3/131015_ENTRANZE_D33_Cost_Energy_Curves_Calculation_v18.pdf

inventory of the public building stock and a more detailed assessment of the investment needs is urgently needed.

4.2.2 Overall building stock

Table 1 summarises the overall picture in terms of investment needs, based on own calculations as well as other sources. For the residential building stock, total investment volumes are well above 200 billion euros, while the non-residential is well above 100 billion euros. In total, this implies an investment cost of about 334 billion euros, to be spread over the next 30 years (taking 2050 as horizon). This implies annual investment of more than 11 billion euros.

Table 1 Overview of cost required to make the building stock energy efficiency, by building type (billion euros)

<table>
<tr><td colspan="6">Residential: 203</td></tr>
<tr><td colspan="2">Flanders: 120 (1)</td><td colspan="2">Wallonia: 63 (2)</td><td colspan="2">Brussels: 20 (3)</td></tr>
<tr><td colspan="6">Non-residential: 122</td></tr>
<tr><td colspan="3">Public: 33 (4)</td><td colspan="3">Private: 89 (5)</td></tr>
<tr><td colspan="6">Total: 325</td></tr>
</table>

Sources: (1) Communication of Flemish energy Agency at congres of Vlaamse federatie Bouw (22/3/2018) (2) Stratégie Wallonne de rénovation énergétique à long terme du bâtiment (3) extrapolated based on estimation for Flanders and Wallonia based on number of inhabitants (4) calculated as explained earlier in this note (5) calculated with the same methodology as public buildings

Also here, care should be taken with interpreting these figures. Adding up figures from different studies (which each one having their own ambition level for energy efficiency, and their own methodology) presents an extra factor of uncertainty. These estimations therefore only serve to get an idea of the order of magnitude of required investments.

4.3 Economic impact

Apart from being a necessary investment to realise long term climate objectives, renovation of buildings also generates a number of positive economic effects. These include additional economic output as induced by goods and services needed for the renovation.

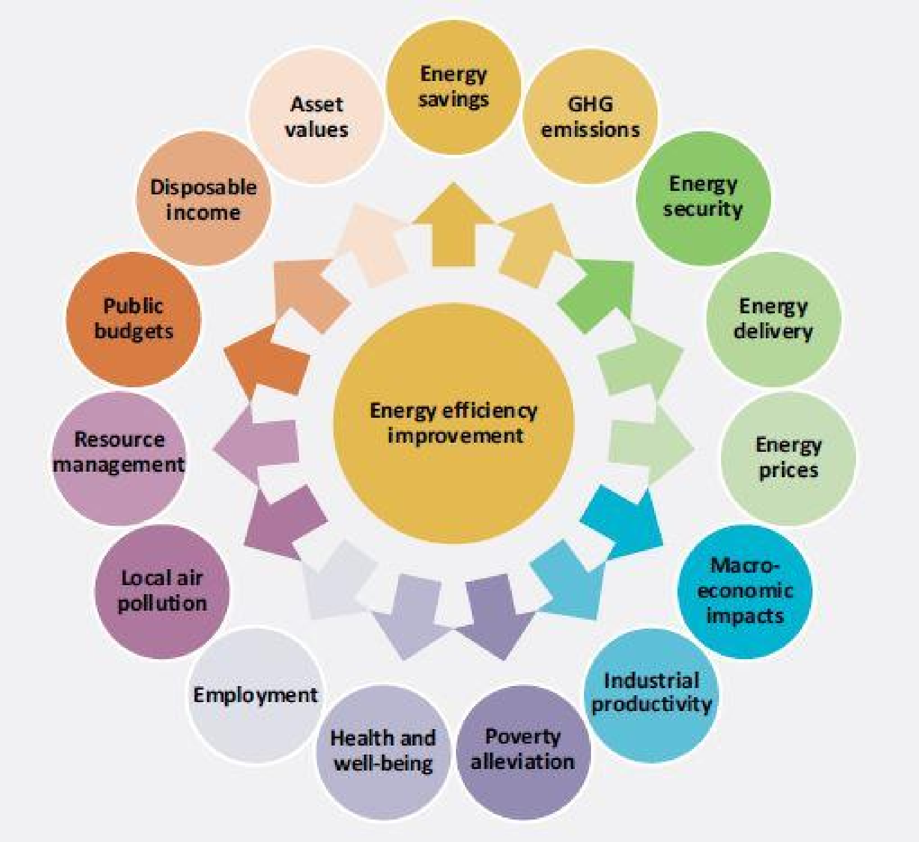
Construction is a very labour intensive activity. Therefore, the employment effects of a major renovation wave can be significant. To get a rough estimation of this effect, we base ourselves on input-output tables published by the Federal Planning Bureau for the year 2010. We model the economic effect of a ‘demand shock’ which represents the increased investment in renovation. In first instance, this leads to additional output of the construction sector (*direct effect*). In second instance, this leads also to additional output for the suppliers of the construction sector (*indirect effect*). Additionally, employees created by the direct and indirect effects have now a wage to spend, which in turn creates additional economic activity (*induced effect*).

Taking these effects together, we estimate that yearly investment of 1.6 billion in public buildings generates about 12,000 jobs during that period. Considering the investment in all building types together, we find that over a period of 30 years, this investment wave will support some full time 80,000 jobs. It is important to note that his figures relate to domestic employment.

4.4 Other impacts

For building renovation, generally the CO_2 emission reduction and its economic impact (high investment costs versus lower energy bills and more employment creation) are apparent. But there are much more effects at play, as illustrated by the International energy Agency which has devoted an entire publication to highlight the several co-benefits of energy efficiency (see Figure 5). These are very diverse and go from more energy security (less import dependency) over better indoor comfort and wellbeing (less temperature fluctuations, better indoor quality) to less air pollution outdoors, less energy poverty, higher building values, ... Moreover, environmental impact due to particulate matter, NO_X emissions, water use, waste disposal, etc. can be reduced too. Often all these benefits are overlooked as a number of them are hard to quantify / monetize, yet they may bring about a significant added value to society at large.

Figure 5 The multiple benefits of energy efficiency improvements



Source: International Energy Agency (2014) - Capturing the Multiple Benefits of Energy Efficiency

4.5 Finance

While the environmental and economic benefits of investment in building renovation is clear, an obvious question is how public entities can finance such significant amounts. A combination of several routes can be envisaged.

First and foremost, the share of public spending in Belgium going to investment in fixed assets (roads, buildings, …) in the period 2011-2015 was about 0,6% of GDP. This is lower than the average in the neighbouring countries, and 0,4% of GDP less than the EU average[8]. Shifting public spending towards investment in fixed assets, by rationalising other types of expenses, would already give a major boost with increasing the net spending or debt of Belgian governments.

Secondly, in the context of a long term vision on its buildings portfolio, a government might decide to sell (redundant) parts of its stock, or sell and lease back buildings in case it decides that building management is not among its core activities. In both case, space is liberated in the budget for other investments.

However, to the extent that additional investments cannot be compensated by reducing expenses elsewhere or selling assets, there will be an effect on the government budget and debt positions. Eurostat rules determine that investments need to be recorded completely in the government financial accounts in the year they are commissioned. When the government would be starting an investment wave in buildings like described above, this would immediately increase government deficit, and conflict with EU rules aiming to lower national deficits.

Yet, a recent Eurostat note opens the door for budget neutral investment. It specifies that energy performance contracts (EPC), whereby a private party commits to reducing energy consumption of a building and is paid with savings on the energy bill, can be used without affecting government deficit in case both the risks and rewards of the investment lie with the private party. EPC contracts are increasingly being used as it allows public entities to significantly reduce their environmental impact, while the necessary investment can be financed in part or fully with energy savings.

EPC contracts are only one example on how the deficit constraint can be overcome. Generally speaking, this constraint can for example be overcome by letting a private party doing an investment (e.g. in solar panels) and having the government leasing it subsequently. Other solutions include the so-called 'right of superficies' in which government provides the right to a third party to install e.g. an efficient CHP unit on land owned by the government. Evidently, all these solutions need to be evaluated on their merit on a case by case basis, but deserve further investigation. For a more detailed overview on ways to promote budget neutral investments, we refer to a study that has been conducted for the Federal Council of Sustainable Development on this matter[9] .

While the text above illustrates how engaging private finance can help to overcome the public deficit constraint, this constraint should definitely not be the only driver to do this. The management and optimisation of heating and cooling systems in buildings can sometimes be quite complex. Specialised companies are often better equipped to perform this task, which can include for example large scale data collection allowing to detect behavioural or physical anomalies in the buildings, improving energy efficiency. The decision to engage in

[8] Eurostat
[9] http://www.frdo-cfdd.be/nl/nieuws/studie-financiering-energierenovatie-van-gebouwen

an EPC contract should in first instance consider this type of ‘intrinsic’ advantages, and only in second instance the positive impact on the budget deficit.

4.6 Implementation

To turn the ambition outlined in this document into reality, a number of hurdles need to be overcome. Based on discussions with a broad range of stakeholders, we therefore would like to provide following recommendations.

Firstly, we call on the government to unambiguously take the lead in renovating the building stock. So far, investment in the public building stock has been limited and there appears to be some inertia / lack of awareness at different levels that is delaying investment. At the same time, the interfederal energy pact shows a clear ambition to make the public buildings energy neutral by 2040. Continued, strong political support over the coming years will be necessary to achieve this objective. There have been a number of interesting bottom-up initiatives (e.g. at the level of towns, provinces …) but they need a strong top-down framework in order to take things to the next level.

Secondly, investments should not be done ad-hoc but in the context of a long term vision on public real estate. Such a vision should start with a view on the evolution of government services, and derive from that a vision on portfolio of buildings that will be required to enable that service provision. The definition of this portfolio should also take into account considerations about mobility (e.g. closeness to train station…) and energy (e.g. possibility for district heating …). Once there is clarity on the building portfolio of the future, long term investments can be scheduled.

A very practical constraint in defining the future building portfolio is lack of data on the existing building stock. Indeed, data is dispersed among several entities and a coherent, central overview is often lacking. At the same time, it needs to be acknowledged that several initiatives have been started over the past years to overcome this barrier. These efforts will need to be continued and strengthened in order to allow for a more thought building policy. In this context the government can lead by example. An energy dashboard is desirable to make the achieved results visible. To this end results need to be measured based on the real performance. Thus, demonstration, sensibilisation and information can be realized.

At the level of individual buildings, investments need to planned and executed with a long term objective in mind, in order to avoid technical or economical lock-in. As outlined above, a series of energy efficiency measures (e.g. optimising settings of heating installations, relighting, …) have a good payback time while others (insulation of the building envelope) have often a longer payback time. If only the ‘quick-wins’ are realised, public entities may find themselves later on with investment projects with unattractive economics that are hard to finance. To overcome this, two approaches can be followed:

- Public entities invest directly in deep renovation (combining quick wins with more structural measures)
- Public entities invest first in quick wins, but with a clear long term renovation plan for the building in mind. The money saved through energy efficiency measures is kept aside (e.g. in the form of a rolling fund) for investment in deep renovation later on.

A key lever to promote renovation is to cluster investments in several buildings into one project. This has several advantages:

- It creates return to scale w.r.t. administrative procedures, which can be quite heavy for both public and private actors
- It makes it more interesting for third party finance
- It makes it easier to finance individual projects with a long payback time when they are put together with more interesting ones
- It can lower risks by levelling out uncertainties at the level of individual buildings

Working in clusters also fits well with the idea of looking at building renovation at portfolio level rather than at individual building level

Another important point is to further standardise contracts and procedures among public entities, which will reduce lead time and promote market development.

Learn from domestic experiences as well as abroad.

- In Belgium, over the past years several initiatives have been taken at different levels (local, province, regional, federal) … the question is whether the experience that have been gained (e.g. related to tendering, contracts, project management, …) are shared sufficiently. Governments should reflect on how they can promote knowledge sharing and avoid that each public entity starting to 'reinvent the wheel' by itself. In this context we refer to the report of the working group on alternative finance, where the idea of increased collaboration between public entities in Belgium is discussed in more detail ('infrastructure investment community').
- Abroad, there are a number of interesting examples, such as the RE: FIT project in London which entailed among others a dedicated project delivery unit. A few other countries have also conducted inventory exercises which may provide inspiration.[10]

Engage in a structural dialogue with the private sector and research institutes. It is certain that public and private sector will need to collaborate to realise the overall objective. Moreover research results obtained within Belgian research institutes and their international network might further strengthen this action and provide innovative approaches. It may therefore be interesting to organise a structured dialogue between different public, private actors (from different parts of the value chain), and researchers in order to exchange experiences and improve ways of working.

5 CONCLUSION

The building stock in Belgium is old and far from energy efficient. There is a broad consensus among stakeholders that investments in this area are urgently needed. Two main benefits would result from this. Firstly, it could significantly reduce CO_2 emissions, as buildings account for about a third of Belgian CO_2 emissions in the non-ETS sectors. Secondly, this would also generate positive socio-economic effect, as renovation is a very labour intensive activity.

The project focuses on making public buildings energy efficient and smart. This means that buildings should not only be properly insulated, but that they also should have ICT tools which monitor and optimise energy usage and allow the building to interact in a smart way with the environment (e.g. consuming electricity when wind or solar energy provide overproduction,

[10] A comparison of a number of policies promoting renovation (both public and private buildings) across the EU can be found at: http://www.citynvest.eu/content/comparison-financing-models

and vice versa). Total required investments for public building are estimated at about 33 bio. Investment needs for the complete building stock (including residential buildings) are even an order of magnitude higher, around 325 bio.

Making the public building stock energy efficient constitutes a major challenge. This note presents a number of options to tackle this challenge, both with regards to financing (with own means or third party financing) as well as a number of suggestions on implementation strategies. At the same time, gearing up investments in public buildings should be feasible. The most important first step is to create sufficient awareness and ambitions at all levels of public entities.

A.2 DECOMMISSIONING AND TRANSMUTING SPENT NUCLEAR FUEL PROJECT

1 CONTEXT

The back-end of the nuclear lifecycle includes spent fuel, radioactive waste management and decommissioning. This back-end of the nuclear lifecycle will need increasing levels of attention, as the European Commission estimates that more than 50 of the 129 reactors currently in operation in the EU might be shut down over the next decades[11]. Nuclear power plants will be shut down across the world because of aging, technical or political reasons and need to be dismantled in a correct manner.

The market for the back-end of the nuclear lifecycle is significant in size and requires experience, appropriate nuclear expertise and skills, technology and a safety culture to perform such operations in a proper way.

Nuclear waste management faces substantial challenges. Current “solutions” for spent nuclear fuel consists of either direct geological disposal without reprocessing (after temporary surface storage for about 50 years, but with subsurface timescales of about 300,000 years to reduce the radiotoxicity to safe levels) or reprocessing of spent nuclear fuel followed by geological disposal (with timescales of about 10,000 years). Transmutation at industrial scale offers promising possibilities with final disposal duration of about 300 years. However, this solution requires additional research and demonstration at pre-industrial scale.

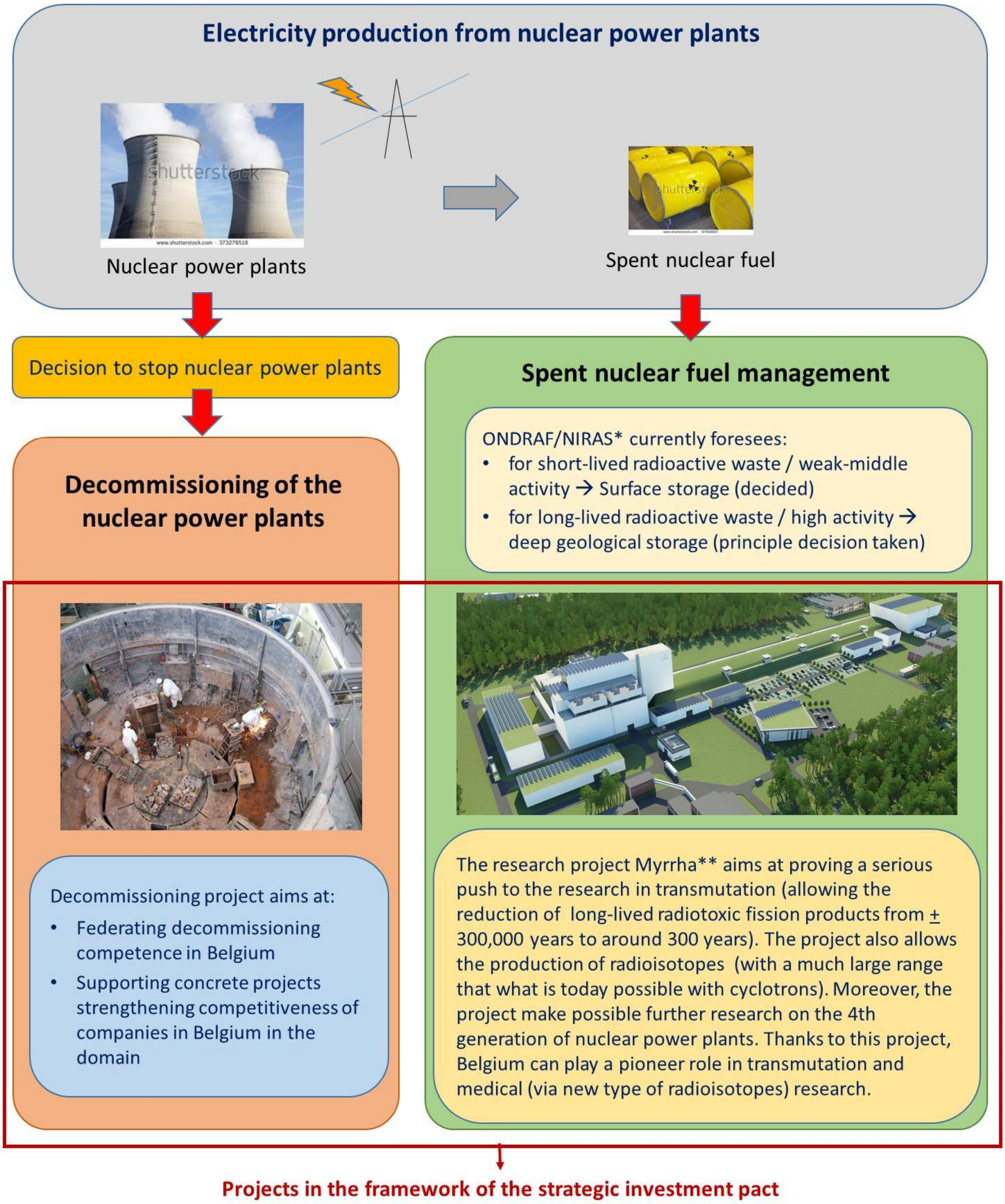
In the same way as Belgium has played a pioneering role in many fields of the nuclear new build and construction era (PWR reactors, Mox fuel, reprocessing technology, dismantling of BR3 and Eurochemic), Belgium and its nuclear industry can now assume a pioneering role in:

- smart and high tech decommissioning techniques and approaches;
- technical demonstration and research around transmutation in a research infrastructure that offers additional opportunities in the area of medical radio-isotopes and a number of other fields. The MYRRHA project is the implementation of such an infrastructure.

Both projects (decommissioning and MYRRHA) are a unique opportunity to position Belgium internationally in the field of decommissioning and research (transmutation, medical radio-isotopes, roadmap to fusion reactors). These opportunities are further explained in the present note.

[11] Source: European Commission. 4th April 2016. *Communication for a Nuclear Illustrative Programme (PINC).* 4th April 2016. COM(2016) 177 final.

Figure 6: Scope of document: Decommissioning & Transmuting spent nuclear fuel



* Belgian National Agency for Radioactive Waste and enriched Fissile Material

** **M**ulti-purpose h**Y**brid **R**esearch **R**eactor for **H**igh-tech **A**pplication

2 DECOMMISSIONING WHAT IS IT ABOUT?

2.1 Dismantling steps

Dismantling of nuclear power plants is the back-end phase, after decades of operation of these power plants. It is important, for the purpose of dismantling, to know that

- about 99 % of the materials in the nuclear plant are either not-contaminated nor radioactive after appropriate treatment, and that they can be released or recycled;
- about 99 % of all the radioactivity is concentrated in the spent fuel or the reprocessing residues

For all stages of the decommissioning process, adequate solutions exist to guarantee extremely low exposure risks for present and next generations. However, there is still room for continuous improvement in terms of dose exposure minimisation, safety of operators, quality of collected data, quality of final waste products and overall costs of the operations to be performed.

The different dismantling steps include:

- the ***preparation of the works***, with careful planning of the chronology of the various tasks to be performed on site, taking different levels of radiological and conventional safety into account

  The first operations however include emptying fuel from the pools, surface cleaning and first decontamination works, adapting utilities and HVAC (Heating, Ventilation and Air-Conditioning) systems for the works, emptying tanks, removing insulation materials, cabling etc.

  The preparation phase requires also engineering and investments to build new systems and auxiliary (temporary) infrastructures such as units for local sorting, decontamination, cutting, compacting, waste packaging, water treatment etc.

- the ***specific nuclear dismantling works*** which require special care and techniques (radio-monitoring etc.) to guarantee safe operations in terms of dose exposure minimisation to workers and which include a strong management system and smart *work flow to get all presumed* waste and materials streams radiologically *characterised*, *categorized and channelled into their* appropriate storage and pre-treatment *and treatment systems*.

  The operations include, amongst others, disassembly works (primary reactor loop components such as steam generators, pressurizer, primary pumps and piping, fuel handling equipment etc.), local volume reduction of components by different techniques, local storage and transport, decontamination, inspections, sorting of materials on radiological and physico-chemical characterization, radioactive waste temporary storage and transports, material management systems, as well as dismantling and cleaning (e.g. concrete) of auxiliary and other buildings, site remediation etc.

- the ***conventional execution*** *phase* comprises the *conventional decommissioning works of the non-nuclear part* - similar to any other process plant, a chemical plant, etc.

- the ***post-treatment of radioactive waste streams*** includes several operations performed by the Belgian operator Belgoprocess or by the nuclear operator under the authority of NIRAS / ONDRAF.

  They include operations such as incineration (combustible waste fractions), super-compaction, cementation, possibly vitrification, temporary storage and monitoring in attendance of final (surface or geological) disposal, in the same way as the rad waste management today for operational waste streams from the nuclear power plants and other producers.

- the ***conventional demolition works*** and -depending on the requirements- green field restoration.

2.2 Required knowledge / competence

The competences for nuclear decommissioning works comprise, amongst others and not as an exhaustive list:

- project management and general work planning and follow-up
- safety assessments and management of decommissioning works from nuclear plant building inspections towards decommissioning inspections
- radiological monitoring and detection of all kinds
- radioactive waste visual screening, sorting, characterization and categorization technologies
- extreme heavy nuclear lifting works such as steam generator, pressure vessel and primary pumps removal
- moderate heavy lifting works (various components) in changing environment
- fuel handling, decontamination works, primary components cleaning, storage, surface cleaning / decontamination by a variety of technologies
- diverse filtering/handling methods for decontamination cleaning liquids / WAB experience Doel NPP – MEDOC experience SCK•CEN.
- various types of remotely operated mechanical cutting (circular milling, bandsawing, reciprocating sawing, pipe cutters,…)/ (abrasive) water(jet) cutting/ Electric discharge machining cutting / plasma beam cutting of big activated steel pieces
- robotics for contaminated and activated components and areas
- demolition robots / sawing and various diamond cutting of reinforced concrete walls
- decontamination and conventional dismantling works, blue collars
- storage containers for spent fuel
- storage containers for contaminated tools or waste
- treatment of radioactive waste by incineration, cementation, supercompaction, plasma melting
- transport of radioactive components and transport permits and paper works
- transport of spent fuel and contaminated steel for recycling abroad
- trainings, education and nuclear upgrades of conventional companies, safety issues
- quality assurance in the handling of dismantled materials and waste
- site remediation after decommissioning (characterization, cleaning, sorting, removal of contamination,…)

- characterization before (components), during (pieces and waste) and after (remaining structures and infrastructures) dismantling.
- …

2.3 Belgian knowhow

2.3.1 POSITIONING BELGIAN INDUSTRIES

Several Belgian companies, institutes and organizations have developed competences in the various phases of dismantling and radioactive waste management both in terms of processes, technologies and specific equipment. On the basis of earlier projects, many useful experiences have already been gained in this field (Belgium was a pioneer in many of them). However, it is clear that there is still room for substantial improvement on the basis of new technologies and ideas.

A financial boost to further innovate and develop new technologies would help to increase the strengths of Belgian competences in this field and better position them on the market for future dismantling works all over the world.

2.3.2 BELGIAN TECHNOLOGY ACTORS POTENTIALLY INVOLVED IN DECOMMISSIONING WORKS

The following companies and institutions could potentially be involved in decommissioning of nuclear power plants: SCK•CEN, BESIX, AKKA, TRACTEBEL, ENGIE, VN Safety, VINCOTTE, MIRION, DSI, SARENS, ALE, PHIBO, NETALUX, KRIVA ROCHEM, HELAXA, DECO, TYROLIT, HUSQVARNA, WESTINGHOUSE , TECNUBEL, ALM, CMI , BELGOPROCESS, TRANSRAD, TRANSNUBEL, ECS , BINDING ENERGY,…

As explained in the next chapter, Agoria is currently in a process of clustering them.

2.4 The market

The total cost for the decommissioning of:

- nuclear power plants is about $185 billion;
- research reactors and critical assemblies is about $ 6,320 million;
- fuel cycle facilities is about $ 71 billion;
- industrial facilities is about $ 40 million;
- research facilities is about $ 3,360 million; and
- facilities from the Cold War legacy is about $ 640 billion.

This leads to a total decommissioning liability for the period 2001–2050 of about $1,000 billion.

3 AGORIA CLUSTER

3.1 Objective

AGORIA, the federation for new technologies, is currently putting in place a decommissioning cluster ABCD (**A**dvanced **B**elgian **C**luster on **D**ecommissioning). The project counts on this cluster to gather Belgian knowledge and know-how on this domain.

The objective of the cluster is:

- to *play a federating support role* in the identification of relevant Belgian players for nuclear decommissioning and create a collaborative company network covering the full supply chain for decommissioning works;
- to *help national authorities to maximise the domestic economic return* on investments made in the frame of future dismantling works on the domestic market of nuclear power plants of Doel and Tihange;
- to *identify gaps in the competence portfolio* of Belgian players which may prevent them today from becoming important actors *on the world market* in this business;
- *get these actors actively supported by Belgian authorities* (on different levels) in their ambition to increase their competitiveness by acquiring new skills, by improving existing technology or buying new technology, by reinforcing manpower and detecting synergies between companies;
- *to create a relevant export oriented company pool* for the decommissioning world market;
- to *bring critical and complementary mass* together to cover full dismantling projects (abroad).

3.2 Organisation & members

A close collaboration will be set up between Agoria ABCD (with its members being companies as identified under "Belgian knowhow" section) and the nuclear plant owners (Engie), relevant research centres (mainly SCK•CEN), mandated actors and national organisations (Belgoprocess, Bel V) and any other organisation (FANC, NIRAS-ONDRAF) which may contribute to reinforcing the specific competences to do the job,

4 INVESTMENT PACT

4.1 Vision

The Belgian companies in this area need to further develop tools as to be amongst the best performers in this area. They have the potential to provide a unique and efficient selling proposition to the society challenge of dismantling of nuclear power plants across the world.

In order to better position our industries in this niche business, some investments are required. The decommissioning project as presented for the investment pact proposes to financially – through specific projects - support those industries to perfect or develop tools / instruments / knowledge etc. needed for efficient dismantling of nuclear power. A selection committee will be required to ensure quality and return of the provided investment support.

4.2 Financing needs

The currently identified proposed project requires roughly 50 million investment budget.

4.3 Selection committee

There is a need for a selection committee in order to assess and select the projects to be financed. Selection criteria will have to be clearly defined (e.g. relevancy of the project, impact, …).

The committee should be independent, but also needs to be familiar with technology and industrial practices in the field of nuclear operations, and more in particular, dismantling and decommissioning operations

5 CONCLUSION

Belgium has a strong case for the development of decommissioning competences by industry and for the Belgian government to play an active supporting role in this process, given:

- the existing Belgian dismantling experiences, R&D and know-how;
- the need for nuclear technology companies to update their knowhow and technologies according to new international developments and societal needs;
- the opportunity to occupy an export market where some others don't actively step in yet today;
- the upcoming market in this field because of aging of first generation plants worldwide;
- the motivation and interest of keeping an efficient nuclear educational system driven, amongst other things, by presence of active companies in the field and job perspectives in "future fitted" nuclear technology.

MYRRHA

6 MYRRHA: WHAT IS IT ABOUT?

6.1 Spent nuclear fuel

In 2017, the European Union had an annual production of 2500 tonnes of spent nuclear fuel containing:

- 25 tonnes of plutonium, as well as
- “High Level Wastes” or “HLW”, including 3.5 tonnes of minor actinides (neptunium – Np, americium – Am and curium – Cm) and 3 tonnes of long-lived radiotoxic fission products.

Globally, General Electric Hitachi estimates the total volume of spent high-level radioactive fuel in the Western world at 180,000 tonnes (General Electric (David Powell), November 8th 2016)[12].

These minor actinides and long-lived radiotoxic fission products must be treated in a safe and specially adapted manner. Reprocessing of spent nuclear fuel (partially closed nuclear fuel cycle) followed by geological disposal or immediate geological disposal without reprocessing (open nuclear fuel cycle) are currently the most cited options for most countries, depending on the national nuclear fuel options and nuclear waste strategies. The required timescale for geological disposal (required to reduce the radiotoxicity to safe levels) is about 300,000 years for the open cycle and 10,000 years for partially closed nuclear cycle, which is far beyond current technological projection safety margins.

6.2 Studied solutions thanks to MYRRHA

For Belgium the questions of whether the most adequate solutions (both social and economic) have actually been considered[13]. The FOD-FPS Economy made a study on this issue. It compares the various options for the future treatment of spent nuclear fuel and radioactive waste generated, and was made publicly available in January 2017 (FOD Economie, K.M.O., Middenstand en Energie, 2014). The study explicitly mentions “Partitioning and Transmutation (P&T)” as a strategy that could reduce the requirements for geological disposal as a final solution, and may reduce the radiotoxicity timescale from 300,000 years to a technologically feasible timescale of 300 years. As Belgium has an excellent worldwide research programme in the field of P&T, it is therefore logical to (officially) integrate P&T in the Belgian nuclear fuel cycle.

For 20 years, SCK•CEN has been working on the design of a new multifunctional irradiation installation: the Multi-purpose hYbrid Research Reactor for High-tech Applications, also known as MYRRHA.

MYRRHA is a demonstration milestone at pre-industrial scale for transmuting spent nuclear fuel. The project demonstrates that the Accelerator Driven System (ADS) can reduce the volume of waste by a factor of 100 and can shorten the burden of the actinides from some hundreds of thousands of years to some hundreds of years, via the process of transmutation.

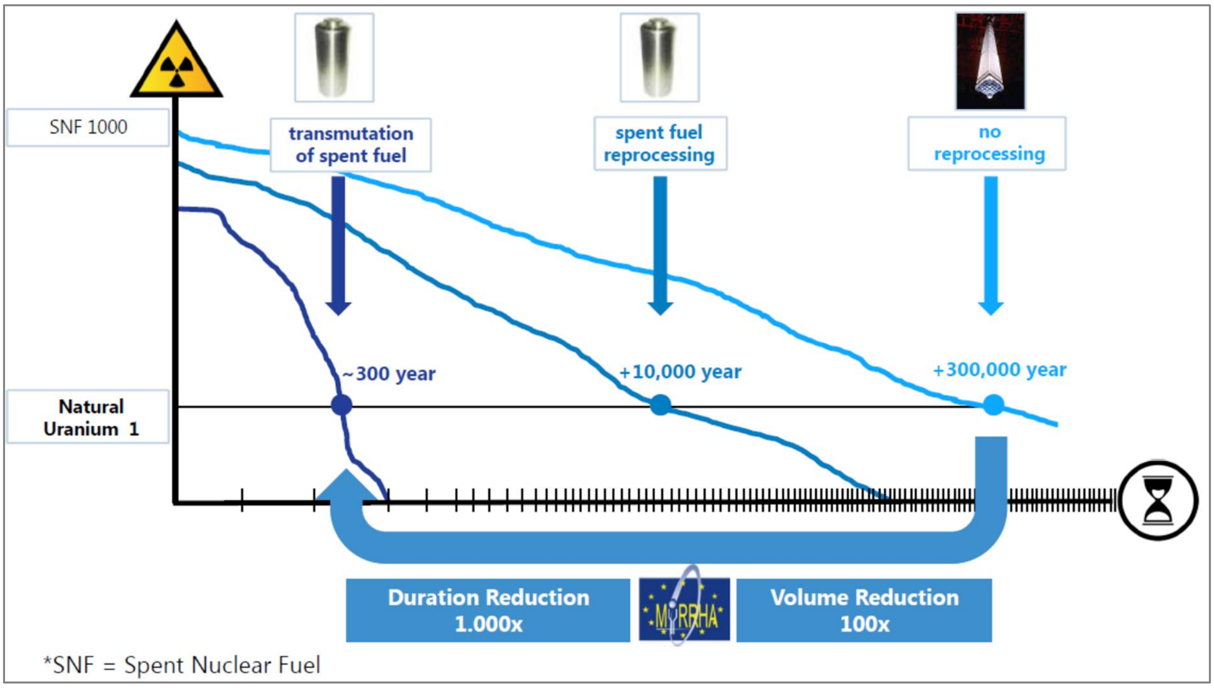
[12] General Electric (David Powell). November 8th 2016. *Presentation at the Agoria VIP SMR (Small Modular Reactor) event in Brussels.* s.l. : General Electric, November 8th 2016

[13] Questions that became more acute due to the EURATOM Resolution of 2011

The figure below compares the strategy of partitioning[14] & transmutation (P&T) with 2 alternative solutions for spent nuclear fuel, namely

i. immediate geological disposal
ii. current technology of enriching spent nuclear fuel (so-called “classic reprocessing”, as currently performed in Europe in La Hague (FR) and Sellafield (UK)).

Figure 7: Reduction time of radio-toxicity of spent nuclear fuel by 3 technologies



6.3 The MYRRHA project

The MYRRHA research facility will be the first prototype in the world of a system driven by a particle accelerator (Accelerator Driven System, abbreviated as ADS). MYRRHA will be built at the SCK•CEN site in Mol (Belgium). MYRRHA will be an international magnet for organisations and scientists involved in research into nuclear reactors with fast neutrons and particle accelerators and their applications, making new partnerships and innovations possible. MYRRHA will allow Belgium to continue its ground-breaking tradition of peaceful nuclear applications for the next 50 years.

6.4 Other possibilities of MYRRHA

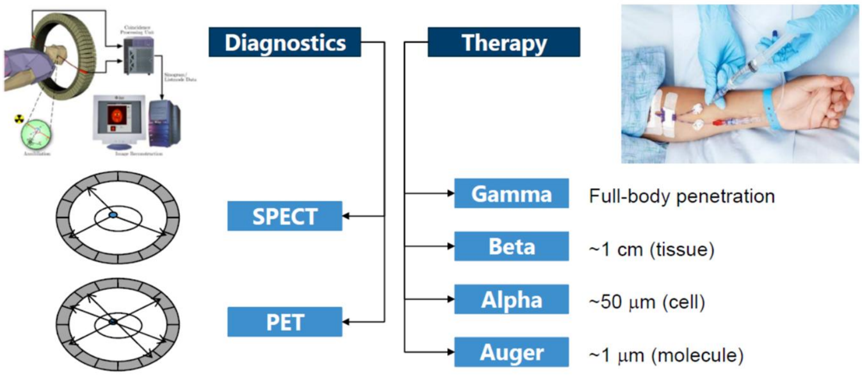
The MYRRHA research facility enables a wide range of new applications. One of the key applications has already been discussed: demonstrating transmutation as a socially and economically superior solution for spent nuclear fuel and high-level nuclear waste.

As the name MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) suggests, there are a number of other possibly crucial applications.

[14] Separation of the different elements in the spent nuclear fuel

6.4.1 RESEARCH AND PRODUCTION OF MEDICAL RADIOISOTOPES

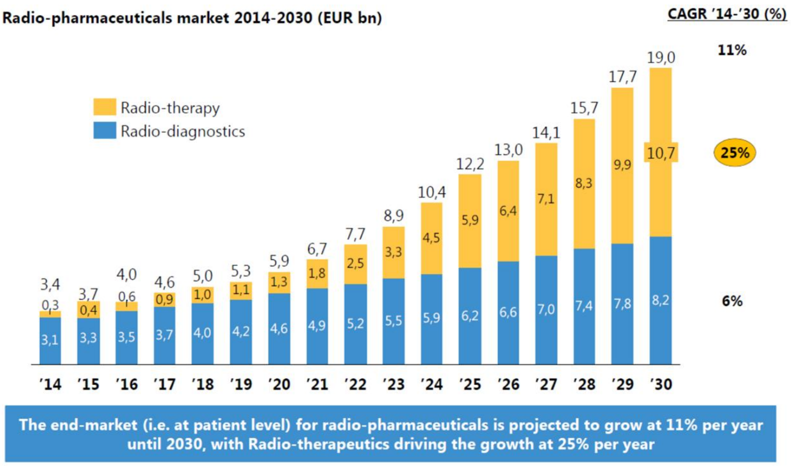
Figure 8: Key applications of radioisotopes in nuclear medicine



In the fields of nuclear medicine and cancer research, Belgium has always stood at the forefront, benefiting from the presence of SCK•CEN. The most commonly used medical radioisotope is technetium-99m (99mTC), which is formed by the decay of molybdenum-99 (99Mo). It is used in around 80% of diagnostic tests, which means 30 million tests per year worldwide. Only six reactors in the world are equipped to produce this type of medical radioisotope, including the SCK•CEN BR2 research reactor. Every year the BR2 produces over 25% of the global demand for medical radioisotopes, and even up to 65% in the case of heavy demand. Nearly 7 million tests are therefore carried out every year thanks to the Belgian production. In Europe, over 700,000 healthcare professionals use nuclear medicine on a daily basis.

MYRRHA enables Belgium to continue its position as champion in nuclear medicine, and to ensure global supply of diagnostic and therapeutic medical radioisotopes[15] for which the demand is increasing. Starting from the first phase, MYRRHA will develop new types of therapeutic medical radioisotopes capable of better targeting the areas to be treated and therefore considerably reducing the side effects for patients. These innovative therapeutic medical radioisotopes are a strongly growing market, as illustrated by the yellow bar in Figure 9.

Figure 9: The Market for Radio-pharmaceuticals (nominal EUR bn)[16]



[15] Technical feasibility for MYRRHA Phase 1 to produce radio-isotopes is outlined in *"The ISOL technique for high-purity radioisotopes production and its implementation at the 100-MeV accelerator of MYRRHA"*, 1st March 2018, by Lucia-Ana Popescu, SCK•CEN report 28382002

[16] Source: Zimmermann, Paul-Emmanuel Goethals & Richard. 2015. NUCLEAR MEDICINE, *World Market Report & Directory*, Edition 2015. s.l. : MedRaysIntell, 2015

As the economic value of radiopharmaceutical products is significant the production of radiopharmaceutical products in MYRRHA can generate significant revenues and profits.[17] Every year more than 10 million nuclear medical procedures are performed with radioisotopes in Europe. Over 700,000 European healthcare professionals use nuclear and irradiation technology on a daily basis. There is a substantial European market for medical imaging materials with an estimated value of EUR 20 billion in 2030. This market enjoys an annual growth of about 5% (European Commission, 4th April 2016).

6.4.2 FUNDAMENTAL RESEARCH

The MYRRHA multifunctional accelerator is suitable for both fundamental and applied research.[18]

The radioactive ion beams are of such high intensity that new opportunities for fundamental research are created in the field of atomic physics, nuclear physics, solid-state physics, biology and medical applications. This research into Radioactive Ion Beams (RIBs) is recognised as one of the top priorities of nuclear physics, as well as the other fundamental research domains stated above.

6.4.3 MATERIALS RESEARCH FOR FISSION AND FUSION REACTORS

Materials research, both into structural materials and fuel materials for a nuclear reactor, is necessary to be able to guarantee and increase the safety levels of current and future nuclear reactors. For over 50 years, SCK•CEN has been researching nuclear materials by irradiating them with a high neutron flux (between 100 and 1000 times higher in the BR2 reactor than a commercial reactor). MYRRHA offers the possibility to further develop the current material tests and study new materials for the next generation of reactors that use nuclear fission and for future reactors that use nuclear fusion. Compared to the current research reactors, the radiation conditions just below MYRRHA's spallation target are much closer to the conditions in a fusion reactor.

In the next decade, MYRRHA will be the only flexible EU reactor with fast neutrons, allowing it to support the crucial materials research for fusion energy (in particular for the DEMO scheduled after the ITER project).

6.4.4 RESEARCH INTO NEW AND MORE EFFICIENT FOURTH-GENERATION (GEN. IV) REACTOR SYSTEMS

The MYRRHA reactor is cooled by a mixture of liquid lead and liquid bismuth, and will serve as an Experimental Technological Pilot Plant (ETPP) for fast lead-cooled reactors. This new type of reactor produces significantly less waste and uses the nuclear fuel much more efficiently (between 50 and 100 times more power generated from the same quantity of uranium compared to current water-cooled reactor technology).

Several countries worldwide are involved in the “Generation IV International Forum (GIF)”, an international partnership created to perform the research and development (R&D) required to demonstrate the feasibility and to develop capacities for the next generation of nuclear energy systems.

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[17] Two Business Plans outline revenue potential of MYRRHA: Total MYRRHA infrastructure is outlined in *"MYRRHA Business Plan 2017"*, 24th February 2017 by Stijn Proost, SCK•CEN report 22239376. MYRRHA (Phase 1 only) is outlined in *"MYRRHA Phase 1 – Business Plan 2017 (EUR 2018)"*, 2nd February 2018 by Stijn Proost, SCK•CEN report 28355074.

[18] Fundamental and applied research opportunities with the MYRRHA Phase 1 accelerator are outlined in *"Identified Physics Cases for the ISOL@MYRRHA Facility in Phase 1"*, 1st January 2017, by I. Cherednikov, L. Ghys, L-A. Popescu, SCK-CEN report 22239496.

The development of Gen. IV reactors required the availability of a suitable (fast) research reactor for the qualification of structural materials and innovative fuel (one of the key obstacles for the development of Gen. IV reactors). MYRRHA could fill this void.

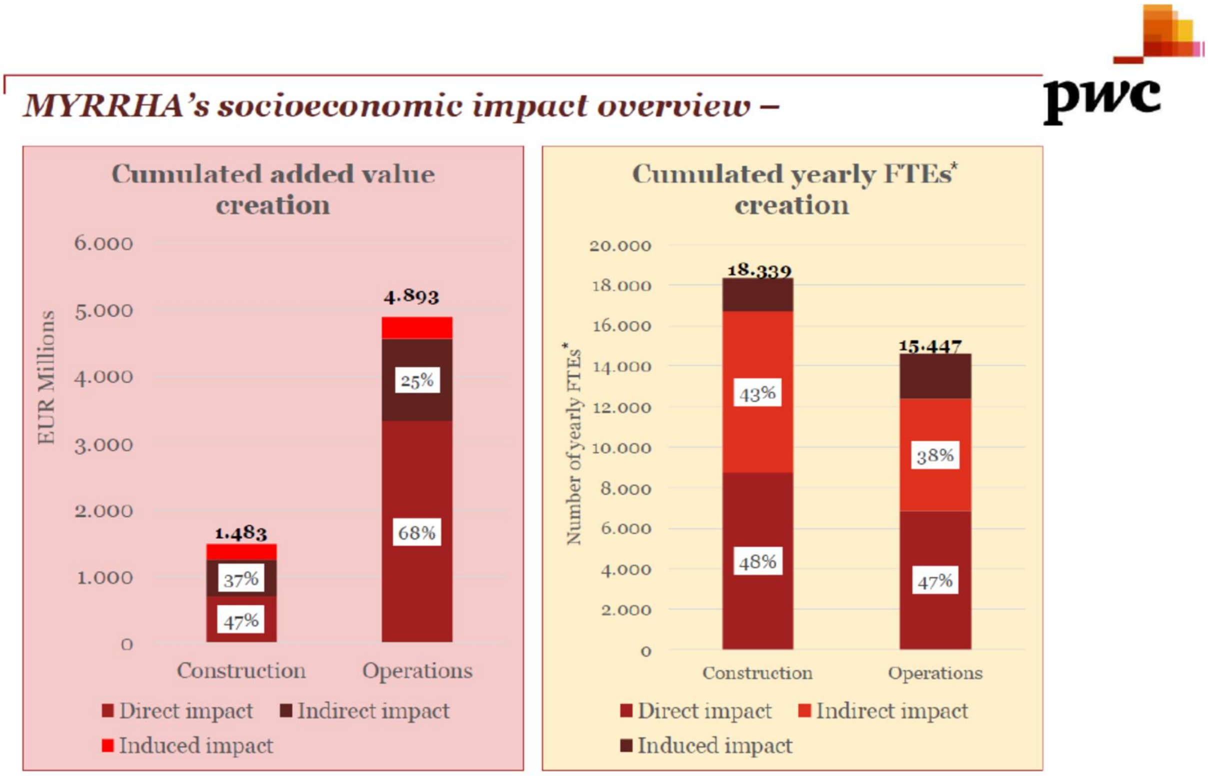
7 MYRRHA'S ECONOMIC IMPACT

In addition to the scientific and technological added value generated by MYRRHA, the project will also have a significant socio-economic impact on Belgium. The research consultancy PwC has analysed the socioeconomic impact of constructing and operating this new research infrastructure in Belgium[19]. The following information comes from this report.

7.1 Added value creation

The added value generated by MYRRHA is estimated at nearly 7 billion euros, taking into account a spill-over effect during both the construction and operation of the infrastructure (2018-2065). Figure 10 outlines MYRRHA's socio-economic impact. The added value created is shown on the left-hand graph, the employment creation on the right-hand graph.

Figure 10: MYRRHA Added Value and Employment creation during Construction ('18-'33) and Operations ('34-'65)



*FTE = abbreviation for man-years of work by a full-time-equivalent

[19] Source: *"SCK•CEN MYRRHA Socio-Economic Impact Assessment (SEIA)"*, September 2017 by PwC

7.2 Employment creation

MYRRHA creates 34,000 full-time person/years of employment in both Belgium and abroad, according to PwC as outlined in Figure 10 in the right-hand graph. In addition to creating jobs, the dynamics generated by the investment in MYRRHA and by its operation will allow a skills hub and a new industrial cluster to be developed in the SCK•CEN region, while also creating spin-offs.

Thanks to its wide range of applications, MYRRHA will act as an international magnet for research centres and universities, which will use it like an open-users facility. This technological hub will give rise to further collaboration and partnerships to the benefit of innovation.

A multitude of Belgian-based companies spread over a wide spectrum would benefit from the construction of MYRRHA. The spectrum of companies is widely spread geographically, by sector, and by size and includes many SMEs.

8 SCK-CEN ROLE

Operationally, the MYRRHA project has been driven and managed since the origin in 1998 by SCK•CEN, the Belgian Nuclear Research Centre. SCK•CEN is a Foundation of Public Utility (FPU)[20] [21] with a legal status according to private law, operating under the tutorship of the Belgian Federal Minister for Energy.

As the next phase in the MYRRHA Project is the start of the actual Construction of (part of) the physical Infrastructure, the creation of a separate legal entity for the MYRRHA physical infrastructure is envisaged.

Even after the creation of the MYRRHA legal entity, an important link will continue to exist between with SCK•CEN, guaranteed by the following elements:

i. The MYRRHA installations will be built on and be physically located at the premises of SCK•CEN in Mol;
ii. Moreover, there will be a strong collaboration with regard to (nuclear) safety and security, access and organization;
iii. Numerous SCK•CEN employees will be working on the construction of MYRRHA;
iv. SCK•CEN will be the operator of the facility and a future key user;
v. As its operator, SCK•CEN will hold the nuclear liability of the MYRRHA nuclear research infrastructure.

[20] SCK•CEN is a legal person according to private law (Stichting van Openbaar Nut, Fondation d'Utilité Publique, Foundation of Public Utility).

[21] Legal profile information on SCK•CEN can be found on https://www.sckcen.be/en/About/Structure/Legal and Statutes can be consulted on http://www.ejustice.just.fgov.be/tsv/tsvn.htm

9 INVESTMENT PACT

9.1 Existing commitments

In 2010, the Belgian government decided[22] to finance 40% of the total infrastructure investment cost for the implementation phase of MYRRHA, on condition that a foreign third party participate in the project and engage in the MYRRHA International Consortium.

In this framework:

- The Belgian government supported the MYRRHA Project with specific funding of €$_{2010}$ 60m for the period 2010-2014 for the installation and testing of technical components in the run-up to the actual build
- The Belgian government renewed its commitment to MYRRHA with specific funding of €$_{2015}$ 40m for the period 2016-2017 in order to develop a detailed and balanced implementation plan (possibly in steps), including the final conceptual design and a risk analysis to minimise the risks regarding technology, financing, costs and planning. At the same time, the Belgian government set a number of objectives on the basis of which it will decide, no later than beginning of 2018, to proceed with the intended development of the MYRRHA infrastructure and the associated funding to which it committed itself in 2010.

9.2 EU involvement

The European Commission has been supporting MYRRHA since 1999 through the scientific framework programmes. Since the 6th Framework Programme (FP6) of the European Commission, MYRRHA has been serving as the basis for the European Research Programme for the transmutation of high level nuclear waste in an accelerator driven system (EUROTRANS).

Since then, the EU support has continued in FP7 and H2020 programmes. In 2010, the European Strategic Forum for Research Infrastructures (ESFRI) promoted MYRRHA to its high priority list of major research infrastructures for energy. In addition, MYRRHA was selected by the European Investment Bank as a potential project for financing via the InnovFin programme, and is on the high-priority list of the European Fund for Strategic Investments (EFSI, also called "Juncker Plan").

9.3 Next steps

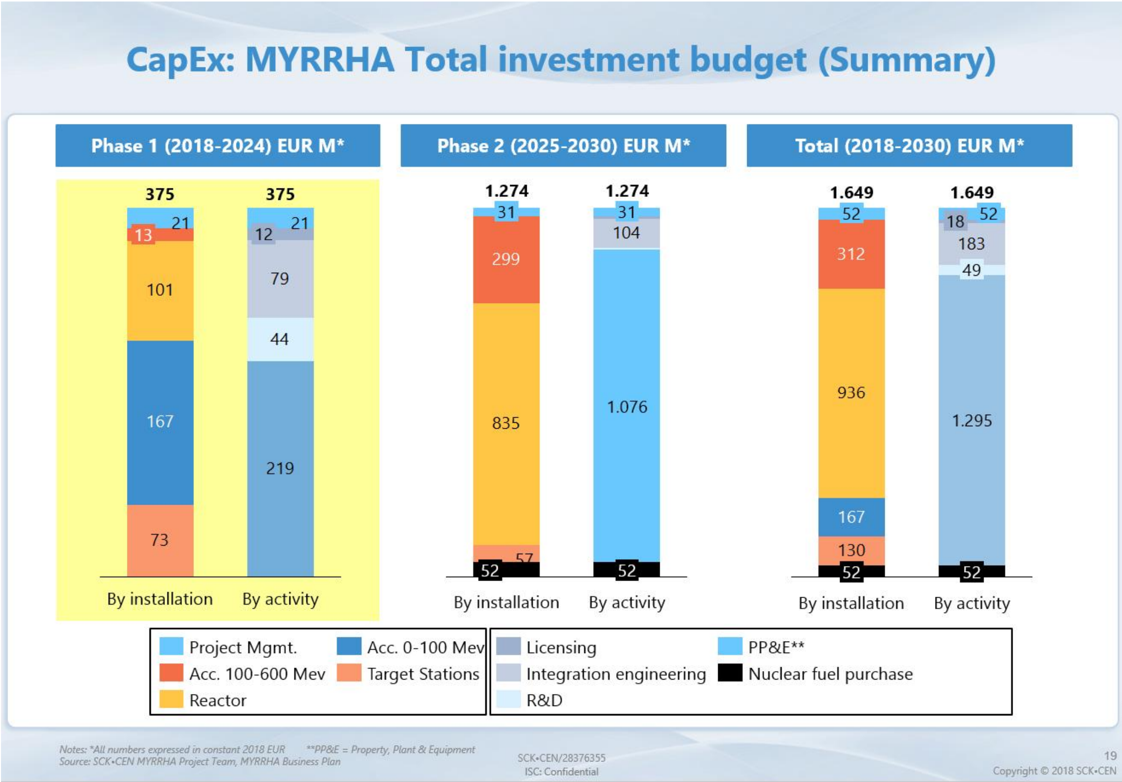
The MYRRHA project team developed a solid implementation plan consisting of 3 phases:

- During the first phase (2016-2024) the first part of the accelerator will be built. This small accelerator is budgeted at €$_{2018}$ **255m** and is a fully modular installation that can function on its own, it will be operational from 2025 onwards and generates income. Phases 2 and 3 will also be prepared in the first phase; these require €$_{2018}$ **120m**.

[22] decision by the Council of Ministers on March 5th 2010. Reference: CMR 05-03-2010 Nota van 04-03-2010 (2010A42450.003)

- In 2024 it can be decided to execute phase 2 (extension of the large accelerator) and phase 3 (construction of the subcritical reactor) either sequentially or in parallel. Phases 2 and 3 require a total investment of €$_{2018}$ **1,275m**.

Figure 11: MYRRHA Investment Budget (in EUR 2018) – By Phase and Activity (2018-2030)



9.4 Current needs

With regard to the funding for MYRRHA, the strategy of SCK•CEN is to set up an international consortium of investors, as well as to obtain funding from the EIB. To make its position towards both the EIB and international investors as strong as possible, an official confirmation of the financial commitment of the Belgian government to invest in MYRRHA is a crucial lever. The construction of similar research infrastructures (XFEL GmbH in Germany with a budget of ~€1.2bn and European Spallation Source ESS-ERIC in Sweden with a budget of €1.83bn) shows that a clearly communicated and substantial commitment from the host country is required to entice members of an international consortium to participate.

The phased implementation plan also facilitates funding in phases. The first phase corresponds to a budget of €$_{2018}$ 375m. In 2010, the Belgian government committed itself to pay 40% of the total infrastructure investment cost, i.e. for the 3 phases combined. To emphasise Belgium's commitment to MYRRHA, it would be preferable for the Belgian government to make a substantial investment during phase 1. The aforementioned similar projects in Europe (XFEL GmbH and ESS-ERIC) were supported in the same manner by the governments of their respective host countries, with a greater commitment (more than 50%) from the host countries in the initial phase in order to launch the project and convince international partners.

The MYRRHA project team is currently busy setting up an international consortium, whereby a number of major consortium partners (including France, Japan, Sweden, the USA and China) are contacted. An explicit and substantial commitment from Belgium as the host country is crucial to convince these international partners to commit themselves financially to the MYRRHA Project consortium.

In September 2017, the Belgian government has entrusted Pieter de Crem, Secretary of State for Foreign Trade, with facilitating the international financing needed to develop MYRRHA. As Special Envoy of the federal authorities, Pieter De Crem has already met several international stakeholders, such as Yukiya Amano, Director General of the International Atomic Energy Agency (IAEA).

Pieter De Crem was also present during the state visit to Canada in March 2018 to support the collaboration agreement between the Canadian research institute TRIUMF and SCK•CEN. Both centers intend to share their expertise in designing their respective research facilities – ARIEL and ISAC; MYRRHA – with a common goal: producing rare medical radioisotopes and developing their knowledge in physics and accelerator technology.

9.5 Required action & investment pact

Explicit confirmation and a substantial commitment from the Belgian government for phase 1 of MYRRHA are absolute conditions for convincing international partners to commit financially to a consortium. Furthermore, these decisions are of an urgent nature, taking into account the project's high level of maturity and the fact that all the conditions have been met to start with the implementation.

Providing the required complement budget to financially book the first phase of the MYRRHA project **in the framework of the strategic investment** plan would:

- provide additional visibility to the MYRRHA project and demonstrate Belgium's involvement towards this international and knowledge-focused flagship project;
- allow the realization of the first phase and benefit from the economic impact;
- provide an impulse for the scientific community with regards to future possible analysis, product development and collaboration as well as pride of being part of a future significant contribution;
- support the creation of the MYRRHA international investor consortium, as an explicit and substantial commitment from Belgium as the host country would act as a crucial lever to convince international partners to commit themselves financially to the MYRRHA Project consortium.

10 CONCLUSION

Belgium has a strong case with the MYRRHA project. It shows Belgium ambition to remain a worldwide player at high level of research at international level.

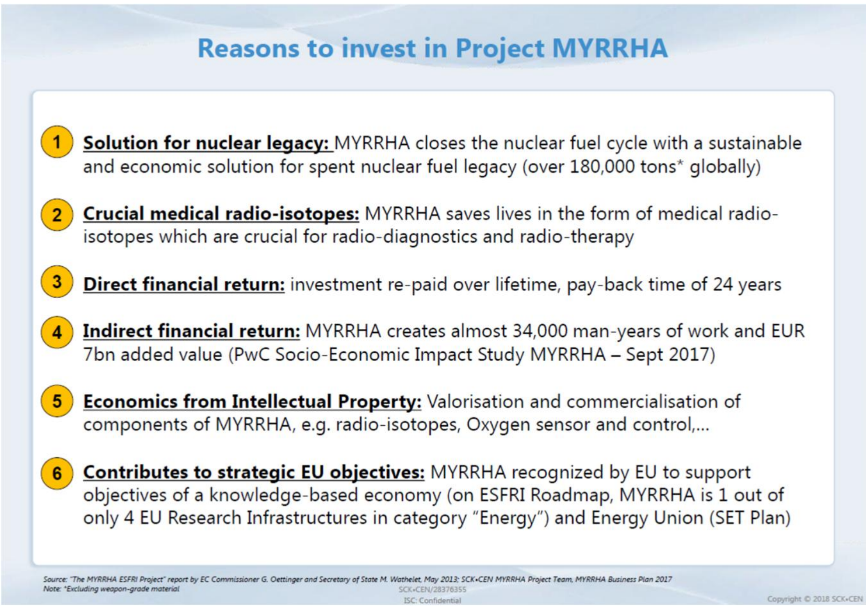
Assuring the financing of this project would allow:

- Demonstrating, at pre-industrial scale, the transmutation of nuclear spent nuclear fuel. Transmutation of high-level radioactive waste would allow to reduce the radiotoxicity timescale from 300,000 years to a technologically feasible timescale of 300 years;
- producing medical radioisotopes (used in diagnosis for the identification of cancer and in therapy for the treatment of cancer);

- new opportunities for fundamental research in the field of atomic physics, nuclear physics, solid-state physics, biology and medical applications;
- materials research, both into structural materials and fuel materials for a nuclear reactor, both for fission and fusion. This is necessary to be able to guarantee and increase the safety levels of current and future nuclear reactors;
- experiment Technological Pilot Plant (ETPP) for fast lead-cooled reactors (new type of safer and more efficient nuclear reactor).

The strategic investment plan is a unique opportunity to publicly support the MYRRHA project and to finalize its financing. This would allow the start of phase 1 of the project and show Belgian trust and involvement, facilitating the required research of international funds.

Figure 12: Reasons to invest in Project MYRRHA

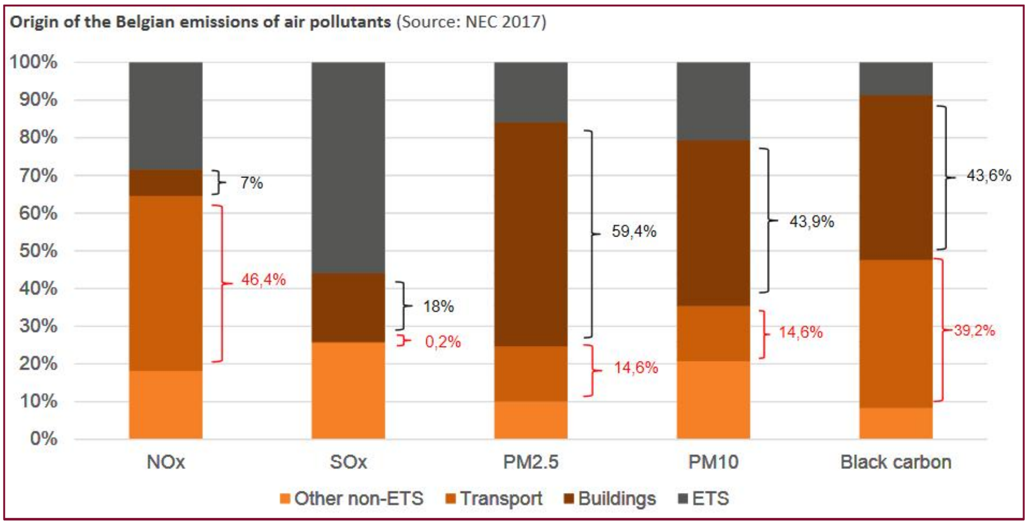


A.3 CNG PROJECT

1 CONTEXT

Cities' air pollution has two main origins: transport and heating system of buildings (residential and commercial). Next to air pollution (fine particulates, NO_X, …), both are also responsible for important CO_2 emissions.

Figure 1: Importance of transport in air pollution



Source: www.climatechange.be/2050 / Belgian National Debate on carbon pricing – workshop on the Transport sector 07.12.2017 (slide 132)

In 2015, CO_2 emissions in the transport sector accounted for 37% of non-ETS emissions. Between 1990 and 2015, CO_2 emissions in the transport have risen by 29%, i.e, +1.2% per year on average vs -2.9% per year on average required between 2015 and 2050 to reach zero emissions[23]. In order to improve the situation, EU Commission adopted regulation with e.g. EURO norms.

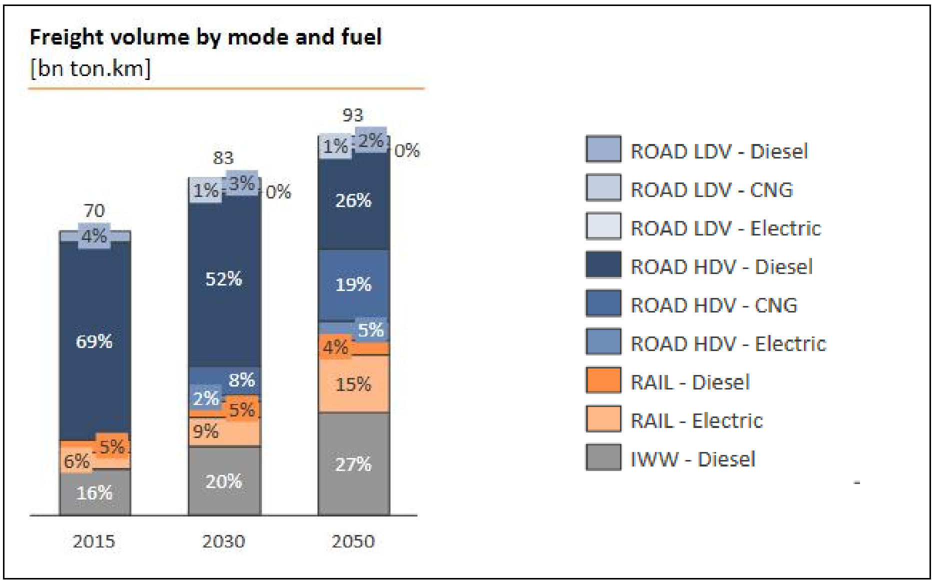
The energy transition implies for transport serious reduction of its emissions. That will happen through better efficiency of combustion engines and switch to alternative “fuels”.

Electric vehicles are now perfectly suited for urban mobility and as battery improves, the range of possibilities for electrical vehicles would cover more and more transport’s needs. Investments in this domain will happen anyway and vehicles deployment issues are currently more of a financial nature (cost of vehicles). Charging moments of all those electrical vehicles will have to be correctly steered to avoid charging at peak moments (moments with possible stress on the electricity network).

Next to electricity, gas is an interesting fuel as it produces less air pollutants as well as, though to a lesser extent, less CO_2 emissions. Gas riding provides more range autonomy for cars than electric vehicles and is currently the only alternative fuel for medium and long distance trucks as batteries are heavy and do not provide sufficient range autonomy (and have higher costs).

Gas riding requires gas filling infrastructures. An inhibiting factor for the development of these “new fuels” often seems to point at a chicken-and-egg problem: consumers don’t buy electrical, gas or H_2 vehicles because of the lack of filling stations versus, no investments in filling stations for a new technology is performed as there are too few vehicles. In that matter, it is suggested to support, in the framework of the strategic investment pact, a push for CNG (compressed natural gas) filling stations, further than it is the case today.

Figure 2: Foreseen scenario on fuel evolution



Source: Climact, "Scenarios for a low carbon Belgium by 2050", own calculation based on OPEERA model / Belgian National Debate on carbon pricing – workshop on the Transport sector 07.12.2017 (slide 34)

The EU Clean Power for Transport package of 2013 (adopted in 2014) aims to facilitate the development of a single market for alternative fuels for transport in Europe. In that matter, a

[23] Workshop on the transport sector; Dec 2017 – Belgian National Debate on Carbon Pricing

Directive on the deployment of alternative fuels recharging and refuelling infrastructure [COM(2013)18] was adopted.

2 CNG VEHICLES VERSUS OTHER

2.1 Vehicle characteristics

Currently cars use gasoline or diesel fuel, depending on the needs. By default, trucks and light-utility vehicles run on diesel to accommodate the transport of (heavy) goods and the intensive use of the vehicles.

CNG/LNG[24] combines the benefits of ease-of-use with low-emissions, which can be particularly useful for vehicles that are used intensively. However, CNG/LNG is still a greenhouse gas. Therefore, H_2 fuel could be a valuable alternative from the car technology perspective. However, H_2 production requires a lot of electricity and is therefore expected to become only relevant for transport when the energy system is realized with a high share (> 50%) of renewable energy. The time horizon for such a system is expected to be beyond 2030.

Therefore the remainder of the text focuses on advantages of CNG for trucks.

Ease-of-use – Refilling times and autonomy of a gas-powered vehicle is similar to any other diesel or gasoline vehicle, and does not require any specific skills from the driver. Gas-powered vehicles do not significantly impact the weight or dimensions of a vehicle. Furthermore, CNG engines can run on gasoline as well when needed.

CO_2 – Gas-powered vehicles emit about 10% less CO_2 than conventional diesel vehicles, to 80% less when biogas is refuelled.

Air quality – Gas-powered vehicles emit up about 60% less NOx than diesel vehicles (NEDC test)[25] and no fine particles.

Noise – Gas-powered vehicles produce up to 50% less noise (in dB), making them more suitable for late night city deliveries in urban areas.

On the downside, gas-powered vehicles are 10-30% more expensive to build and they use about 25-35% more fuel than a conventional diesel vehicle. The positive business case is therefore strongly influenced by taxation policies on ownership and fuel.

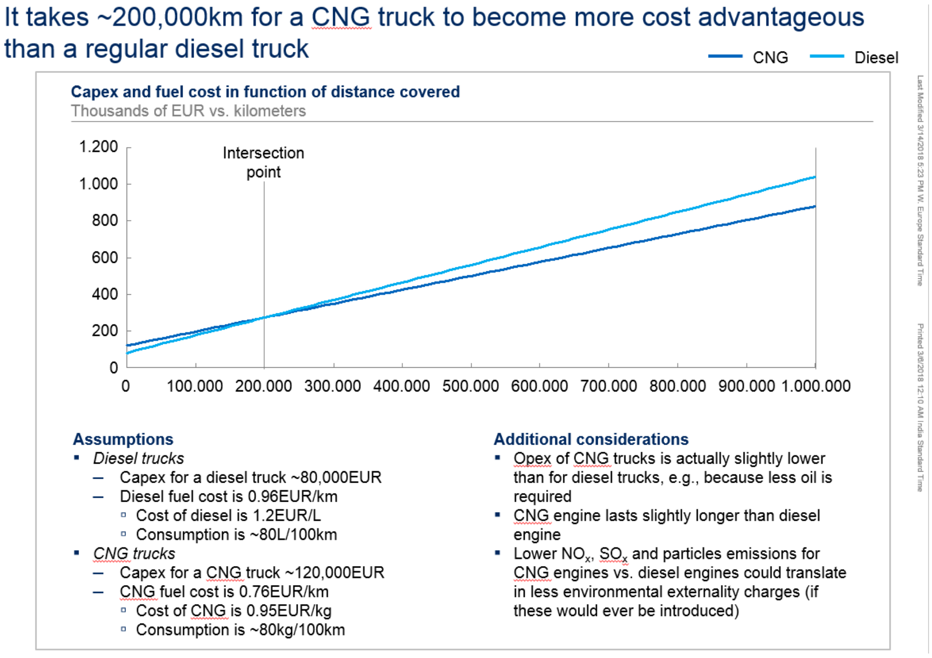
2.2 Break-even curve

The following curves show the total cost of ownership in function of driven km.

[24] "LNG stands for Liquefied Natural Gas. To form LNG, natural gas is liquefied by cooling at ambient pressure to -162 °C. This makes the volume 600 times smaller. The range of LNG is about 3.5 times greater than that of CNG on a similar tank content. So that makes it very interesting for trucks and long-distance traffic. LNG can also be reconverted to gas in the fuel station in order to be used to fuel CNG vehicles. This is referred to as L-CNG refuelling" (source www.energuide.be/en/questions-answers/are-natural-gas-cars-a-real-alternative/198/).

[25] As of 1 September 2017, new vehicles are homologated on the basis of the new WLTP test cycle and RDE-tests in real driving conditions.

Figure 3: total cost of ownership- CNG trucks versus diesel trucks



Source: McKinsey Tans Logistics Practice

3 CNG REFUELILING STATIONS

CNG stations are generally supplied via pipeline connection but can, just as LNG stations, also be supplied by truck.

Figure 4: Type of natural gas stations

	CNG	LNG	LCNG
			
Fuel	> Compressed natural/bio gas	> Liquified natural/bio gas	> Compressed and Liquified natural/bio gas
Target vehicles	> Personal vehicles, (light) vans and light trucks, buses	> Heavy trucks	> Personal vehicles, (light) vans and light trucks > Heavy trucks
Main components	> Compressor station > High pressure storage vessels > Dispenser	> Cryogenic LCNG tank > Dispenser	> Cyrogenic LNG tank > Compressor station > High pressure storage > Dispenser

Source: Fluxys, Roland Berger, Gas.be

Natural gas stations can be built from greenfield or come in addition to existing classic filling stations.

Figure 5: Investment costs - Natural gas stations

Investment example: CNG station[1)]

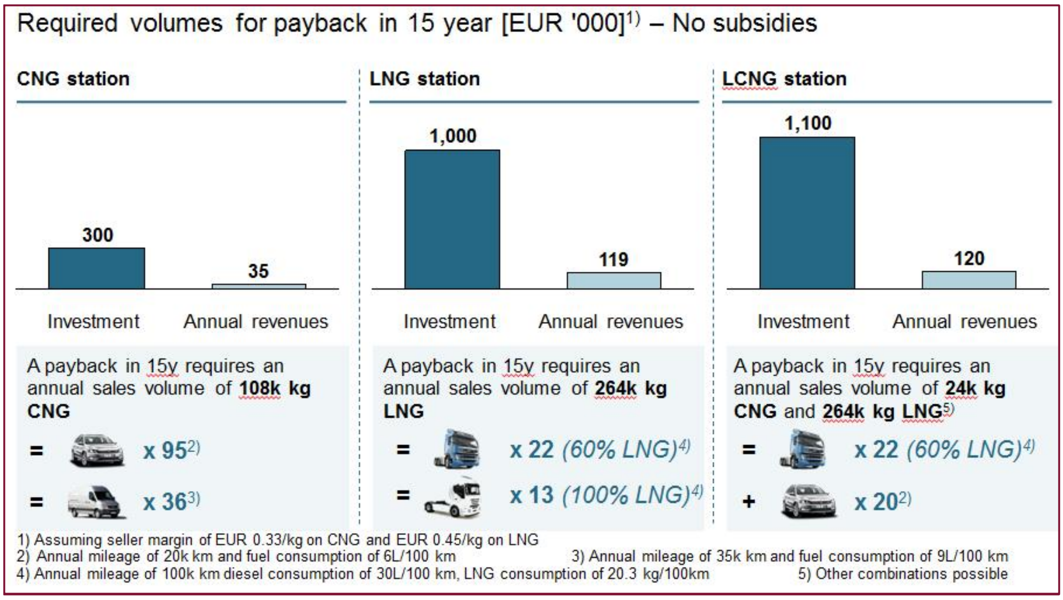
	 ▪ Civil works ▪ Gas pipeline connection[2)] ▪ Exterior works	 ▪ Pre-treatment (dryer) ▪ Compressor station	 ▪ Buffer storage vessels ▪ Priority panel	 ▪ Dispenser ▪ Terminal ▪ Electronic equipment	
Addition to existing station	EUR 50,000	EUR 120,000	EUR 50,000	EUR 80,000	**Total investment: EUR 300k**
Greenfield installation	EUR 150,000	EUR 120,000	EUR 50,000	EUR 80,000	**Total investment: EUR 400k**

1) Cost estimation for a CNG fast-fill installation with a direct fill capacity of 200 Nm^3/h and a 3-bank buffer capacity system of 2,240L (180 KG)
2) Assuming low pressure pipeline available on location of fuel station

Source: Gas.be

The business case of the stations is defined by the sold volume. The figure below identifies the volume requirements for each type of gas filling station.

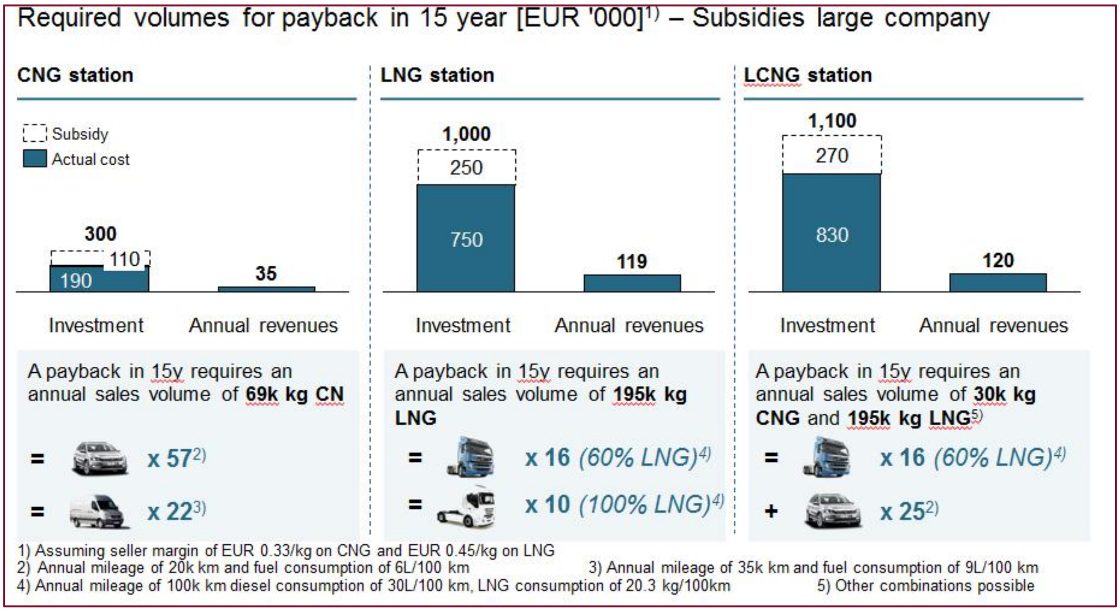
Figure 6: required volumes for a payback time of 15 years



Source: VW, Mercedes, Volvo, Iveco, Fluxys, Roland Berger analysis

Subsidising partially the building of gas filling stations would reduce the required volume to be profitable. Another way to provide support to gas filling stations is to ensure a consumption volume through captive fleets (buses, garbage trucks, city vehicles, …) which will mainly fuel to a specific station. These stations will be open to private vehicles in order to complement its guaranteed volume.

Figure 7: required sales volumes for a payback in 15 year considering subsidies

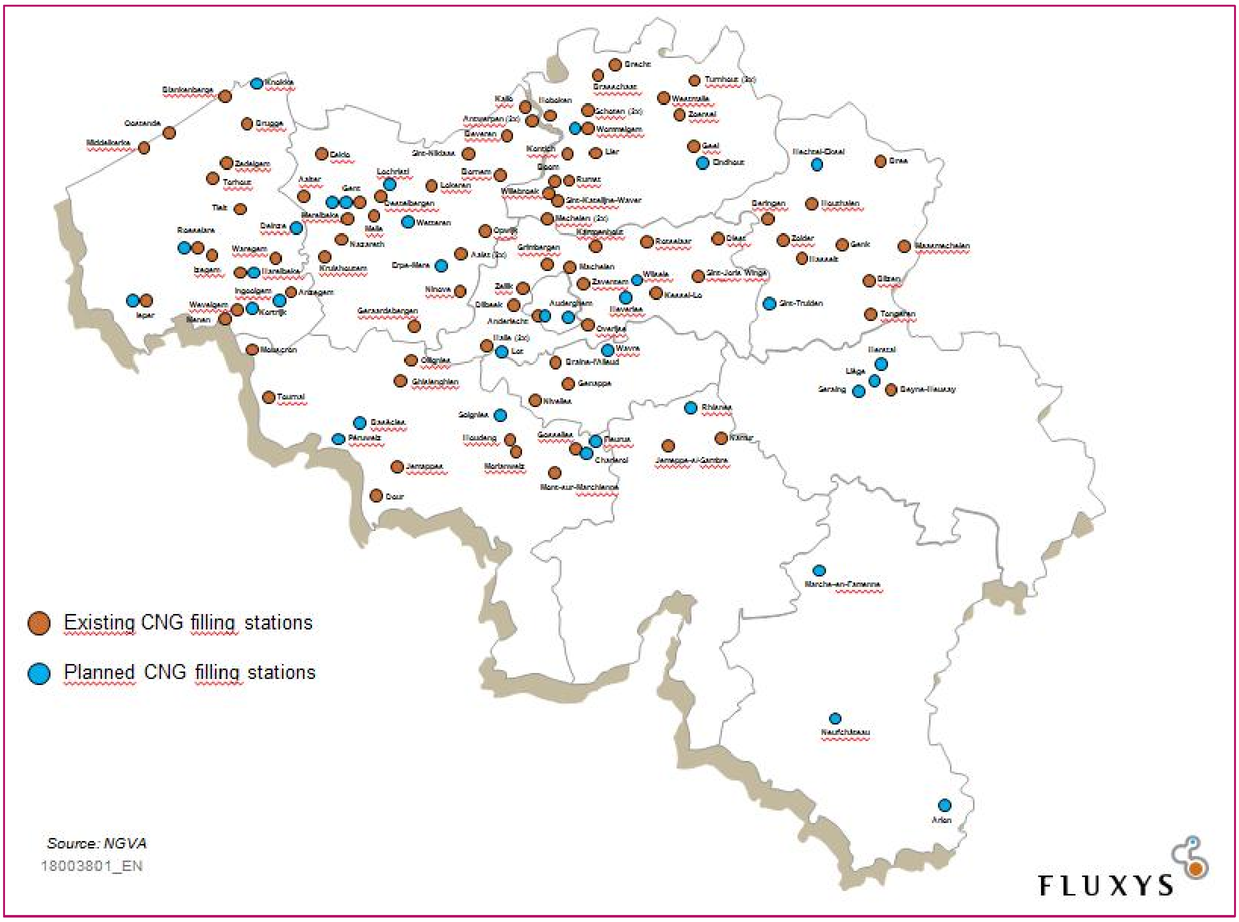


Source: VW, Mercedes, Volvo, Iveco, Fluxys, Roland Berger analysis

3.2 Existing and foreseen CNG refuelling stations

The number of gas filling stations has strongly increased the last years. By June 2018, Belgium will have 100 gas filling stations: 81 in Flanders, 18 in Wallonia and 1 in Brussels. 30 more stations should be built in the 2nd part of 2018 and 2019.

Figure 6: Existing and foreseen CNG refuelling stations



Source: Fluxys

4 CNG REFUELLING STATIONS PROJECT

4.1 Project

The present project aims at ensuring a complementary – to existing and planned - supply of CNG refuelling stations. Ensuring this complementary supply offer would encourage use of gas vehicles by removing the fear that not enough filling stations would exist.

The project can also be viewed in a trend of developing urban distribution centres that would then use CNG trucks to "feed" the city. This latter would allow a sharp decrease of air pollutants in the city due to trucks.

4.2 How many stations

Based on currently known ambition of the Regions, on reality check[26] and on ambition for deployment of gas vehicles, the following table provides targets for number of filling stations in Belgium. We already know that 130 stations should be built by the year 2019.

Table 1: Whished gas filling stations

	Flanders	Wallonia	Brussels
2020	130	30	3
2025	220	70	18
2030	300	100	32

Source: gas.be

Considering an equivalent repartition of sold volume among the stations, the minimum number of vehicles required for the stations to be profitable is around 50,000 gas vehicles in 2030. On the other side, this number of stations could host up to 150,000 gas vehicles. If the gas vehicles are successful, profitability of gas filling stations would be ensured.

Depending on the global framework and its potential to incentivise the use of gas vehicles the above table could be more ambitious. However, building new stations (or adapting existing ones) requires time … and 2030 is not so far away. Having a support from the strategic investment pact for gas filling stations offers a solid guarantee that the stations will be there and therefore provide additional motivation for investing in gas vehicles. Moreover, the more successful the gas vehicles are the lower the required subsidies are.

4.3 Clustering and supporting additional stations

Current players are building gas filling stations at their own risk and distribution systems operators (DSO) are pushing for further implementation of gas stations. However, the needed density of gas filling stations (cf. table 1) has to be ensured for locking opportunities provided by gas and biogas fuels.

Therefore, one suggests organising tenders for the building of gas filling stations. Tenders should aim at ensuring enough station density in the country. To do so, one should work with clusters of stations in specific areas. The tender should be open as well to existing stations as for new build stations. Tendering permits to have a competition between project developers and to focus on the missing part of the business case and therefore avoid over-subsidisation. Tendering structure as well as density requirements should be carefully thought.

Finally, the cluster should also consider building gas filling stations on suited place for public transportations (busses) or for captive fleets.

4.4 Investment budget

CAPEX for newly build gas filling station is of around € 400,000 and € 300,000 for adding CNG to existing stations.

The amount of needed subsidies (to cover part of CAPEX) will depend on the amount of expected sold volume. In the less dense part of the country, more support will be required. On more dense part, the number of stations to be foreseen will be high but will require less support.

[26] Flanders had ambition of 300 gas filling station in 2020 what will not be a reality

Between 2020 and 2030, 269 gas filling stations should be built (cf. table 1). Considering € 100,000 per station of subsidies which is a very prudential estimate, the total budget would be in the range of € 27 mio for an investment of more than **€ 100 mio**.

5 CONCLUSION

To provide an additional push at CNG transportation and to help in the paradigm of the chicken-or-egg, one suggests supporting the building of additional gas filling stations. That would be an additional push to CNG cars and trucks which would in return have an enormous impact on air pollution. This would also have an impact on CO_2 emissions if stations are providing biogas.

The support should be organised via tenders and would maximum be € 27 mio. Such project would remove a barrier to deployment of gas vehicles in Belgium.