Investment Plan 2024-2033

June 2023 version

Version
for public
consultation

Fluvius is preparing this plan on behalf of

Fluvius Antwerp, Fluvius Limburg, Fluvius West,

Gaselwest, Imewo, Intergem, Iveka, Iverlek, PBE and Sibelgas

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Foreword

Dear Reader,

Our society is changing rapidly. In order to combat global warming, we need to think about new and different ways of living and working. Several governments – such as the United Nations, the European Union, and federal, Flemish and local authorities – are developing plenty of new policies to deal with the impact of climate change on our lives. In terms of energy as well, the energy transition – the switch to fully renewable energy – is underway and will only accelerate in the coming years.

This energy transition is causing major shifts in many areas of society. How do we produce as much renewable energy as possible? How will we heat our buildings? How will the way we make journeys change? How will manufacturing processes in the business world change? And how can new digital applications and staggered electricity consumption help us keep investments in cables and cabling under control? Something that is in the long-term interest of our entire society. These are just a few of the many issues on the table.

With each of these questions, there is one constant: electricity and gas distribution grids play a crucial role in them. As a society, we do not always think that much about how crucial these grids are in our society. They are, as it were, the 'lifelines' that enable comfortable living, working and doing business. Therefore, their role will only increase on the way to a climate-neutral society.

This is precisely why the document you are reading now is so important. In this Investment Plan for 2024-2033, Fluvius, on behalf of the Flemish distribution grid operators, provides a thorough overview of the investments we are planning for the next ten years in the distribution grids for electricity and gas. We are doing so following consultation with governments and input from many sectoral federations, and on the basis of thorough technical analyses and simulations. This document contains the concrete plan for how we can make the Flemish distribution grids ready for the next ten years in this rapidly changing world.

This is the second version of our reasoned and developed proposal to Flemish society. Those who have read the 2023-2032 version will recognise many assumptions. But we have also identified some striking new trends. After all, last year's energy crisis accelerated the transition, belief in electric mobility – including for heavy trucks – grew, and there were never more initiatives for decentralised generation than there are now. We also put a lot of energy into coordinating our plans with the other utility companies. And because we are convinced that we can only determine the right priorities when we know the concrete spatial plans, we also developed the necessary tools for coordination with municipalities.

During the summer months of 2023, our stakeholders will have the opportunity to respond and comment on this. In the second half of 2023, we will then submit the final version to the Flemish energy regulator VREG.

At Fluvius, we stand ready to help achieve the next phase of the energy transition. We invite all stakeholders in the community to join us in this effort.

Happy reading!

Frank Vanbrabant
CEO

Jean Pierre Hollevoet,
Director of Energy and Climate Transition

Management Summary

The energy transition is set to accelerate in the coming years. Fluvius wants to help ensure it becomes reality, that it is feasible and affordable for everyone and that it is in line with Flemish and European climate ambitions. In this Investment Plan, we describe the investments in the Flemish electricity and natural gas distribution grids and the conditions necessary for alternative solutions to grow, such as the capacity tariff and flexibility services.

The electrification of society and industry is increasing exponentially

Fluvius takes the social context and the policy framework as a starting point when formulating this Investment Plan. In order to determine our grid investments, we based our plan on a number of long-term assumptions, including the ambitions contained in the Flemish Energy and Climate Plan:

- that passenger vehicles will be fully electric;
- that waste heat will be utilised in district heating grids;
- an upward trend in freight transport electrification;
- that heating systems in new-build properties and properties undergoing major renovations will be electrically powered;
- that the growth in solar and wind energy will accelerate over time;
- that electricity consumption will rise and peak loads in industry will increase.

Additional proactive strengthening of the electricity grid is needed

With the above assumptions, there are still many scenarios imaginable in terms of the extent and speed of electrification. The electrification of mobility is the main factor underlying the increase in peak consumption on the electricity distribution grids. The simultaneous charging of electric cars on the electricity distribution grid poses a major challenge to the grid operator. In a second phase, the electrification of heating will also have a significant impact on the distribution grid.

The future is uncertain. As of 2023, we do not know which scenario will become reality. We can, however, identify the necessary additional 'no regret' investments for a broad range of scenarios:

- that must be implemented at a high enough speed (before 2033) to avoid running into problems, and
- that are certainly not superfluous when you consider the electrification that we are expecting to see 2050, even if we can limit the impact of electrification on the peak load of the grid and limit the investment needs by means of all kinds of mitigating measures (capacity tariff, flexibility);
- that take into account spatial planning: the future filling of the public domain helps to make technical dimensioning for the grids correctly;
- that seek maximum responsible synergy with other works in the public domain.

Since the energy crisis, there has been a decline in load on the distribution grid. Despite the downward trend in decreased volume and asynchronous peak, we do continue to observe larger local peak loads. Moreover, we expect a significant increase in electrification in the coming years as a result of the energy transition. Therefore, we are maintaining the same strategy as last year and retaining the 'no regret' investment budget of 4 billion euros for the period 2023-2032.

To enable low-voltage customers to electrify, we need to upgrade or expand at least 40% of low-voltage cables by 2032. This will involve strengthening one in three cabins and the modification of home connections. This strengthening of the low-voltage distribution grid will also provide increased capacity to receive locally generated energy.

An additional load will also be placed on the high-voltage distribution grid as a result of electrification at low-voltage customers and electrification involving customers connected to the high-voltage distribution network. In addition to expanding the grid in order to accommodate the increase in large, decentralised generation units, 13% of the high-voltage distribution cables will need to be strengthened by 2032.

Electrification will increase the load on the interconnection points with the transmission grid. Additional investment will be required over the next 10 years will also be required at those locations.

For the period after 2032, we will build upon the electrification scenarios, providing an additional budget of 270 million euros in 2033 to be on the safe side, pending sufficiently effective mitigation measures.

However, the implementation of the necessary grid investments will be a challenge, in which Fluvius aims to fully assume its role within society. This challenge can only be met if the necessary resources are also provided on a financial level and there is sufficient availability of technical personnel and equipment, not only at Fluvius, but throughout the sector as a whole.

In order to more accurately assess further investment needs during the period up to 2050, we are investing in measures to

- closely monitor how the actual grid load evolves and how more detailed scenarios can be handled. The digital meter will be an important tool for this purpose.
- grow alternative solutions, such as the capacity tariff and flexibility services.

By doing this, we want to reduce the distance between the 'no regret' investments up to 2033 and further investments made during the period up to 2050. The investment rhythm can be slowed down or accelerated, depending on future developments or adjustments within energy policy, in consultation with our stakeholders.

Focus on the reliability and safety of the gas distribution network

Due to the fact that massive use is being made of the gas network today, Fluvius must guarantee a reliable and safe supply of energy via the gas grid. In time, our customers will switch to alternatives that are in keeping with the concept of a climate-neutral Flanders. In order to achieve this, the necessary preconditions must be met, such as a higher renovation rate and additional grid investments for heat or electrification. Where possible, we are reducing investments in the gas grid.

Due to the expiry of a number of policy rules and investment programmes (the roll-out of digital gas meters and the conversion from low to high calorific gas), the investment budget for the gas grids will continue to decline in the coming years. By 2033, the current budget for regular investments will continue to drop to 63 million euros annually. These investments are necessary to ensure safety and maintain operational efficiency.

Introduction

As an operating company for the Flemish distribution grid operators, Fluvius must provide sufficient capacity to cover the electricity and gas needs of users connected or seeking connection to the distribution grid. To this end, Fluvius is investing in the electricity and gas distribution grid. These investments are necessary to be ready for the great challenges of the future.

What is the Investment Plan?

The Investment Plan indicates the investments in the electricity and gas distribution grid that Fluvius considers necessary for the next 10 years. The Investment Plan is reviewed annually, discussed, adjusted as necessary and published. As a grid operator, we are committed to continually making the Investment Plan more concrete and transparent for stakeholders and the Flemish energy regulator VREG.

The Investment Plan brings together the principles, assumptions and network investments for proper management of the distribution grids over the next 10 years. This is we make things transparent to our stakeholders as to what investments are planned, and why. The Investment Plan provides a detailed overview of short-term investments and a longer-term view of network development. The horizon for short-term investments is three years. The horizon for long-term grid development is 10 years.

Every year, we submit the Investment Plan to VREG for approval. The VREG analyses the Investment Plan and assesses whether the distribution grid operator is doing what is necessary to comply with the tasks imposed by the Energy Decree. Fluvius must maintain sufficient capacity for the distribution of gas and electricity on its distribution grid.

If VREG determines that the investments provided for in the Investment Plan are inadequate, the regulator may require Fluvius, as a grid operator, to amend the plan within a reasonable period of time.

Legal context

The European EMD Directive was revised in 2019, as part of the Clean Energy Package (EU, 2019). One of the aspects in this review is the requirement for the preparation and public consultation of an Investment Plan.

It was transposed into Flemish regulations in 2021. The Energy Decree requires the distribution grid operator to produce an annual Electricity and Gas Investment Plan. The distribution grid operator now also prepares the Investment Plan in the longer term and holds a public consultation on those plans.

The VREG imposes on the grid operator a reporting model for electricity (VREG, 2022) and reporting model for gas (VREG, 2022) for the Investment Plan – see the Technical Regulations. This model describes the manner in which distribution grid operators should submit the required information on the Investment Plan.


fluvius

Fluvius' role in the energy landscape

Fluvius System Operator at a glance

Fluvius, sticking with you

The cooperative company Fluvius System Operator (known operationally under the working name of 'Fluvius') is the Flemish multi-utility grid operator that came into being on 1 July 2018 from the merger of Eandis System Operator CVBA and Infrax CVBA. On 1 April 2019, the former Integan OV joined the Fluvius Economic Group by being acquired by ex-Iveg (now Fluvius Antwerp).

Fluvius is responsible for the construction, management and maintenance of distribution grids for electricity and natural gas, sewerage, cable distribution and heat.

The company also manages the municipal public lighting system in Flanders with over 1.2 million lighting points.

In total, Fluvius manages over 230,000 kilometres of utility networks. Fluvius is active in all Flemish cities and municipalities, which means that everyone in Flanders can benefit from the professional service provided by our 5,437 employees.

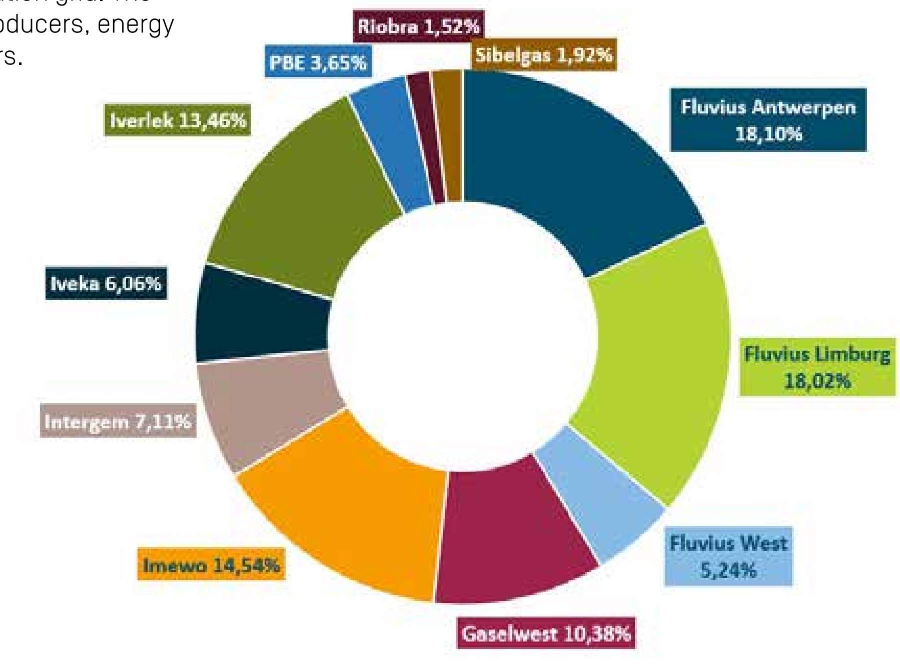
A vital link

In the free energy market in Flanders, Fluvius is an indispensable link as an operator of the distribution grid. The company is the liaison between energy producers, energy consumers and transmission grid operators.

Working for its shareholders, the mandated associations

Fluvius is the umbrella name for eleven Flemish municipal associations (inter-municipal partnerships), for which Fluvius System Operator is the operating company.

These 11 municipal associations fully own Fluvius: Fluvius Antwerp, Fluvius Limburg, Fluvius West, Gaselwest, Imewo, Intergem, Iveka, Iverlek, PBE, Riobra and Sibelgas.



Fluvius System Operator is not the owner of the grid infrastructure (cables, pipelines, cabins, pumping stations, metering installations, etc.). Ownership remains with the various mandated associations.

Supported by three subsidiaries

Fluvius System Operator calls upon a small number of subsidiaries and associates to carry out some of its work:

- De Stroomlijn CV: the customer communication centre that handles calls from our end customers.
- Atrias CV: the federal clearing house platform for the energy sector in Belgium.
- SYNDUCTIS CV: the company for coordination and synergy for infrastructure works carried out by utility companies.

Our mission and vision

The mission and vision for Fluvius give our company direction. We live and breathe them in all our dealings with our shareholders, employees, customers and partners.

Mission

To sustainably connect society through our multi-utility solutions.

Fluvius connects society. This involves not only the physical connection that we make through our grids. We also bring people together. And Fluvius is there for everybody.

We create sustainable connections. We work for the long term, and we want to contribute to a better environment and climate. And we will support municipalities with forward-looking solutions that provide comfort and convenience not just over the short term, but over the long term too.

Fluvius is a 'multi-utility', working in a range of different utility sectors. Because we believe in the synergies and economies of scale this creates. For society, all the partners and customers of our business.

Vision and strategy

Fluvius, along with all its stakeholders, aims to become the number one multi-utility company in Flanders.

Fluvius aims to be the number one operating company for the majority of utility sectors in Flanders. When you think of utilities in Flanders, we want Fluvius to be the name that comes to mind.

Our starting point is always the world around us. We work not for ourselves, but for all of the cities, municipalities, customers, partners, suppliers and investors around us. Only with their support can we grow, by responding to their expectations.

Everything we do, we do with and for Flemish society. This means we always strive for consultation and collaboration. Openness and transparency are central for us.

Based on our vision and mission, we focus on four strategic pillars:

- We are going all-out for one Fluvius: we want to arrive at a single integrated organisation with a uniform operation across Flanders.
- We create maximum synergy across networks: not only do we want to expand and enhance our grids, we also want to collaborate with other parties.
- We provide future-proof networks: by investing correctly, managing our grids intelligently and putting full effort into data, we are ready for the challenges of the future.
- We put the customer and the employee first: any answer to the energy transition, digitalisation or climate change must help everyone move forward.

The focus of Fluvius

In order to make Fluvius the Flemish multi-utility company, we need to connect society with our networks. To achieve our vision, we are working on many projects.

Objectives of Fluvia programme achieved – further optimisation within the HST programme

Only when we are working as a single integrated organisation can we help achieve the various transitions in Flanders. The Fluvia programme was initiated several years ago to shape the new Fluvius and achieve its integration objectives. Fluvia was to create a single Fluvius organisation, with uniform operation across Flanders, which will allow us to achieve synergy savings. The final phase of integration was completed in 2022. Just about all the integration projects were executed and implemented. We also achieved the objectives in terms of creating a unified organisation and culture.

In order to achieve the major goals for the coming years, we want to further simplify and automate our operation. This is the main goal of a new programme under the name HST, which stands for 'High-Speed Transformation'. Within this programme, we will be further optimising the support systems for connection works, investment works, maintenance works and fault management, integrating them with various asset management systems. In addition, we are implementing a new GIS system.

Accelerated digital meter roll-out

The Government of Flanders wants to accelerate the roll-out of digital electricity and gas meters. By the end of 2024, 80% of residential customers should have digital meters. To this end, two comprehensive purchase cases were launched.

The first case involves contracting three major contractors (groups) to perform the large-scale conversion from traditional to digital meters on a geographical basis. The processes and tools for communicating with these contractors have since been set up, and the conversion is underway. Three Flemish water companies have joined this contract. During a joint pilot project, technicians from these contractors are simultaneously installing digital electricity, gas and water meters.

The second case involves the procurement of new digital electricity and gas meters, as well as the procurement of the associated data capture system. Through this procurement case, the operation of the meter chain was also outsourced to the contractor. Given the significant scale-up and in order to avoid stock-outs of meters, this procurement case was awarded to two different suppliers. Each supplier provides both digital electricity and gas meters and a data capture system. They will ensure the operation of their chain during the life cycle of the meters (15 or 20 years, respectively).

Fluvius staff will integrate these two chains into our operation.

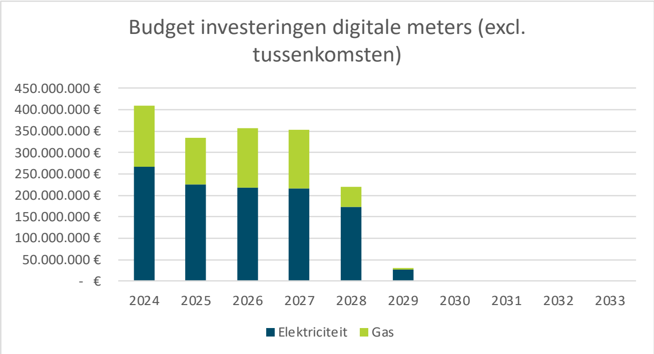
The other Belgian distribution grid operators (ORES, RESA and Sibelga) are participating in this procurement case for some of their meters. Following implementation, they will use the same meters and data capture systems as Fluvius. The data capture system will transfer the measurement data read for these other Belgian system operators to the respective grid operator.

Three Flemish Water Companies (De Watergroep, FARYS and Pidpa) are also participating in the implementation of these data capture systems. The idea is to have the digital water meters (which these water companies will procure themselves) communicate through Fluvius' electricity meter with the data capture system, which will transfer the water companies' metering data to them. After a successful trial with 70,000 digital water meters, it was decided to carry out the large-scale roll-out in synergy.

These meters and data capture systems should be implemented during the first half of 2023, such that the roll-out of these new meters can occur thereafter.

In addition, the roll-out of digital meters is well underway. In May 2023, the 2.5 millionth digital meter was installed. In late April 2023, 40% of electricity and gas meters had been fully converted. 41% of prosumers already have a digital meter. For budget meter customers, Fluvius is achieving a conversion rate of 100%.

The roll-out of digital electricity and gas meters will continue over the next few years. Fluvius anticipates the following budget from 2024 to 2029:



Implementation of capacity tariff

Through its social role, Fluvius wants to keep future investment costs (and the impact on future grid tariffs) at an acceptable level. Through cost-reflective tariffs, network costs can be distributed such that customers pay 'their share' of the costs through tariffs. Tariff incentives can play an important role in keeping future grid investments manageable.

Customers should be encouraged to use the distribution grid as efficiently as possible. This is made possible thanks to the combination of the digital meter and the capacity tariff. The digital meter and capacity tariff make customers aware of the effect of their behaviour on (future) grid investments. Peak capacities determine whether any grid reinforcements are necessary. With the introduction of the capacity tariff on 1 January 2023, customers will be charged in part for their peak power from now on. Thus, tariffs provide an incentive to shift consumption to times of local production (self-consumption) and/or spread consumption over time.

In addition, we are studying the impact of time-dependent tariffs, i.e. tariffs that evolve according to the time of day, or depending on the season. Here, we are not only taking into account the impact on the distribution grids, but also considering, among other things, the complexity for customers and the social interests for the various customer groups. This study is being conducted on behalf of VREG; the results will be available in late 2023. Depending on the outcome, a pathway will be established in consultation with the regulator and the market for introducing a time-dependent capacity tariff, if desired. In this context, we are working with various stakeholders from the energy sector.

Vision for data 2025

Fluvius is the neutral and facilitating data manager for the energy market in Flanders. Data will play a crucial role in the energy transition. Fluvius aims to further shape its vision for future data management. We are writing a collective and realistic story for the period to 2025, taking into account the world around us. We are creating a framework that will help make decisions about new projects and data management initiatives.

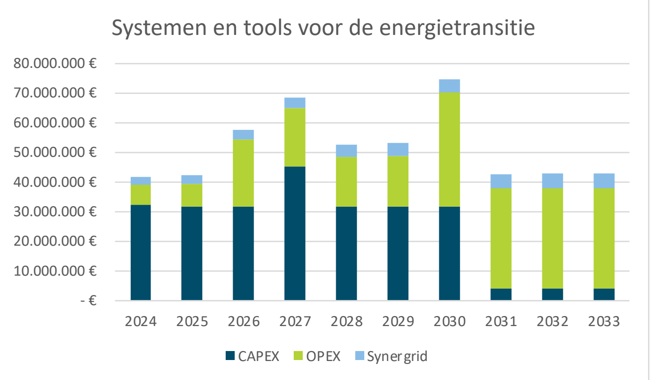
Along with policy-makers, stakeholders and the free market, we are aiming to achieve four key objectives:

- We make data available that helps customers use energy more efficiently.
- We help customers gain maximum control of their energy costs.
- We ensure that all customers can participate in the trading of renewable energy.
- We help to build the energy market of tomorrow.

In the coming years, we will make provision for investments in data infrastructure or applications that will help build tomorrow's energy market and provide new opportunities for the active customer.

Developing systems and tools for the energy transition

In order to make the energy transition possible, significant investments in ICT platforms, applications and processes must be made in addition to grid-related investments. New systems and tools are needed to shape the new energy market. To make this possible, we have included the necessary provisions in the Investment Plan.



Market-based initiatives

In order for grid users to take an active role in the energy market, we need to give them access to data on their own consumption and on the state of the distribution grid (voltage and current measurements). To enable access to this data and make it available to customers or mandated third parties through a self-service portal, we need to provide the necessary ICT tools. Some of these tools are being developed jointly with the transmission grid operator, given the close interaction of the two energy systems. We are doing this together under the umbrella of Synergrid.

Through our customer portal (my.fluvius.be), customers with a digital meter can gain an insight into their energy consumption and how to optimise it. Later this year, high-voltage distribution grid customers will be able to consult overview maps showing available grid capacity on the Fluvius portal. This means a customer can immediately see what power is readily available.

A changing market will also give rise to new data needs. For example, we will continue to develop initiatives that support sub-metering in mobility services.

Grid and system-related projects

An active market requires active grid control. We will build it up gradually based on the evolving market. In order to provide maximum support to grid users in the development of energy-related projects, we want to give them an insight into free grid capacity in an accessible way, both for injection and consumption. We will explain this further in the *Digitalisation of the electricity distribution grid* section.

In order to achieve the proposed Investment Plan efficiently, we need to coordinate with cities and municipalities, among others. We are developing the applications necessary for creating implementation plans. By further enabling access to grid and meter data within a so-called 'digital twin', we can further refine these implementation plans and reduce disruption.

The deployment of flexibility requires a more automated network with associated applications, which allow for monitoring the use of flexibility services and collecting data. It is necessary to build upon the current control system, both from operating needs and for market forces.
In order to deploy market flexibility, we are developing a customised procurement platform.

Strategic studies and living labs

Fluvius is aiming to follow up on innovations in grid management, data needs, market forces, the flexibility market, the grid user and energy carriers. Below, we will discuss a number of specific research projects. By participating in these research projects, we are aiming to explore the feasibility at a large scale, as well as test and help shape the industrialisation of these developments.

Evoluties op vlak van netbeheer

Evoluties op vlak van databehoeften

Evoluties op vlak van marktwerking

Evoluties op vlak van flexmarkt

Evoluties op vlak van netgebruik(ers)

Evoluties op vlak van energiedragers

Living lab Mechelen

At our site in Mechelen, we are building a 'living lab'. This should answer the following questions:

- How can we design the public domain, extending common spaces, such that it flexibly improves comfort and the quality of life for citizens?
- How will the Fluvius Living Lab become the incubator for the energy transition in Flanders?
- What trends and evolutions should we consider?
- What makes the lab 'future-proof' (changing standards and legislation)?
- How should the site be conceptually constructed to flexibly implement the energy transition (in terms of technology, collaboration and efficiency)?
- How will we ensure that collaboration at the Fluvius Living Lab is practical and cost-effective?
- What assets will make the Fluvius Living Lab attractive to external parties?
- How should we organise the Fluvius Living Lab to respond to opportunities?

Green Energy Park Zellik

As a strategic living lab centre at the Research Park of Zellik, Green Energy Park promotes collaboration between companies, knowledge institutions, governments and end users. This is done by offering them unique testing grounds or living labs where they can test and refine their innovative developments in a realistic environment.

In developing these living labs, the focus is on four areas of research: 'Energy & Mobility', 'Smart regions', 'Hospital of the future' and 'Biotech'. Here, digitalisation, circularity, sustainability and CO_2-neutrality are the guiding elements.

By encouraging and supporting collaboration, Green Energy Park aims to enable the development of innovative solutions for a healthy and sustainable community. Indeed, Green Energy Park's vision is '**Collaborate today on tomorrow's solutions by bridging the gap between research and implementation as a co-creation hub and strategic living lab centre**'.

Fluvius is participating in several research projects and is supporting the development of the living labs with expertise and infrastructure:

- The **CO_2-neutral Smart Multi Energy Grid**, which will be responsible for energy distribution at the business park. Not only electrical energy, but also heat, cold, hydrogen, CO_2, etc.
- The development of a **new switching station** that will provide redundant and failsafe power for the new data centre and will be connected to the power grid.
- The development of a **large-scale mobility hub** at the front of the business park with a view to 'the fuel station of the future' – fast charging infrastructure for public transport and parking with charging infrastructure for 1,000 electric cars.
- The implementation of the **Smart Home Lab** where companies and knowledge institutions can work on new technologies for the smart homes and digital meters.
- Testing the **impact of district batteries** and their deployment in support of the low-voltage distribution grid.

- Expansion of a **fifth-generation heat grid**.
- Testing a **hydrogen-powered CHP** for flexibility services.
- **Island mode** for critical clusters.
- Transition of an existing industrial park to a **CO_2-neutral zone**.
- Circularity of **residual construction materials**.
- Collection and **reuse of rainwater**.
- **Basic infrastructure** for minimising the impact when working on utility lines.

In addition to this, Fluvius is also participating in several research projects, along with EVERGi as a research group and Green Energy Park as a living lab:

Rolecs (ICON): Gaining an insight into the operations of local energy communities (LEC).

- **SMEL** (ERDF): Smart Multi Energy Lab responsible for energy distribution at the Smart Village Lab.
- **Je t'aime** (ICON/in draft): The development of a multi-energy grid with a focus on the thermal component.
- **Synergising** (energy transition fund/in draft): Energy balancing and security of supply for the transmission grid.
- **Towards a truck electrification (Icon)**: using a pilot to determine the impact of truck electrification.
- **Reformers project**: Making SME zones CO_2-neutral.

Proflex smart energy research.

- **Vlaio** energy management for bus companies.

ADriaN

Along with EnergyVille, we are going through the ADriaN research process. ADriaN examines evolutions on the low-voltage distribution grid that could become significant challenges. ADriaN calculates the impact of these evolutions on the Flemish low-voltage distribution network and examines which solutions are/are not feasible.

This is translated into concrete technical solutions and 'flanking measures' that maximise the use of available capacity. In doing so, we are aiming to go beyond existing study work that is limited to potential high-level impact and often relies heavily on non-realistic preconditions. Often, the study work is also too complex to be implemented in practice.

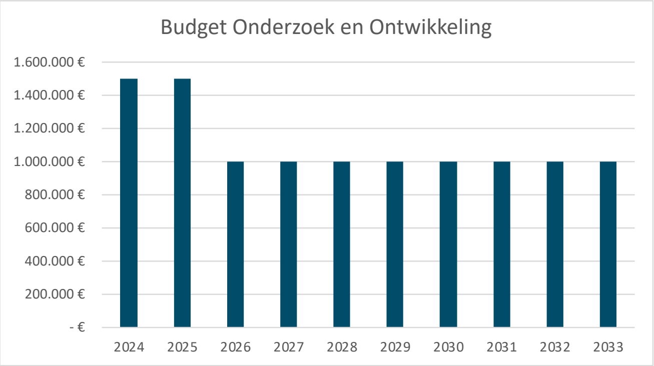
Challenges in this include sufficient scalability of the proposed solutions, and ensuring compatibility with existing initiatives and concepts within the organisation. This includes the translation of study results into a Fluvius position that takes maximum account of policy and external stakeholders.

Other research projects

Furthermore, through collaboration with various partners, we intend to test the feasibility and applicability of projects at a larger scale. To this end, we are collaborating in various research projects:

- Applications of hydrogen in the construction sector (Project Terranova);
- Developing shore power at Flemish seaports and for inland navigation;
- Applicability of DC grids at the Zwevegem Transfo site;
- Leuven Klimaatneutraal ('Climate-Neutral'), where we are the lead for the energy part;
- Various transition projects in Antwerp, Mechelen, etc.;
- Collaboration on Regional Spatial Energy Strategies (RSES) for the provinces;
- Analysis and formatting of heat zoning and its impact on power grids;
- Proof of Concept as an extension to the existing Flex Data Hub for participation of distribution grid users in Elia's frequency-related support service Frequency Containment Reserves.

For this package of research and development projects, we are also providing the necessary budgets in the Investment Plan.



Fluvius asset portfolio

Fluvius is responsible for the construction, management and maintenance of the distribution grids and associated assets.

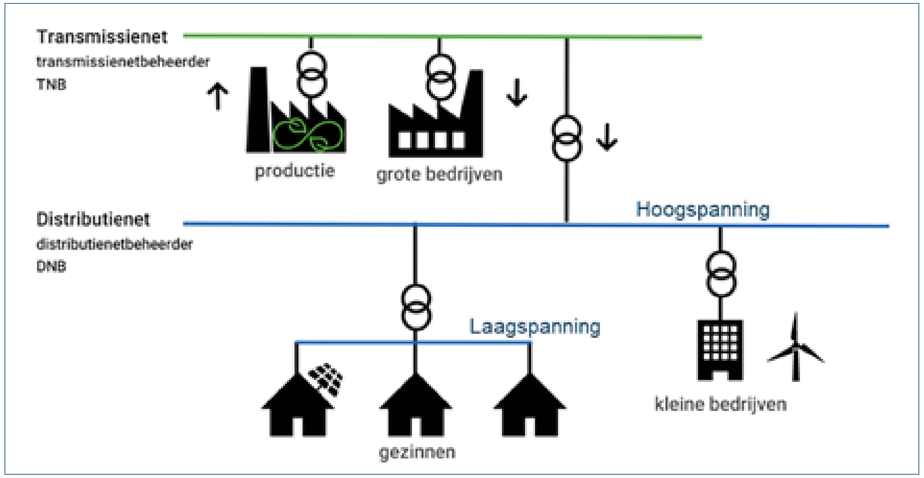
The electricity grid and its assets

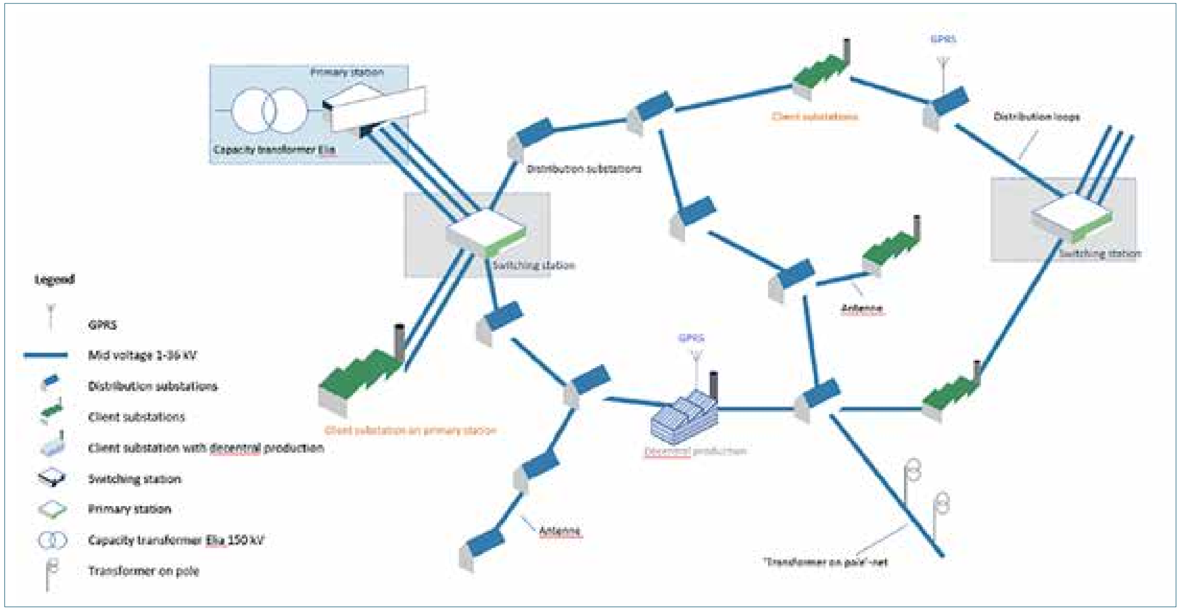
The electricity grid is composed of a transmission grid (managed by the transmission grid operator), the local transmission grid (managed by the local transport grid operator), and a distribution grid (managed by the distribution grid operator). In the following, we will refer to the whole of the local transport network and the transmission grid as the 'transmission grid'.

The distribution grid distributes energy between the transmission grid manager's delivery point and industrial or residential customers, both for consumption and for receiving decentralised production. It is a network of conduits in which there is a systematic change from high voltage to low voltage.

For this paper, we will divide the voltage on the distribution grid into following voltage classes:

VOLTAGE CLASS	OPERATION VOLTAGE
High voltage	> 1kV
Low voltage	≤ 1kV

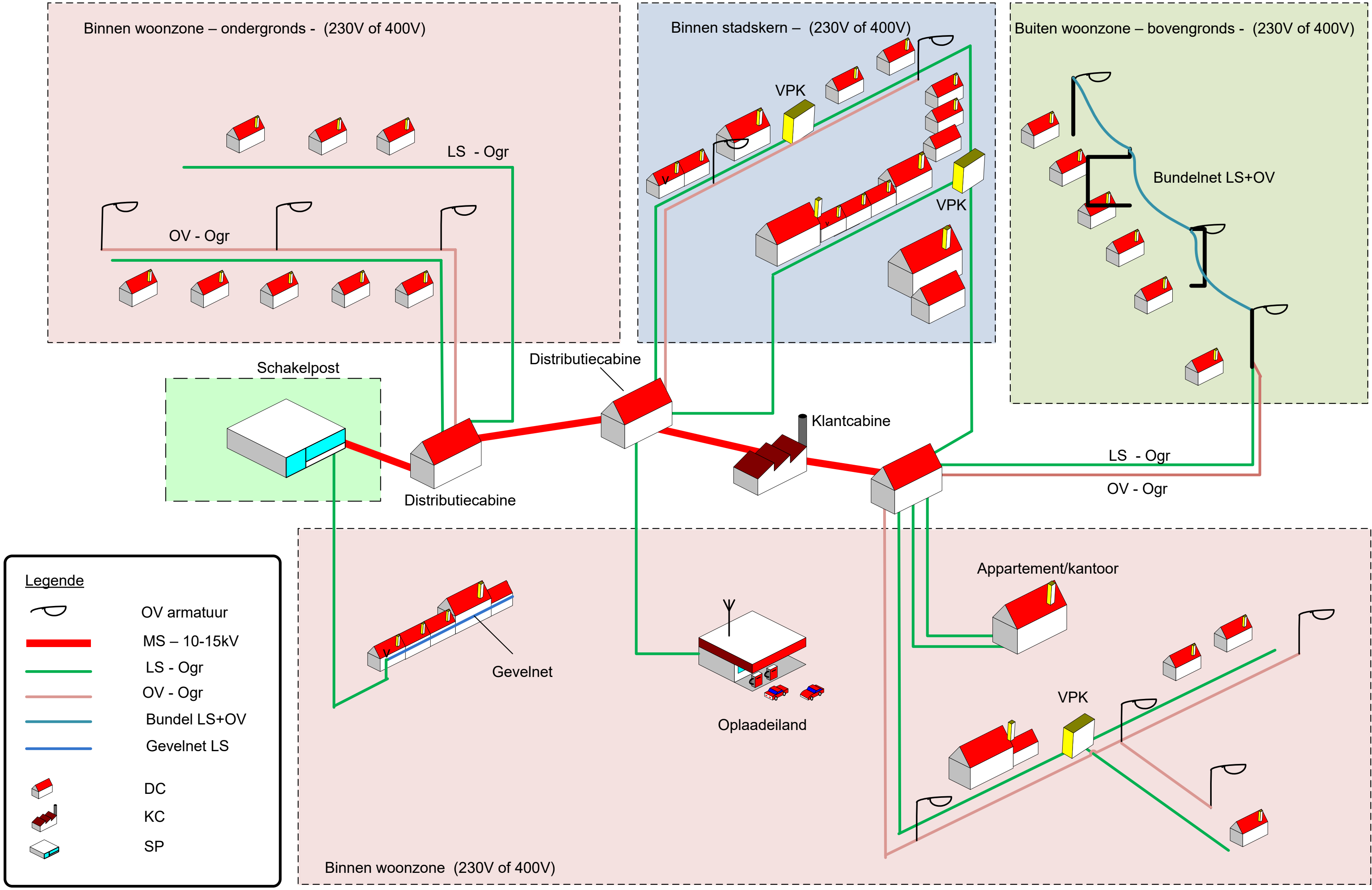




At the **transformer station (TS)**, electricity from the transmission grid is transformed into high voltage on the distribution grid. The transformer station houses the transition **(interconnection point)** between the transmission and distribution grid operator.

A direct connection is made from the transformer station to a **switching station (SS)**. The connection is called a **high-voltage feeder**. The switching station redistributes power flow to multiple high-voltage distribution cables, without transforming distribution voltage.

The set of main connections between transformer stations and switching stations forms the **backbone** of the high-voltage distribution grid.



A high-voltage distribution loop starts from the switching station. Distribution cabins and customer cabins are successively connected to the same high-voltage distribution grid. The distribution loop usually terminates at the same switching station, or one nearby.

At a **distribution cabin**, high voltage is transformed to low voltage and further distributed to the low-voltage distribution grid. At a **customer cabin**, high voltage is transformed to low voltage through a customer's facility, from which the customer's indoor facility is fed.

Several low-voltage distribution grids depart from the distribution cabin, to which distribution grids users are connected via a low-voltage **connection**. The public lighting network is also fed from the distribution cabin.

The connection passes through a **metering device** to the customer's indoor facility. The metering device measures the exchange of electrical energy with the customer.

Description	Figures
High-voltage grids (km)	
Non-insulated overhead line	99,018
Insulated overhead line	0
Underground cable	47,046,564
Total HV lines and cables	47,145,582
Low-voltage grids (km)	
Non-insulated overhead line	266,786
Insulated overhead line	20,933,066
Underground cable	65,560,933
Total LV lines and cables	87,760,785
Low-voltage grids (km)	
230V 3-wire	1,112,754
230V 4-wire	17,317,853
400V	69,330,178
Total LV lines and cables	87,760,785
Stations (high voltage) (#)	
Transformer stations	269
Switching stations	850
Cabins (high voltage/low voltage) (#)	
Customer cabins	21,265
Distribution cabins	39,238
Connections (#)	
High-voltage connections	23,560
Low-voltage connections	3,562,690
Production facility connections – injection >1000kVA	10,217
Metering equipment (#)	
High-voltage billing meters	23,778
Low-voltage billing meters	3,734,168
Budget meters	65,762

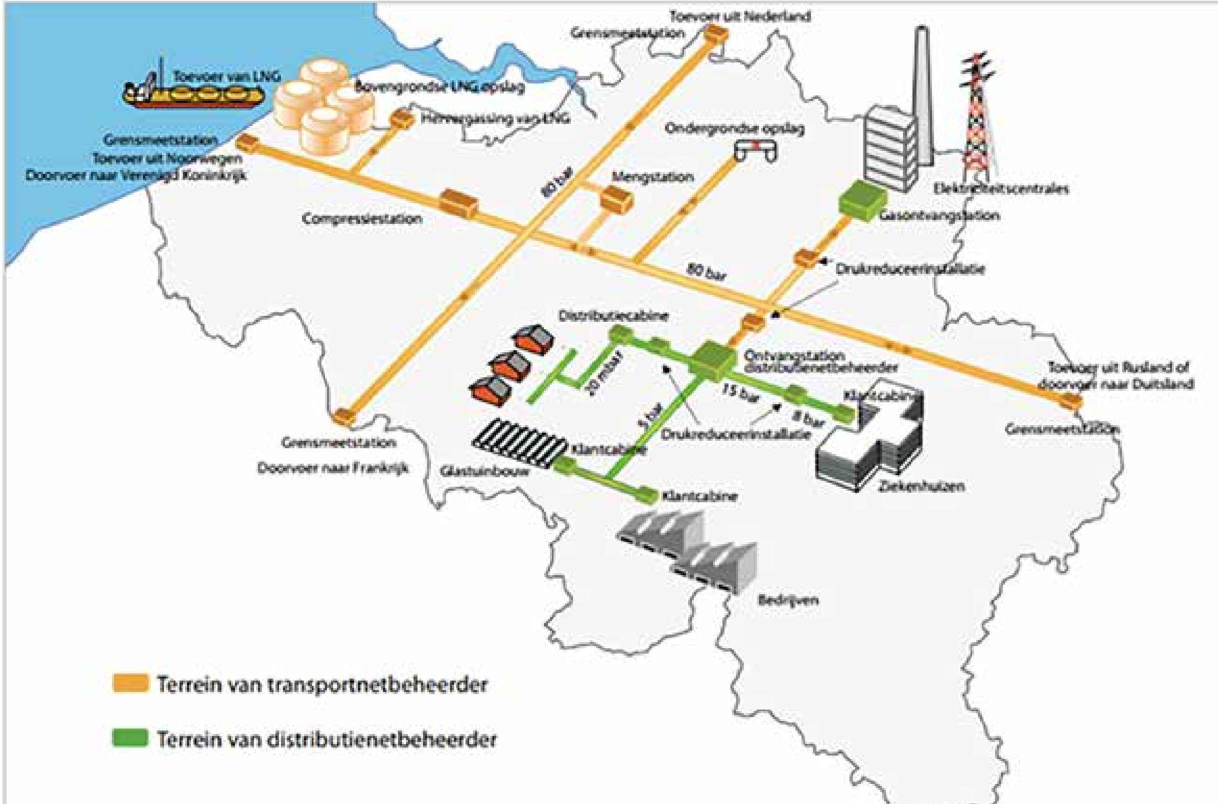


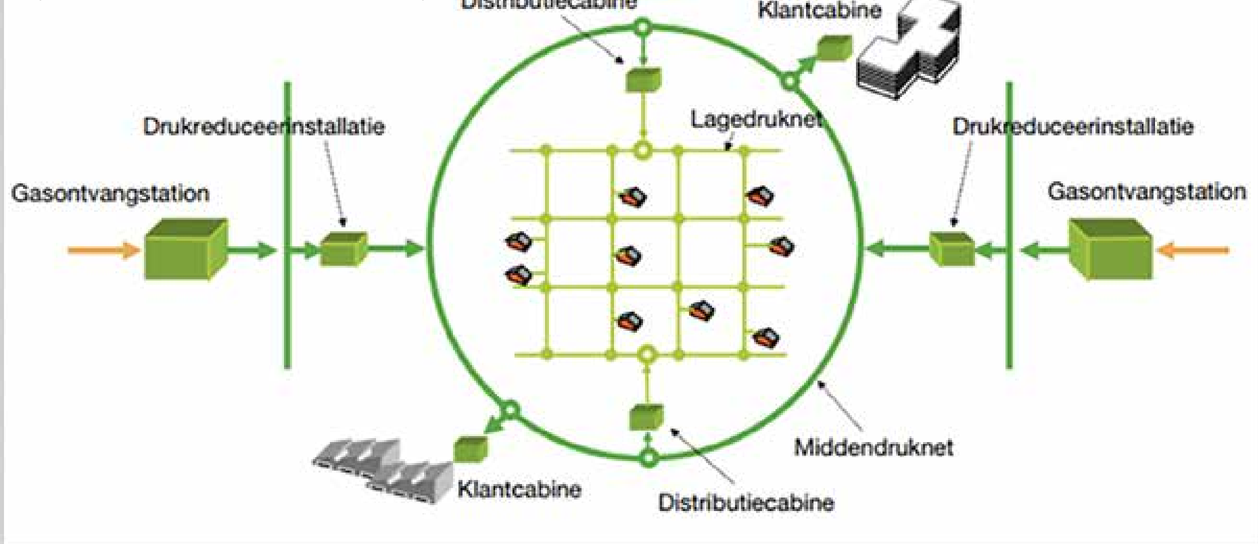
Figure 1: Schematic overview of natural gas grid structure in Belgium

The gas grid and its assets

The natural gas grid is composed of a transport grid, managed by the transport grid manager, and a distribution grid, managed by the distribution grid manager.

The distribution grid distributes energy between the transport grid manager's delivery point and industrial or residential customers, both for consumption and for receiving decentralised production. It is a network of conduits in which there is a systematic change from medium pressure to low pressure.

Figure 2: Schematic overview of distribution grid



Distribution grid pressure is divided into different pressure classes:

PRESSURE CLASSES	OPERATING PRESSURE
Medium Pressure C (MPC)	> 4.9 bar and ≤ 14.7 bar
Medium Pressure B (MPB)	> 0.490 bar and ≤ 4.9 bar
Medium Pressure A (MPA)	> 98 mbar and ≤ 490 mbar
Low pressure	≤ 98 mbar

The natural gas, reduced to a medium pressure C by the transport grid manager, is injected into the distribution system through a **receiving station (RS)**. The gas receiving station is the transition **(interconnection point)** between the transmission and distribution grid manager. At the gas receiving station, the natural gas is measured and odorised (to make it smellable), and sometimes already reduced to a lower pressure.

Several physical receiving stations often feed the same interconnected natural gas distribution grid. These stations are grouped into a notional **'aggregate receiving station' (ARS)**.

The **pressure reduction station** is part of the equipment in a medium pressure grid (MPC) and reduces the pressure to a lower medium pressure (MPB).

A **distribution cabin** reduces the pressure from medium to low pressure and feeds the low pressure grid.
A **customer cabin** is set up for larger individual customers and is connected to the medium pressure network. At the customer cabin, the pressure is reduced from medium pressure to the customer's desired outlet pressure.

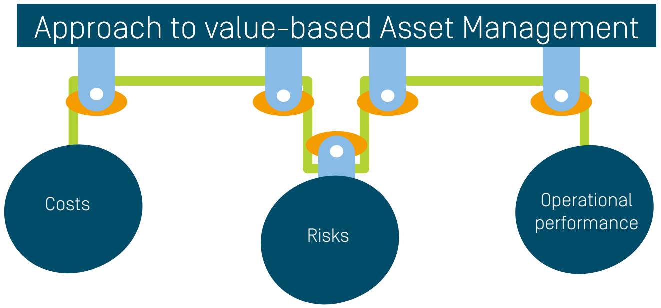
Residential customers are usually connected to the distribution grid via a low pressure **connection**. Exceptionally, the connection may also be implemented on the medium pressure network. The pipe section after the **metering equipment** is called the customer's indoor facility.

Cathodic protection prevents steel gas lines from corroding.

Description	Figures
Piping [m]	
(a) LP pipes	
Steel	2,671,278
PE	44,006,508
PVC	575,847
Fibre cement	367,079
Cast iron (grey)	11,843
Cast iron (ductile)	209,089
Total LP Pipes	47,841,644
(b) MP pipes	
Steel	6,321,599
PE	3,748,567
Total MP Pipes	10,070,167
Receiving stations [number]	89
Reduction stations MP/MP [number]	234
Gas cabins	
Distribution	4,295
Customer	5,325
Total	9,936
Active Access Points [number]	
LP	2,322,260
MP	33,001
Connections	
LP	1,804,589
MP	30,605
Metering equipment	
LP	2,439,766
MP	13,307
Cathodic protection [number]	
Anodes	355
Devices	476

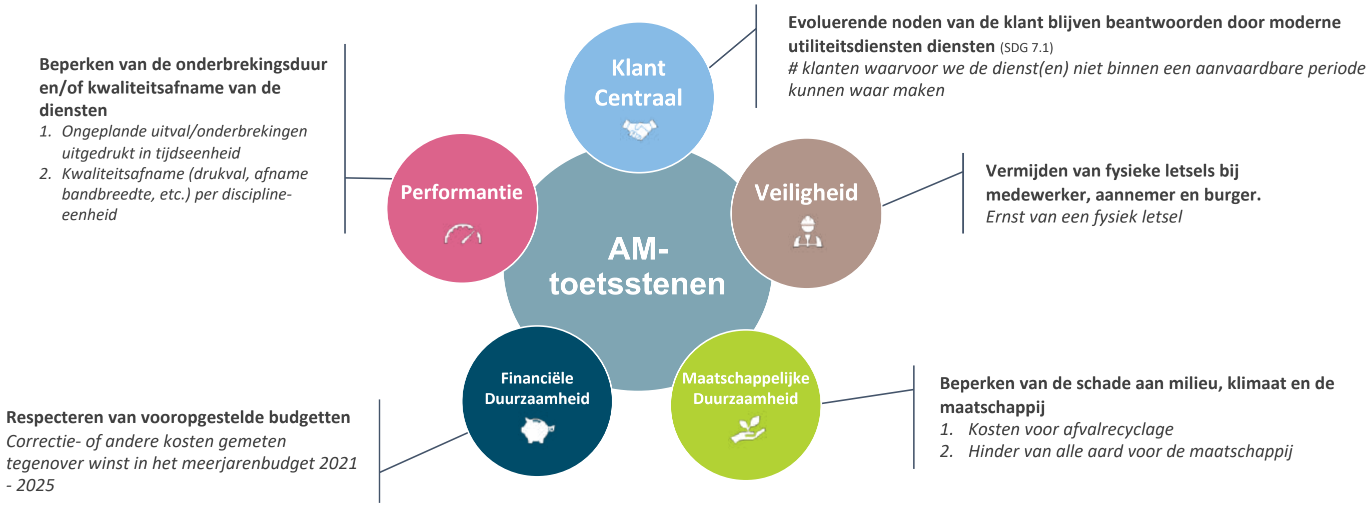
Value-based Asset Management

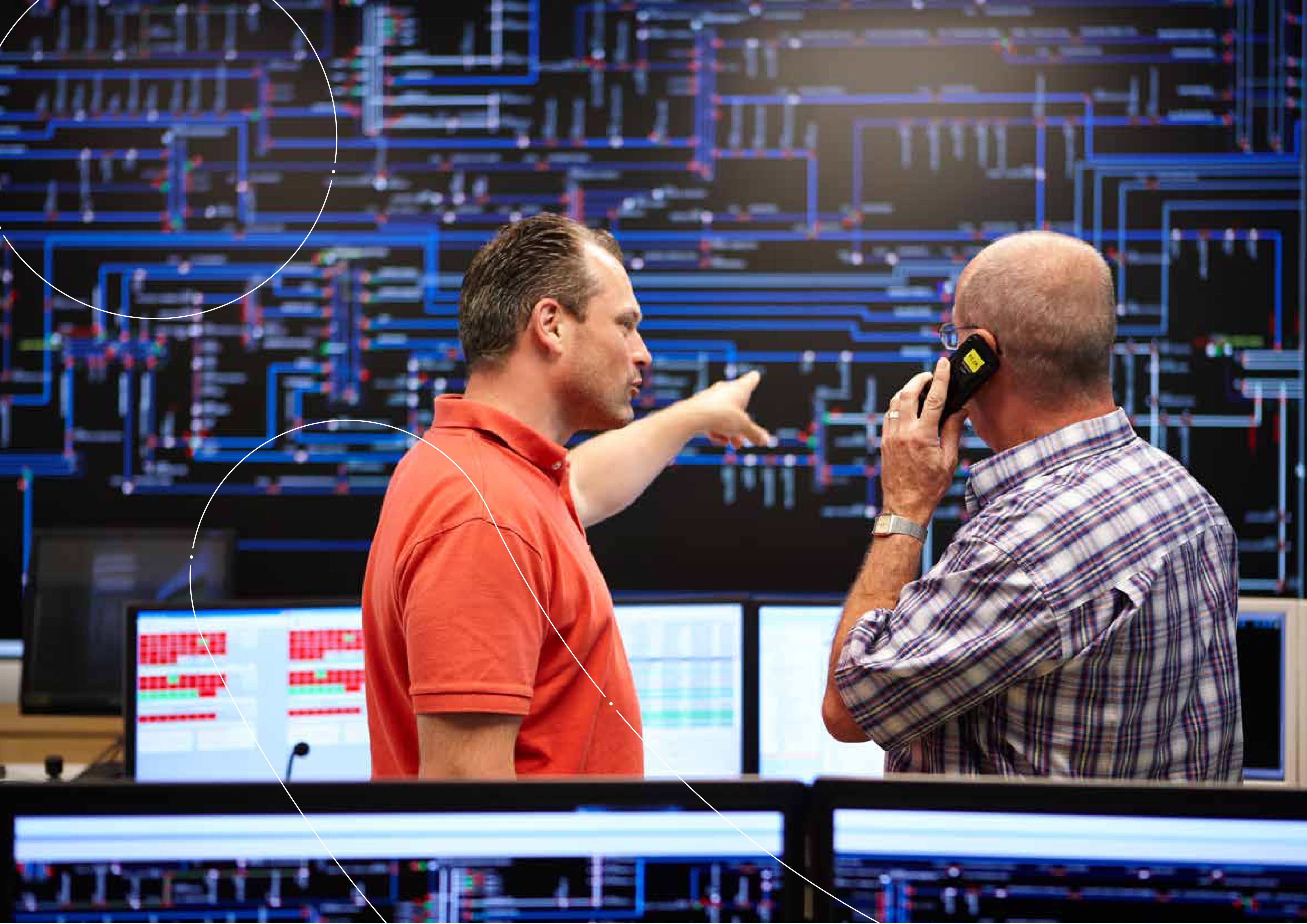
Good asset management (AM) should help Fluvius make the best use of the resources available to manage its multi-utility infrastructure. In order to manage assets effectively and efficiently, Fluvius uses the IAM Competences Framework (The Institute of Asset Management, 2014) as a guide. The framework describes a set of skills that an organisation must have to engage in proper asset management.



The central skill in asset management is making proper decisions. Fluvius uses a 'Value-based Asset Management' model, which seeks the right balance between cost, risk and operational performance. In doing so, we consider the entire life cycle of the asset. From design to final decommissioning.

In order to come to the right considerations based on the asset management strategy, five asset management touchstones were determined. These form the basis for making decisions, including investment decisions. They help provide objective consideration in prioritising different options.





Methodology for Investment Plan

Pathway for the Investment Plan 2023

For this investment plan, we built upon the experience and knowledge we gained from the drafting of the 2023-2032 version, as well as the feedback we were able to receive during the consultation.

In particular, we were able to devote more time to the stakeholder consultation. At this stakeholder consultation, we surveyed sectoral federations, academia and policy-makers, among others, about their assessments and recommendations. In order to make the most of this consultation, we organised a three-step consultation:

1. Stakeholder consultation 15-12-2022: presentation of our analyses regarding regulatory changes, and evolution of assumptions
2. Stakeholder consultation 25-01-2023: 25 January 2023: feedback session where the stakeholders also shared their concerns, recommendations and observations with the group
3. Stakeholder consultation 23-03-2022: 23 March 2023: initial observations of the impact we see on the pricing of adjusted assumptions

In addition to these consultation session, there was also intensive coordination with Elia on the assumptions upon which this Investment Plan is based. While Fluvius fulfils the role of distribution grid operator for the Flemish distribution grid operators (DNBs), Elia has a role as the manager of the local transport and transmission grid and in holding responsibility for the balance in Belgium.

Elia's Adequacy Study for the Belgian electricity system will focus on the balance of the transmission grid, including its interaction with neighbouring countries via interconnectors. Thus, the approach is primarily macro-economic (top down), while the Fluvius Investment Plan ensures that grid components can withstand punctual loads locally without imposing any structural constraints on the customer (bottom up). This applies to both low-voltage and industrial customers. On the low-voltage distribution grid, we have a very branched-out grid where the consumption or injection behaviour of the individual customer is noticeable.

The closer we get to the interconnection point with the transmission grid, the more the load profiles are aggregated, and the more we can work with a statistical approach. For example, although we are starting from 20 users for a load on a low-voltage cable, at the interconnection point with the transmission grid, we have a cumulative number of 10,000 users.

The purpose of the alignment is to translate changing individual behaviour to the aggregate level, involving both professional low-voltage and high-voltage distribution grid users.

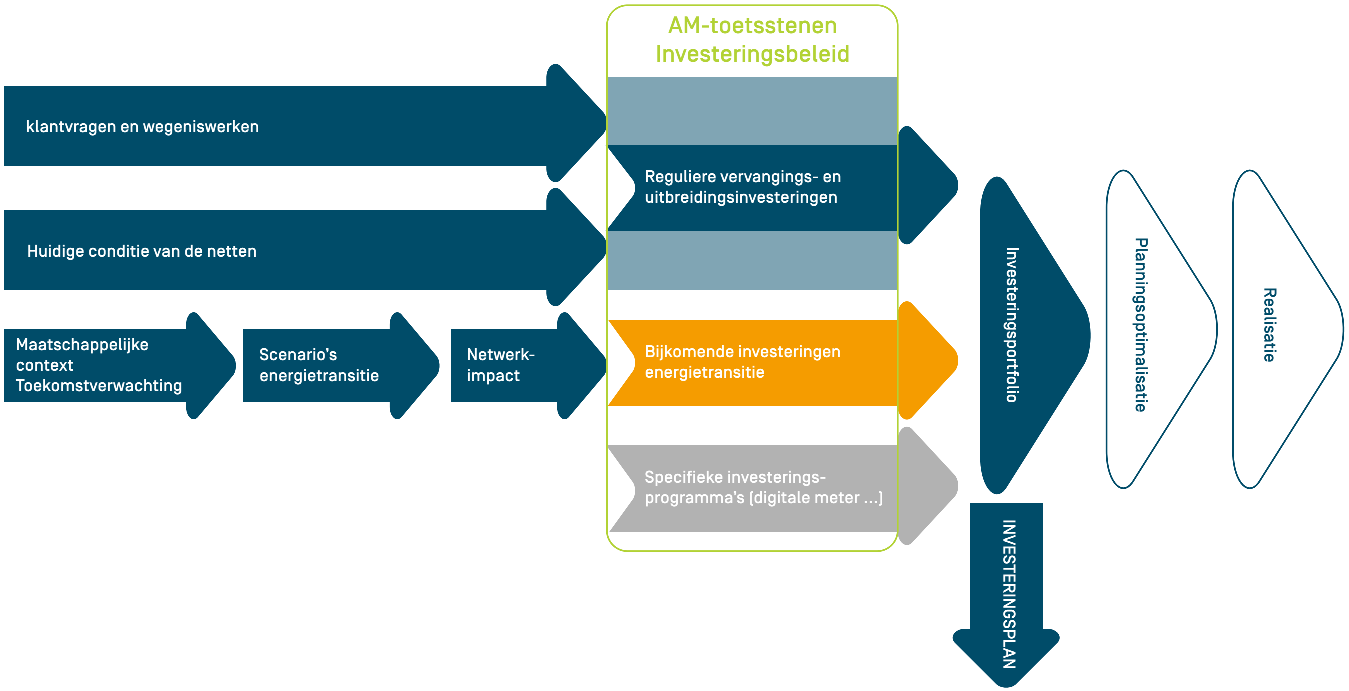
In order to enable this translation, separate coordination sessions will be organised in addition to existing consultations. In addition, we will determine the impact of different scenarios. Of course, we must take into account the fact that from the common interconnection point, direct Elia customers will also be provided for as to their own transition needs.

Before implementing these plans in concrete terms, we obviously coordinate them with the relevant domain managers. And with the cities and municipalities, given the effect of spatial planning on the necessary grid capacity.

We also engage with other utility companies to maximise any opportunities for synergy. Arrangements have been made with the drinking water sector to proactively establish synergy.

The energy transition is moving fast and the future is uncertain. Certain basic principles and assumptions are likely to be adjusted, based on moving insight. Fluvius creates a new Investment Plan every year, where the investment rhythm can be slowed down or accelerated, depending on future developments or adjustments within energy policy. This takes place in consultation with our stakeholders.

Structure of this Investment Plan



The **social context** is the starting point for our Investment Plan. Within this context, we outline some possible futures for a number of themes (electric mobility, heating, etc.) that may have a major impact on the distribution grid. These **future projections**, of course, are not exact predictions. In each case, we consider a whole range of possible developments.

In the sections: *The impact on the electricity grid* & *The impact on the gas grid*, these future projections are combined and translated into concrete **scenarios** for the energy transition and the associated grid load. We provide an insight into the **current state** of the distribution grid and study the **impact** of future scenarios.

Finally, we explain the investments in the sections: *The measures for and investments in the electricity grid* & *The measures for and investments in the gas grid*. In doing so, we distinguish between regular replacement and expansion investments and additional investments to facilitate the energy transition. Along with some specific investment programmes, such as the digital meter roll-out, this forms the input for the investment portfolio and the Investment Plan.

Social context

Climate change is creating some major challenges for our society. Sharply pushing down global CO_2 emissions allows us to keep global warming under control. In order to do so, we must take some specific, ambitious measures.

Following the UN climate summit in Glasgow (October 2021) and in light of the European Fit for 55 package (EU, 2021), a Climate Council of Ministers was held within the Government of Flanders to further refine Flemish climate policy. Flanders is expanding its ambitions for reducing greenhouse gas emissions. The Flemish Energy and Climate Plan fleshes out Flanders' preferred path to a climate-neutral society by 2050. The Government of Flanders is primarily committed to electrification.

It is not only the reduction of CO_2 that affects the energy grid. After a temporary economic downturn due to the corona crisis, we are seeing the economy recovering rapidly, further increasing energy demand. Rising inflation and the geopolitical situation are driving energy prices up sharply. These developments will make energy transition and more efficient energy use even more important.

Criteria for Fluvius (Vision 2050)

Fluvius supports the European climate ambitions.
As a grid operator with an important role in society, we do not intend to merely watch from the sidelines. In 2020, we developed a future vision called Vision 2050 (Fluvius, 2020). This maps out how we, as a grid company, are helping Flanders move towards climate neutrality in 2050. We determined four key objectives and associated criteria that all of our proposed solutions must meet.

- ❶ Helping to reduce energy consumption in Flanders.
- ❶ Maximising the availability of renewable energy.
- ❶ Making Flemish energy grids future-proof.
- ❶ Creating new opportunities for active users.

Along with policy-makers, stakeholders and the free market, we are aiming to shape the public utility infrastructure of the future. Fluvius' initiatives towards climate neutrality are tested against five concrete conditions:

- They must guarantee comfort and convenience for users of the grid.
- They must be socially responsible.
- They must be ecologically responsible.
- They must be financially realistic.
- They must be technically feasible.

To make the energy mix greener, we will have to find new solutions, develop new technologies and build new models for collaboration. Natural gas is a fossil fuel that must be replaced by 2050. It goes without saying that a complete change in the energy mix will have an impact on the structure and management of energy grids in Flanders.

The speed of energy transition means that we face a major challenge in the coming years. With this Investment Plan, we are making clear what steps Fluvius will take in the short term to achieve these objectives.

Future expectations

Fluvius takes the social context and the policy framework as a starting point when formulating this Investment Plan. Our grid investments are based we start from a number of long-term assumptions. These are based, among other things, on the ambitions in the Flemish Energy and Climate Plan (Government of Flanders, 2021):

- that passenger, bus and freight vehicles will be electrified;
- that waste heat will be utilised in district heating networks;
- that heating systems in new-build properties and properties undergoing major renovations will be electrically powered;
- that the growth in the production of solar and wind energy will accelerate over time;
- that electricity consumption will rise in industry.

In preparation for the Investment Plan, we organised several consultation sessions with our stakeholders. Our assumptions in the 2023-2032 Investment Plan were largely confirmed. The biggest adjustment we made based on the stakeholder consultations was to incorporate the roll-out of electric trucks. Last year, there was no definite choice for the future powertrain for trucks. This year showed the strong belief in the e-truck. This Investment Plan envisions the initial pilot projects for charging infrastructure along motorways. We do see transport companies now shaping their vision, and starting to build up initial experience with e-trucks. A larger scale-up is not expected until 2026, once the e-truck is more present in manufacturers' offerings.

As a result of increasing residential densification, Fluvius must focus even more heavily on future urban development when implementing its investment plans. This takes into account a local policy that determines whether or not a property's connection to the low-voltage grid is suitable for charging electric vehicles. This way, we will avoid unnecessary load upon networks for home charging on car-free streets.

Electrification of the construction industry has also begun. Small tools are fully or substantially electrically powered. On-site diesel generator can be replaced by batteries. The site facility becomes more energy efficient thanks to better insulation of the site shack and automation of the facility. For the larger site machines, manufacturers still see both powertrains as a possibility. Both fuel-cell hydrogen and battery-powered machines are being developed. The construction industry is also watching the Netherlands with great interest. Nitrogen regulations and incentives in procurement are triggering trials of CO_2-neutral site machinery.

In the 2023-2032 version of the Investment Plan, we assumed that the number of CHPs would decrease under the impetus of the outgoing certificate policy. Spurred on by the high price of gas last year, Fluvius received several study requests for switching back to diesel engines instead of gas engines. Due to the falling gas prices in the autumn, these conversions were not made. However, some growers did delay the start-up of cultivation from December to March, so there was no injection into the distribution grid during the turn of the year. From surveying the industry, we learn that there is no solution today for replacing the CO_2 emissions from the gas engine, which today serves as fertiliser for plants. The industry is looking at heat pumps for optimising heat demand during the transition season.

Below, we will explain our future expectations for each theme.

Mobility

In 2021, the federal government implemented a tax reform for commercial vehicles. From 1 January 2026 onwards, cars will only be tax deductible for corporate tax purposes if they have zero emissions. The measures will bring about a further increase the sustainability and electrification of companies' vehicle fleets.

Flanders is also pursuing a more ambitious goal. In its the vision paper 'Clean Power for Transport' (Government of Flanders, 2021), Flanders wants to focus on the switch to modes of transport that offer zero emissions and modes of transport powered by alternative fuels. In 2021, the targets were increased. Amongst other things, the Government of Flanders wants to install 35,000 public (or semi-public) charging point equivalents by 2025 and 100,000 public (or semi-public) charging point equivalents by 2030.

These numbers are in line with the updated Flemish Energy and Climate Plan (Government of Flanders, 2021). In that plan, Flanders expresses a clear ambition in the field of electric mobility for passenger, public and freight transport.

Transportation of passengers and light goods

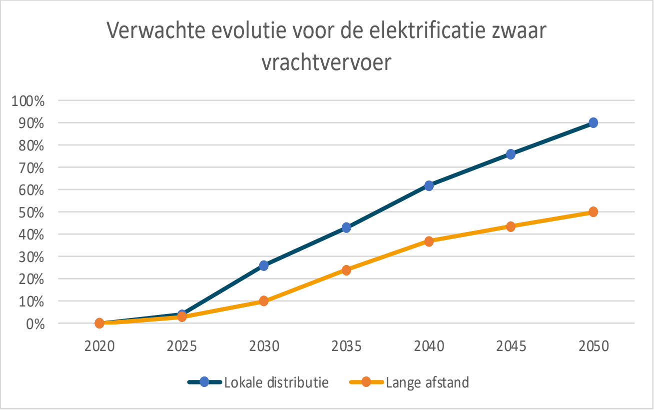
Our considerations are based on the presence of 3.6 million passenger vehicles in Flanders in 2021. The number of passenger cars is continuing to rise slightly year after year, but this increase has clearly been falling in recent years.The number of passenger cars registered increased by 0.5% between 2021 and 2022. In the longer term, the Government of Flanders is expecting the number of vehicles to stabilise due to the effect of home working, the growth of public transport and the sharing economy. We therefore assume that there will be 3.85 million passenger cars in 2050 and that the number of kilometres driven per year will be comparable to today (60 billion kilometres per year).

We then drew up scenarios for the electrification of those vehicles. We assume that by 2050, all of those vehicles will be electric (i.e. 3.85 million electric vehicles or EVs). How this will be achieved is still uncertain, however. To arrive at a supported prognosis, we combined the insights of sector federations, the Government of Flanders and Fluvius. We took into account the following three factors:

- market developments (in particular the moment when an electric vehicle becomes the most attractive offering or 'price parity')
- the legislation and recent policy decisions (the exclusion or obligation of a certain form of mobility)
- customer acceptance (more likely to be progressive or conservative).

To calculate the impact on the electricity grid, we made use of forecasts from the market and information from sectoral federations (FEBIAC) for the period up to 2025. For the period after 2025, we adjusted existing forecasts from the Flemish vision paper 'Clean Power for Transport 2030' upwards, to 1.5 million electric vehicles in 2030. The reason for this is the federal tax reform for commercial vehicles. At the present time, it is unclear how quickly electrification will be implemented in the second-hand market, so making forecasts for the period from 2040 onwards is more difficult. We assume that all 3,850,000 vehicles will be electric by 2050.

The sector federations expect a large increase and that light goods vehicles will go electric between 2025 and 2035. In time, it is expected that this segment will become fully electric.



Passenger vehicles and light goods vehicles will be charged at home, at work and in the public domain. Capacity must therefore be provided at each of these locations.

To calculate the impact on the electricity network, the peak load (kW) must be determined. On the low-voltage grid, peak consumption will occur mainly during the winter period. Electric cars consume the most energy per kilometre in winter and will be charged mainly at home during the evening peak, weekend or holiday periods. Therefore, all the assumptions were projected against the winter period.

Not only the number of vehicles, but the charging behaviour in particular plays a crucial role in the impact on the network. Recent requests to connect charging stations show that customers mainly choose an 11kW charger.

To simulate the impact on the distribution network, we randomly distribute a number of station loads across the network. Here, we consider a combination of slow and fast charging, with an average charging capacity of 7.5kW and a maximum of 60% simultaneous charging. This calculation is based on our own analysis of charging behaviour, as well as the results of national and international studies and measurement campaigns (Roy, 2015) (Baringa, 2019) (ElaadNL, no date). In addition, we consider a percentage of 80% for home charging and 20% for charging at work, since charging at work may decrease significantly during certain periods, such as the Christmas holidays and weekends.

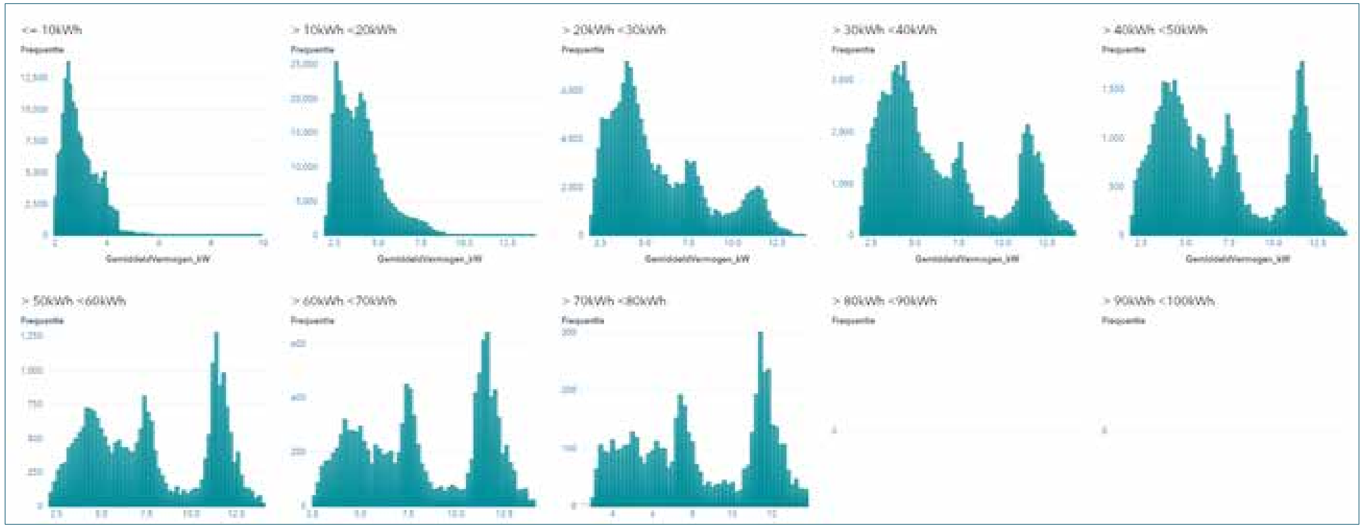
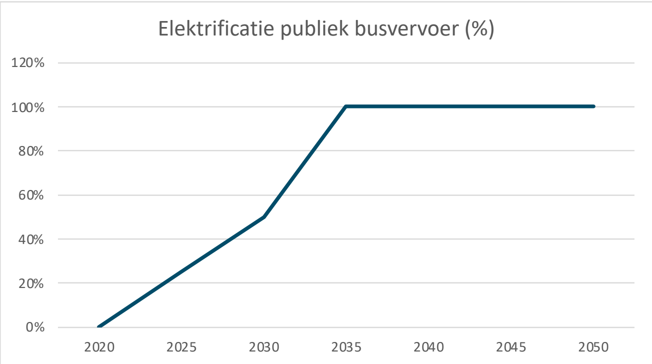


Figure 3: Analysis of anonymised data from the digital meters – average load power in line with energy charged (kWh)

Public transport by bus: collaboration agreement between Fluvius and De Lijn

Both the government, the Flemish transport company De Lijn and the industry expect that buses for public passenger transport will switch to electric by 2035. At present, we can see that both De Lijn and the operators who have already started to switch are opting for buses that are 100% battery-powered.



At the moment, the fleet of buses operates from a total of 135 depots belonging to De Lijn and to the operators.

The schedule for the roll-out of the depot connections will be closely monitored and adjusted if necessary in a monthly consultation with De Lijn. We have included the investments required in the Investment Plan.

The connections for the depots are sized for a scenario of full electrification. This means that the energy consumption gradually increases in proportion to the electrification of the buses.

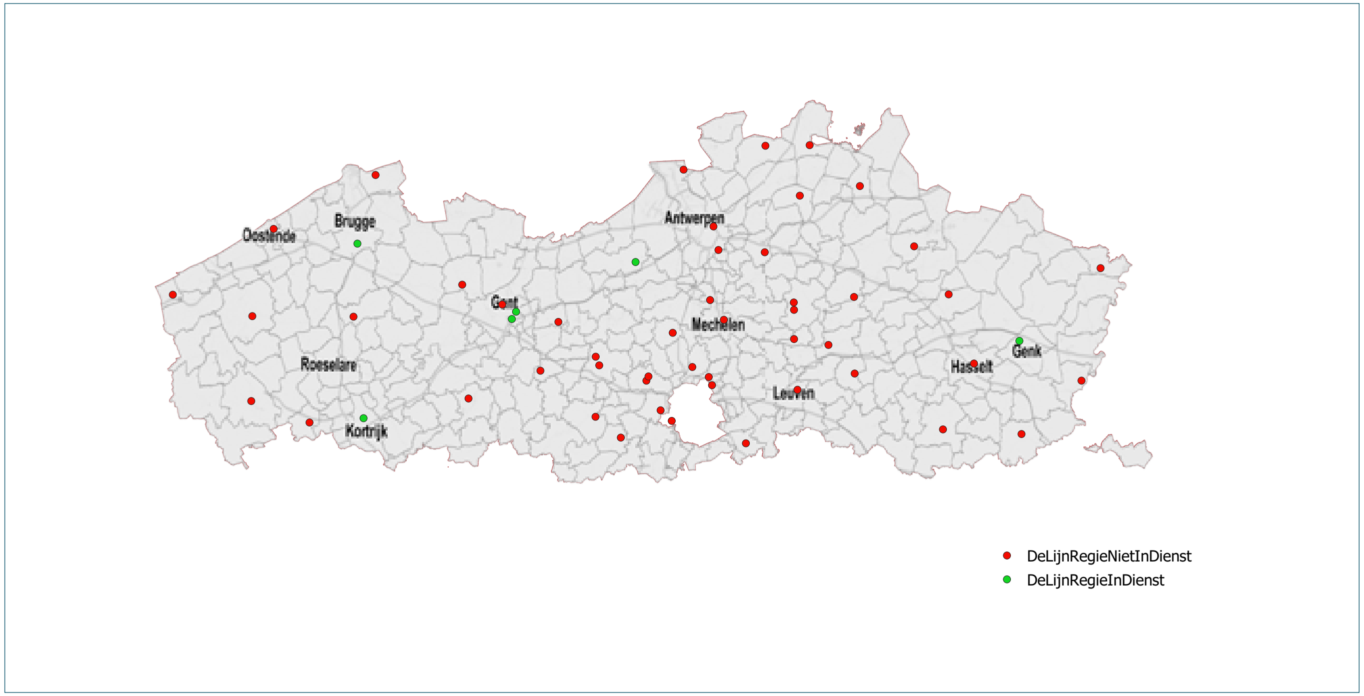


Figure 4: De Lijn's own E-bus connections – 6 depots in service and 49 depots in planning phase

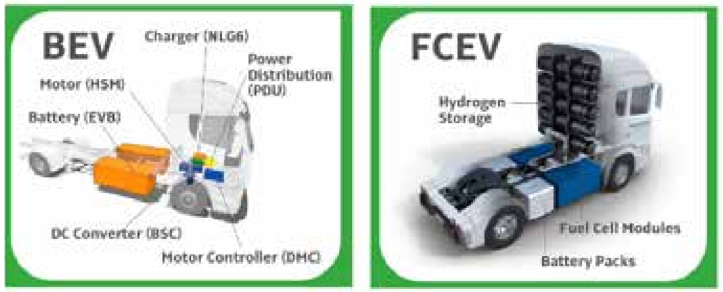
Freight transport

Belief in the ability of the freight transport sector to switch to electrically powered vehicles has grown over the past year. Europe is pushing for the expansion of charging infrastructure for electric freight vehicles. Flanders is promoting the electrification of freight vehicles by implementing measures within the Flemish Energy and Climate Plan (Government of Flanders, 2021).

Of the total 9.07TWh of energy requirements, as much as 4.5TWh is needed for heavy freight transport.

The electrification of heavy freight transport is a fairly recent evolution. It should be monitored, in order to provide the necessary capacity in a timely manner. Manufacturers say they will launch e-trucks with a driving range of 500 km by 2026. The following years will see a sharp increase in supply.

E-trucks are preferred over fuel-cell H2 trucks. This is especially because of the disadvantage of a hydrogen or H2 buffer.



Freight vehicles will primarily charge at high voltage, via DC charging infrastructure with charging capacities ranging from 100kW to 4.5MW. We have included the necessary expansions of the high-voltage distribution network in the Investment Plan. It goes without saying that parking areas alongside major roads and motorways and in stopping or sleeping areas will be equipped with this charging infrastructure.

The figure below shows the sites we included as pilot projects in the Investment Plan. The seven known cases are in planning stages.

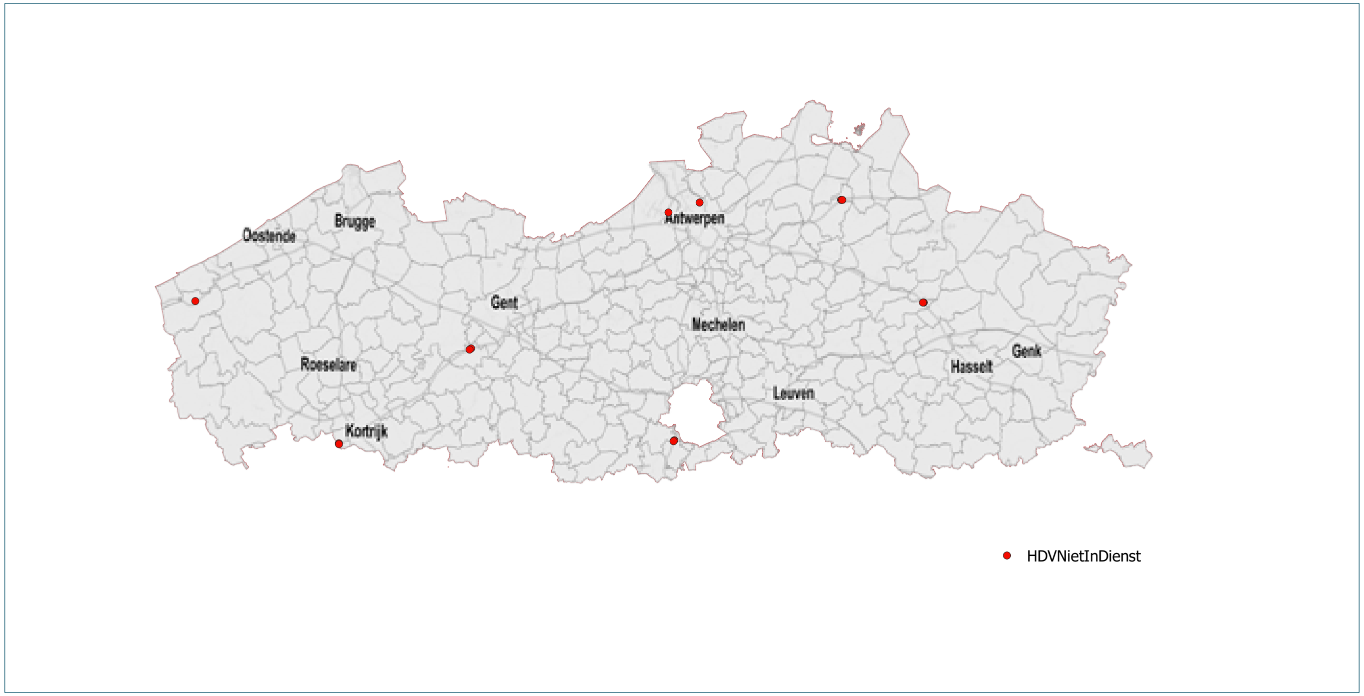
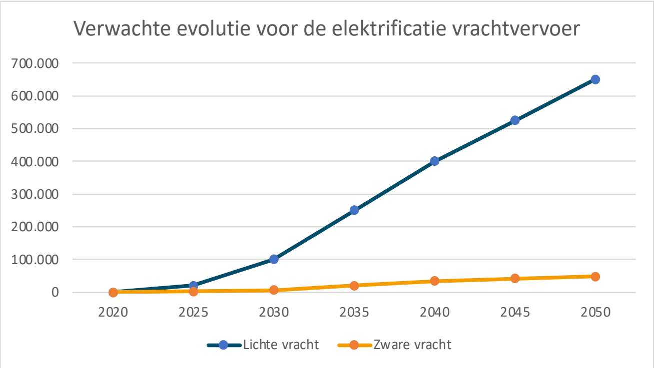


Figure 5: Fast charging infrastructure HDV – 7 known cases in planning stages.

Industry associations are expecting that 20% of new freight vehicles will be electric by 2030. This is about 5% of the total fleet within this segment. The great uncertainty about the development of electrically powered freight transport makes it difficult to make a more detailed forecast. Technological developments, such as Megawatt Charging Systems for freight truck charging (HDV), can also have a major impact. There is still a lot to explore in terms of charging behaviour, charging infrastructure, specific types of transport and the development of electrically powered freight transport in general. When calculating the impact on electricity grids, the following assumption is made. In doing so, we distinguish between local distribution and long-distance freight transport, due to the difference in charging behaviour and infrastructure.



Other alternatives for freight transport – such as hydrogen, bio-CNG or HVO (Hydrotreated Vegetable Oil) – are not ruled out. For example, certain companies are considering converting green electricity into green fuel to power their freight vehicles and tour buses.

In addition to the location and time of day, the energy required is also a concern we must prepare for.

HCV – typical use cases

Transport applications: Flemish annual electricity consumption if all heavy trucks are battery-electric powered

#	Transport application	BE fleet of trucks active (>3.5T)	# working days active	km/day	Avg. e-consump-tion kwh/100 km	Total # km/year	Total e-consumption kWh/year
1	Urban distribution (multiple stops)	8,640	200	150	100	259,200,000	259,200,000
2	Urban intercity (BE, some stops)	21,600	200	200	120	864,000,000	1,036,800,000
3	Distribution interhub (BeNeLux, round trip)	21,600	200	400	150	1,728,000,000	2,592,000,000
4	Long-distance transport (international)	21,600	200	700	150	3,024,000,000	4,536,000,000
5	Public administrations (household waste, green service, etc.)	4,320	200	75	200	64,800,000	129,600,000
6	Construction industry and site transport	8,640	200	150	200	259,200,000	518,400,000
	TOTAL/AVERAGE	**86,400**		**359**	**146**	**6,199,200,000**	**9,072,000,000**

Source: Febiac Knowledge Centre

Charging infrastructure for electric vehicles

In June 2021, the VREG (the independent authority of the Flemish energy market) introduced a new notification requirement applicable to charging points for electric cars. All charging points with a charging capacity of ≥ 5kVA that are connected to the low-voltage distribution network must be reported to Fluvius. This obligation applies to public, semi-public and private charging points. The information we receive in this way should allow us to make timely targeted adjustments to the electricity distribution network.

Between 2016 and 2021, a basic infrastructure of public charging stations was installed in Flanders (+/- 2,500 charging stations), in cooperation with cities and municipalities. In the public domain, chargers with an installed capacity of 2 x 11kW on the low-voltage distribution network are common.

In spring 2022, a new call for tenders for public charging points was issued to the market. This is being coordinated by the Government of Flanders. Fluvius is in close contact with the government to ensure a smooth roll-out of these charging points. Fluvius provides the necessary investments to accommodate these charging stations and provides their connection. We take into account the fact that approximately 50% of these additional charging stations will be semi-public, i.e. connected to an existing connection.

In 2023, the implementation of fast-charging infrastructure for cars and vans along motorways and regional roads looks as follows:

Apart from the rounds of tendering, charging point operators have other investment plans as well. The major players are surveyed on a regular basis and we also include specific plans in this Investment Plan.

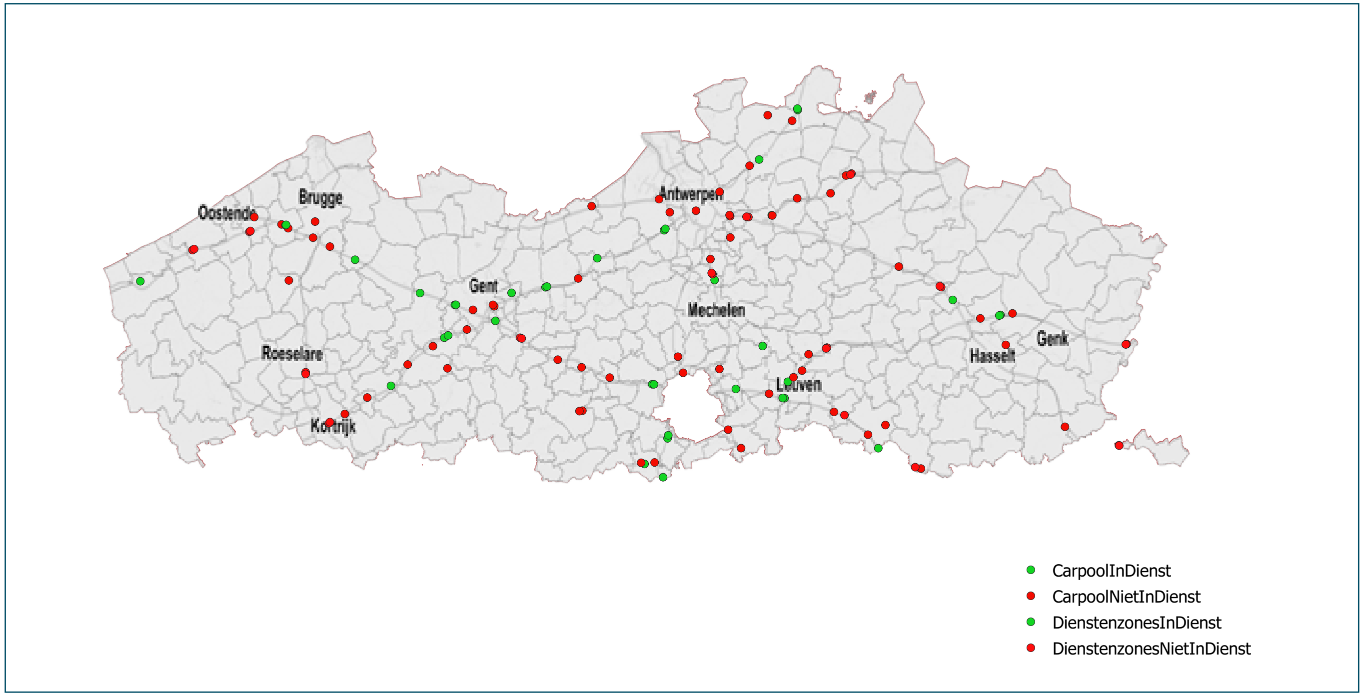


Figure 6: Fast charging infrastructure LWV domain AWV – 23 service zones in service and 26 planned; 14 carpool car parks in service and 58 planned.

On a European level, a Directive (EU, 2013) has been drafted that sets a number of targets for the development of a network of fast-charging infrastructure for electric vehicles. The capabilities listed below must be provided every 60 km along the Trans-European Transport network (TEN-T). The TEN-T network comprises the main transport networks in Europe, including the European motorways.

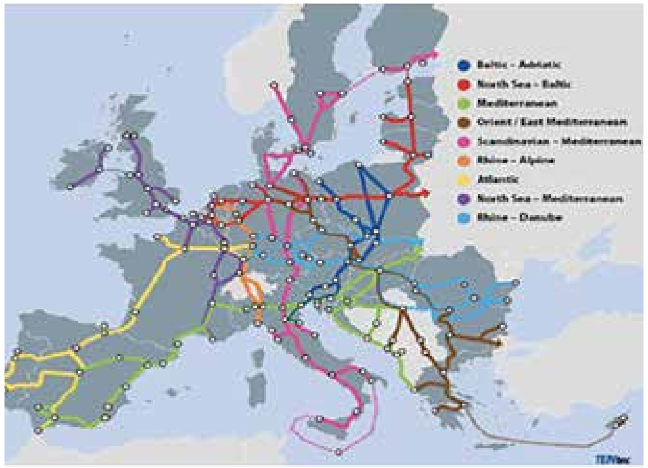


Figure 7: Main transport axes in Europe (TEN-T core network corridors)

Type of vehicles	2025	2030	2035
Light Weight Vehicles	300kW	900kW	600kW
Heavy Duty Vehicles	1,400kW	4,900kW	3,500kW

Previous tendering rounds by the Roads and Traffic Agency have taught us that 2,000kW is requested as standard for this charging infrastructure. Currently, 121 sites have had contracts awarded, are in progress or have been implemented.

It is the Government of Flanders' ambition to provide fast chargers along motorways, with a distance between them of 25 km. Fluvius is responsible for the necessary grid adjustments. Thanks to regular consultations, we are ensuring that we respond in a timely manner to the projects launched by the Roads and Traffic Agency.

Charging infrastructure for shipping – shore power in ports

Each type of vessel requires a different type of connectivity to connect to shore power. Fluvius holds regular consultations with the ports of Ghent, Antwerp and Zeebrugge. We monitor developments so that we can plan the right investments.

Port of Antwerp-Bruges has already commenced a number of initiatives involving charging and changing stations for battery containers used by inland navigation. The storage capacity of these containers is between 2 and 3 MWh.

For the port managed by the City of Antwerp (MAS zone), a project was developed to provide the docks with shore power, as in the case of the Steenkaai. We included those investments in the period from 2023 to 2025.

Port of Antwerp-Bruges requested a number of tenders for the provision of shore power to ocean-going vessels. These involves equipment with charging voltages at 3 or 5kV with inverters to 60Hz and capacities up to 6MVA per charging point. However, no bid has yet been ordered for implementation. Fluvius does see a potential synergy here with the additional wind projects for the ports.

For inland navigation, the power requirements for each type of vessel have also been identified. We have included projects that are known in this Investment Plan. For the inland vessels, a consortium was formed in order to submit a tender for the provision of a charging box that can be connected to both the network of De Vlaamse Waterweg and the distribution network. As far as energy bills are concerned, we are striving to implement a Benelux standard.

Residential heating

70% of homes in Flanders are heated with natural gas. Natural gas is a fossil fuel that emits CO_2 when burned. It will therefore be phased out by 2050. The way in which this is done will depend very much on the economic drivers and the regulatory framework.

The ambition to decarbonise heating in existing buildings is currently being translated into a number of policy measures:

- Fuel oil boilers are being phased out and installing them in new-build projects is no longer permitted.
- When purchased, the government requires that the most energy-intensive buildings be renovated to an EPC label of D.
- New large subdivisions or apartments may no longer use natural gas for heating.
- In the additional measures of the Flemish Energy and Climate Plan (Government of Flanders, 2021), the Government of Flanders states that from 1 January 2025 onwards, connecting new-build properties to the natural gas network will no longer be possible.
- To phase out the reduced rate for gas connection in new-build properties from July 2022 onwards.

As set out above, Flanders wants to make its buildings much more energy efficient by 2050. Energy will continue to be needed for heating, for cooling and for domestic hot water. We integrated the Government of Flanders' intended renovation pathway towards 2050 into the simulations to determine energy demand, and thus grid capacity. Fluvius will make every effort to bring as much green energy to homes as possible.

Heat grids

For phasing out fossil fuels by 2050, in particular natural gas and fuel oil for heating buildings, Fluvius is putting forward two options: connection to a heat grid or electrification through heat pumps. Heat grids can help relieve the electricity grid, as they can (partially) avoid the supplemental power demand of the alternative.

The *Heat Appendices* outline the historical evolutions and technical preconditions for the deployment of heat grids. Based on practical classification, we estimate the potential for this technology.

In early 2023, there were over 3.3 million housing units in the Flemish Region. The housing stock is increasing at an average rate of 1% per year. The total heat demand in Flanders is estimated between 90 and 120TWh/year, but more than half of that is for industry (VEKA, 2020). The net heating demand in the Flemish housing sector is estimated at 38TWh/year, equivalent to about 11.5MWh/year per housing unit. Obviously, the heat demand for a specific home can vary greatly in line with size, type, insulation level, number of occupants and usage profile. For a standard load profile, the average thermal power at an outdoor temperature of -10°C is about 10kW per housing unit.

In the heating scenarios, we assume that 8% of the current housing stock will be connected to high-temperature heat grids by 2050. Homes connected to low-temperature heat grids will also use heat pumps and are included in the impact calculation on the electricity grid.

Fluvius gives top priority to unlocking sustainable waste heat for heating buildings. Since heat is not a regulated activity, the activities and investments by Fluvius are not part of the Investment Plan. Only where relevant to investments in gas and electricity grids do we link them to heat networks, by subtracting the potential from the need for electrification.

Electrification of residential heating by means of heat pumps

Heat pumps are a good technology for heating in new-build properties (E-level 30 or lower). They are also climate-neutral when green energy is used.

For existing homes with lower insulation levels too, an all-electric heat pump may be advantageous, but this choice is not always efficient. Hybrid heat pumps can be a solution if extensive renovation is not possible, but you still want to switch quickly to heating technology with reduced CO_2 emissions. The gas boiler for the hybrid heat pump provides additional power if the desired power cannot be supplied by the heat pump. If the required gas consumption would be filled by green molecules (in time), we can also achieve a climate-neutral solution with hybrid systems.

Owing to a multitude of factors, it is not easy to accurately predict heating electrification in existing buildings. The determining factors are:

❶ **evolution in building renovation** (can a heat pump be used?)

❷ the **legislation for phasing out** fossil boilers (exclusion or requirement of a particular technology and/or energy vector)

❸ **thee energy price** and in particular **the tax shift** between energy sectors (shifting the burden from electricity to fossil fuels)

❹ support from the government through **premiums** (e.g. insulation, heat pump or hybrid heat pump)

❺ the **market evolution** through technical innovation, price evolution and customer acceptance

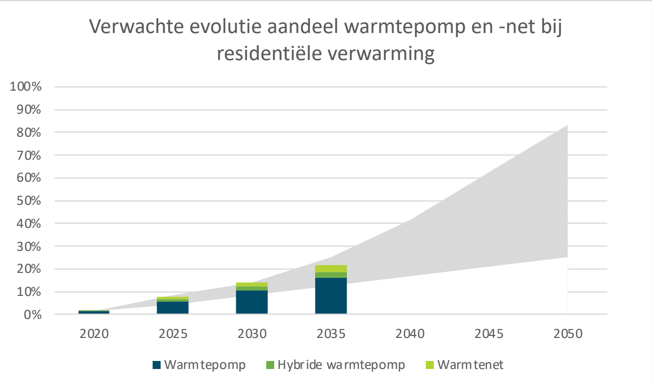
❻ the expansion of **heat grids** (high temperature) as an alternative to a 'Zero Emission' solution. This does not include low-temperature heat grids, because these heat grids also use a heat pump.

The renovation status of buildings – and, in particular, the installation of low-temperature release systems such as underfloor heating – is vitally important when determining the extent to which they can be made sustainable by 2050. The Flemish Climate Strategy 2050 (Government of Flanders, 2019) includes ambitious targets to reduce the average EPC number of the entire housing stock to energy label A (EPC energy score 100). To achieve this goal, the current renovation rate must triple to 3% per year.

To calculate the impact on the distribution network, we assume a transition phase from the current renovation rate to almost 3% starting in 2030. We assume that an ever-increasing proportion of all-electric heat pumps will be installed during the course of renovations. In the case of partial renovations (energy label B or higher), we are also expecting a proportion of hybrid heat pumps to be installed. We have taken the annual growth in the number of new homes to be equivalent to with the current situation, in accordance with which a heat pump will be installed in all cases with effect from 2026.

To simulate the impact on the distribution network, we randomly distribute a number of station loads across the network. Here, we consider a combination of electric and hybrid heat pumps, with a simultaneity of 75% during the winter peak (Christina Protopapadaki, 2017).

	New builds	A	B/C	D/E/F
T power HP	6.0kVA	8.0kVA	16.0kVA	32.0kVA
T power HHP	4.0kVA	8.0kVA	8.0kVA	8.0kVA
E power HP	2.5kVA	3.5kVA	7.0kVA	14.0kVA
E power HHP	1.0kVA	2.0kVA	2.0kVA	2.0kVA



Phasing out fuel oil

Due to the phase-out of fuel oil, we expect an increase in the number of customers switching from fuel oil to natural gas in the next few years. Indeed, until 2017, there was still a requirement for 99% of all residential customers to be connectable to the gas grid, making it easy for many customers to switch to natural gas. Currently, there are nearly 700,000 customers with heating oil systems who are connectable to the natural gas grid, often in older homes with energy label C or higher. Replacing a fuel oil boiler with a gas boiler reduces CO_2 emissions.

Future scenarios are very difficult to estimate. Amongst other things, they will depend on the age of fuel oil boilers, the price differential between natural gas and fuel oil, the renovation rate or cost of a home and the availability/efficiency of other alternatives such as heat grids or heat pumps.

The European Commission's recently launched RE-PowerEU plan (EU, 2022) proposes a number of targets that would prohibit the marketing of fossil-fuel boilers from 2029. Fluvius may adjust its assumptions in subsequent versions of this Investment Plan, based on the transposition of European objectives into local legislation.

Local production

The supply of locally produced renewable energy sources will grow. As a result, we will also see continued investment in renewable energy such as solar panels, wind turbines and smaller-scale combined heat and power plants. The cost of investing in these technologies will continue to decline, visibly accelerating growth.

Solar panels (PV)

The Government of Flanders' solar energy target to increase this by 300MWe per year was increased to 450MWe/year in 2022 for low-voltage and high-voltage customers combined. We have seen strong variation in the rate of installation of solar panels in recent years, due to changing regulations and socio-economic conditions. As a result of higher energy prices, we are anticipating an acceleration in the installation of solar panels.

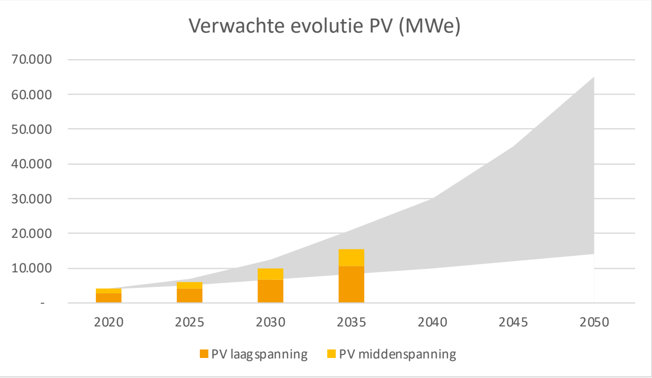
The abolition of the reversing meter and the introduction of the feed-in compensation that customers with a digital meter receive for the energy injected will allow residential installations to be larger in size. At the same time, oversizing the solar panels (in kWp) to more than twice the power of the inverter (in kW) is becoming increasingly possible. This ensures higher efficiency in the morning and evening, when energy is more expensive on average, compared to a loss at times when renewable energy is abundant. In addition, the government took a number of measures to accelerate the generation of solar energy and accelerate the move away from fossil fuels. For example, those included the temporary VAT reduction on solar panels (up to 6 percent).

In addition to an increase in residential installations, companies are now undertaking larger projects. We expect that this trend will continue and will provide a boost in installed PV capacity.

By the end of 2021, there was more than 4GVA of installed capacity in solar panels on the distribution network.
In order to prepare the Investment Plan, we simulated the summer peak, taking account of a linear increase in PV capacity of 300MVA, 450MVA and 600MVA per year until 2033. With our simulations (300MVA, 450MVA and 600MVA), we started from the installed capacity in 2020 and arrived at about 7GW, 8.5GW and 10GW by 2030.
To simulate the impact on the distribution network, we randomly distribute a number of station loads across the network. For the injection peak during the spring or summer months, we take account of a large simultaneity of injection by solar panels.

In the period from now up to 2050, there is still a great deal of potential for up to 65GWp of solar panels on roofs in Flanders – according to a recent study by EnergyVille/VITO (EnergyVille/VITO, 2021). There may also be additional solar panels on car parks (e.g. carports), or in the form of floating solar panels or PV on the ground.

Further, potentially exponential growth is anticipated within a very wide range, and this is difficult to estimate.



We are seeing that, because of the significant price increases for energy due to the war in Ukraine, there has been a large increase in the number of PV installations. This is especially noticeable among industrial customers. It seems that the industry was already anticipating the decision to require large consumers (>1 million kWh) to provide solar panels. For now, the impact on the grid is limited, as people are always sizing installations to match their own consumption. We are seeing that traditionally available injection capacity at the interconnection point level is declining.

Onshore wind turbines

Fluvius works together with various governments and stakeholders – wind project developers in particular – to map out the wind potential of a region and cluster zones. In this way, appropriate scenarios can be studied in good time and adequate investments prepared, including coordination with the transmission grid operator Elia (in connection with the necessary investments in the transmission grid).

The target in the original Flemish Energy and Climate Plan (Government of Flanders, 2019) for an annual additional capacity of 108MW of onshore wind was increased to 150MW last year. With a total annual additional capacity of 150MW/year, the total installed capacity will be 2.8GWe by 2030. In 2021, there was 1.6GW of onshore wind capacity installed. The recent evolution confirms that upward trend. In 2022, there was 1.75GW of wind capacity.

For several years now, Fluvius has been consulting annually with all parties active in the field of wind turbine projects. This allows us to detect projects that have not yet been converted into a study request at Fluvius. We take this information into account when devising our strategy in connection with grid investments.

To estimate the realisation rate of the projects, we survey the provinces about spatial planning. Experience shows that it is not the distance to a sufficiently strong point in the distribution network that is decisive, but rather obtaining the building and operating permit. These are then usually laid down in spatial planning, such as for the Meetjesland and Denderland region of the province of East Flanders, for example

We are noticing an increase in individual wind turbine capacity, which means that inclusion in the existing distribution network is not always possible. For that reason, we therefore specifically set out to construct reception clusters.

The existing capacity will be further expanded by repowering existing wind turbines. The first generation of wind turbines with capacities of 1.7 to 2.2MVA can be replaced in the foreseeable future by more modern versions with larger capacities. A new licence application will need to be submitted for those.

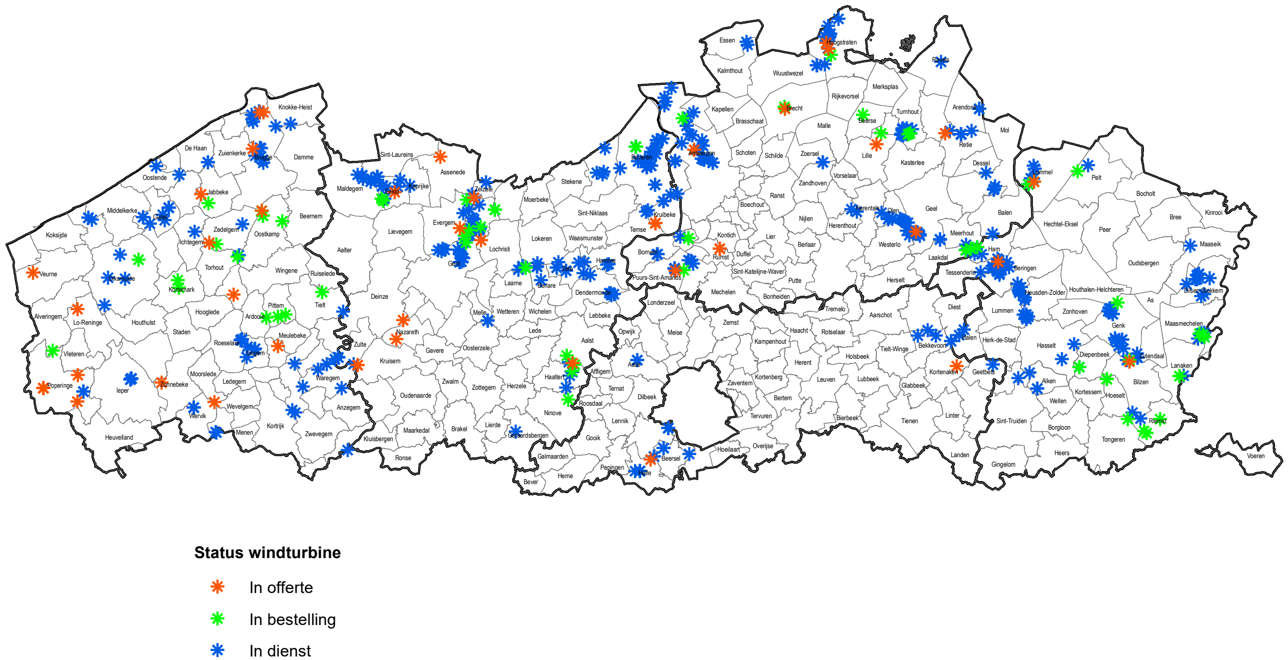


Figure 8: Summary of completed and announced projects, with 1,530MVA in service, 240MVA on order and 121MVA in bid.

Combined Heat & power (CHP) facilities

In combined heat and power (CHP) installations, heat and electricity are produced simultaneously using a fuel-powered engine. That may be a fossil fuel (fuel oil or natural gas) or a renewable fuel (biogas or biomass).

We have noted that the power generated locally by CHPs is continuing to increase. However, the certificate support for all new and substantially modified fossil-fuel CHPs will be phased out completely starting in 2023 instead of 2030. We are therefore expecting a decrease in the number of new CHP cases. In the longer term, this will lead to a reduction in the local injection of electricity and a decrease in gas consumption.

In the horticulture sector, a heat pump is an alternative for heating greenhouses. This has an impact on the available energy production. When switching from a CHP installation to a heat pump, the injection of electricity converts into an uptake of electricity by the heat pump. Given that the high-voltage distribution network is dimensioned for the generally higher power of injection, the need for additional investment will be limited.

Industrial and service sector

For the coming years, Fluvius expects increasing consumption and peak loads, driven by electrification in industry.

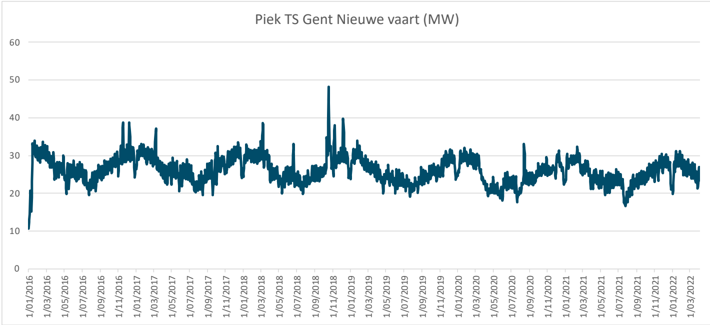
In order to map out this expected increase, Fluvius has made forecasts based on the targets contained in the Flemish Energy and Climate Plan (Government of Flanders, 2021), supplemented with insights regarding current gas consumption and the consumption profile among professional customers. We enriched that information based on a survey of major players in certain sectors (such as real estate companies for logistics) and sectoral organisations.

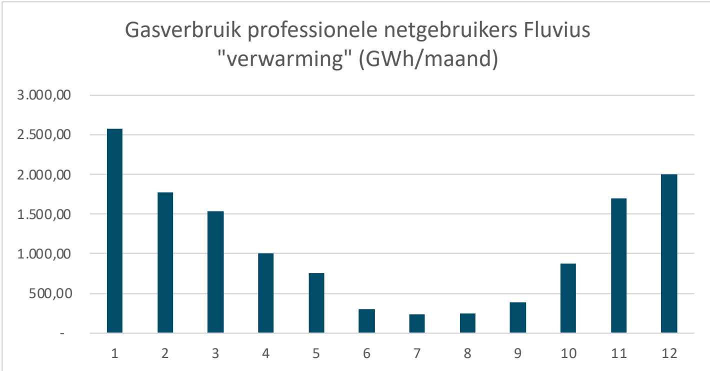
In our predictions, we distinguish between the following elements in terms of their impact:

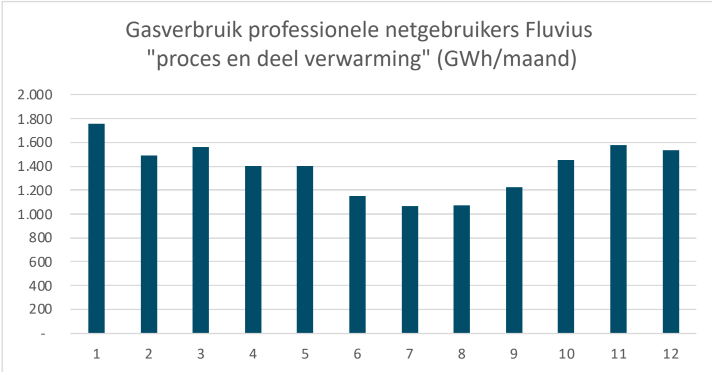
- Impact of **industrial growth** and **energy-efficiency**: The basic assumption for electrified industrial consumption is constant consumption – the growth in the number of industrial customers will be offset by the improved energy efficiency of existing customers. The load history of transformer stations, the load for which (mainly) consists of industrial customers, supports this basic assumption (Figure 1: Peak at the Ghent Nieuwe Vaart transformer station).
- Impact of **electric mobility** and the recharging of vehicles on industrial estates/car parks: The assumptions explained in the section entitled Mobility were used.
- Impact of **electrification of the heating** in commercial buildings and **process heat**: We made a breakdown of gas and other fossil fuel consumption between heating, process and CHP installations. This was done on the basis of monthly consumption and its seasonal variation, combined with the type of sector for the companies involved (Figure 2: Gas consumption of Fluvius professional grid users for 'heating').

This primary energy consumption was converted to electrical consumption and peak demand for **heating**. In doing so, we take into account energy savings resulting from the renovation of business premises and the greening objective, as set out in the Flemish Energy and Climate Plan (Government of Flanders, 2021).

For **process heat**, we further distinguished between high-temperature process heat and low-temperature process heat. In doing so, high-temperature process heat is not electrified in scenarios and low-temperature process heat – because of the temperatures are still relatively high – is partially electrified. This is achieved by means of heat pumps and partly by direct electric heating. The feasibility of this electrification is subject to technological developments (Figure 3: Gas consumption of Fluvius professional grid users for 'process and heating component').







The industry, at least in a transition phase, will rely on green molecules for high-temperature or specific process applications. This industry is spread throughout Flanders and includes several economic sectors. For industrial consumption on the distribution grid, the future scenarios took into account the opportunities of green gases or blends, as one of the alternatives for decarbonising industry. Therefore, we did not include this potential in the simulation in terms of electrification.

- **Region-specific industrial activities:**

  In the Flemish Brabant region, we are seeing many initiatives for new data centres, in addition to growth in the existing ones. These may be causing accelerated congestion (overloading due to excessive current) at some specific interconnection points.

Since last year, we have been participating in a pathway by VLAIO to gain a better understanding of the still relatively unknown energy transition among companies. For example, Fluvius is collecting information on grid impact, based on load profiles and the potential for flexibility.

Energy storage

Electricity storage

Fluvius is following the developments in electricity storage and in its adoption by the market with interest. Indeed, energy storage systems increase the potential flexibility of the energy system, along with flexible generation and response to demand.

Since 2021, we have been noting a sharp increase in the number of electricity storage systems in the private market. That strong growth was triggered by premiums and by the abolition of the reversing meter. Today, these systems focus on increasing self-consumption and not (yet) on reducing consumption or injection peak or other use cases.

A home battery is relatively expensive, but it can be attractive for the customer in some situations. The home battery is not helping to relieve the grid today. The digital meter data teaches us that battery charging starts as soon as the solar panels are producing energy. Due to the limited capacity of batteries, full capacity is still injected into the grid when the battery is charged.

In the case of large batteries, there are already some questions about their feasibility in the context of European grant projects. We can observe this trend mainly in port areas (Antwerp, Ostend and Ghent) and always in combination with industrial sites. We are expecting the detailed studies later, as the projects themselves progress.

Here, it is not important how the peak of decentralised production is captured: it may be via a battery that charges simultaneously with production, via demand response in one's own home that increases simultaneous (self-)consumption, via energy-sharing that maximises local consumption, etc.

Consequently, in order to realise the full potential of energy storage systems, it is important that the focus does not remain purely on increasing self-consumption. For example, a battery can also respond to optimising the capacity tariff or providing flexibility services. We will explain the latter element in more detail later in this plan.

The impact of district batteries is still in the research phase today. An initial pilot project in Oud-Heverlee has demonstrated that the technology needs to evolve further in order to be used as a fully-fledged alternative to grid investment. Besides the financial consideration, which today tilts toward investing in grids, the voltage quality in accordance with standard EN50160 must also be guaranteed after activation of the district battery. A second pilot has been started at Green Energy Park's pilot site in Zellik. We are continuing to monitor evolution, deployment, technical possibilities and financial considerations so that we can incorporate the results into a subsequent version of the Investment Plan.

The initial results indicate that there is not yet sufficient stability to use district batteries as an alternative to low-voltage grid investments.

Electric cars

A battery in an electric car has many times' the storage capacity of the average home battery. By charging the car's battery with locally produced energy, that renewable energy no longer needs to be provided by the distribution grid.

Vehicle-to-Home (V2H) and Vehicle-to-Grid (V2G)

A limited number of electric vehicles can not only store energy, but also feed it back as electricity. This concept is called Vehicle-to-Home (V2H), Vehicle-to-Grid (V2G) or (generically) Vehicle-to-X (V2X).

This technology allows the car battery to be used as an energy storage system, in which electricity from the car to be used directly in the home or fed back into the grid.

We expect that these developments may help us face up to the challenges of the energy transition. In doing so, locally produced renewable energy in the car is stored and fluctuations on the distribution grid, for both consumption and injection, are better controlled or even actively compensated for. Proper implementation of V2G is a valuable extension of smart charging capability. Electric cars can allow local production to be used more efficiently, balance consumption and injection locally, and reduce the risk of overloading the electricity grid. It remains to be seen, however, to what extent consumers and industry will come on board and take part in this development.

We are closely monitoring further evolution, including through pilot projects in our neighbouring countries (e.g. ElaadNL). A pilot with V2G is also to be carried out at the Green Energy Park pilot site. We will incorporate the conclusions into a subsequent version of the Investment Plan.

Thermal and innovative energy storage

In addition to battery storage, thermal storage can also relieve the grid. By advancing demand or increasing self-consumption with heat pumps, electric boilers and accumulation heating, the grid load can be reduced.

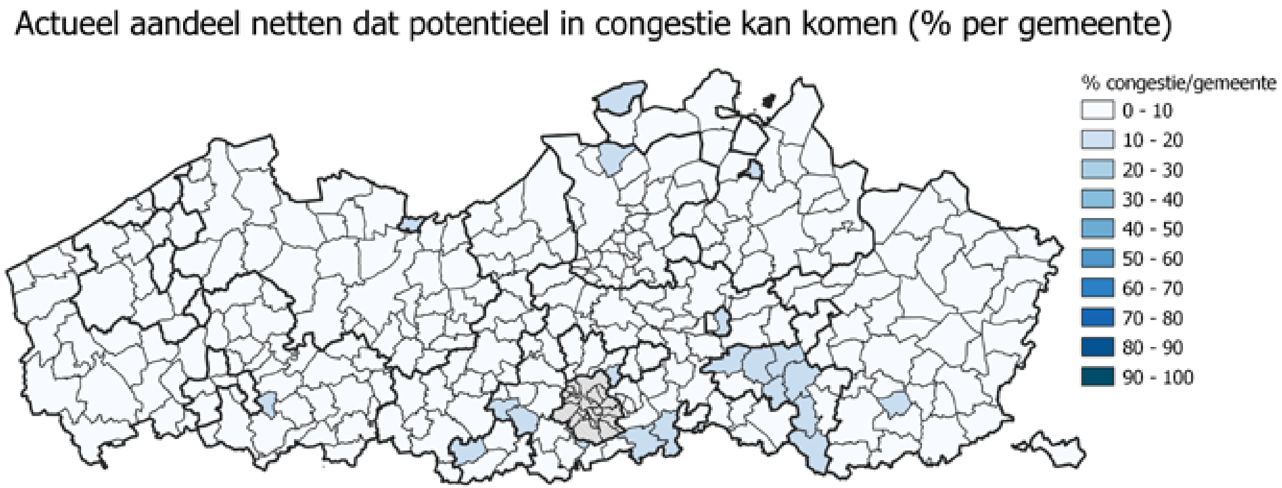
Fluvius has also already been approached in connection with innovative projects involving different forms of energy storage. We gave and are giving the initiators the necessary input to conduct their study and see it through to completion. These involved cold storage systems or hydraulic systems.

The impact on the electricity grid

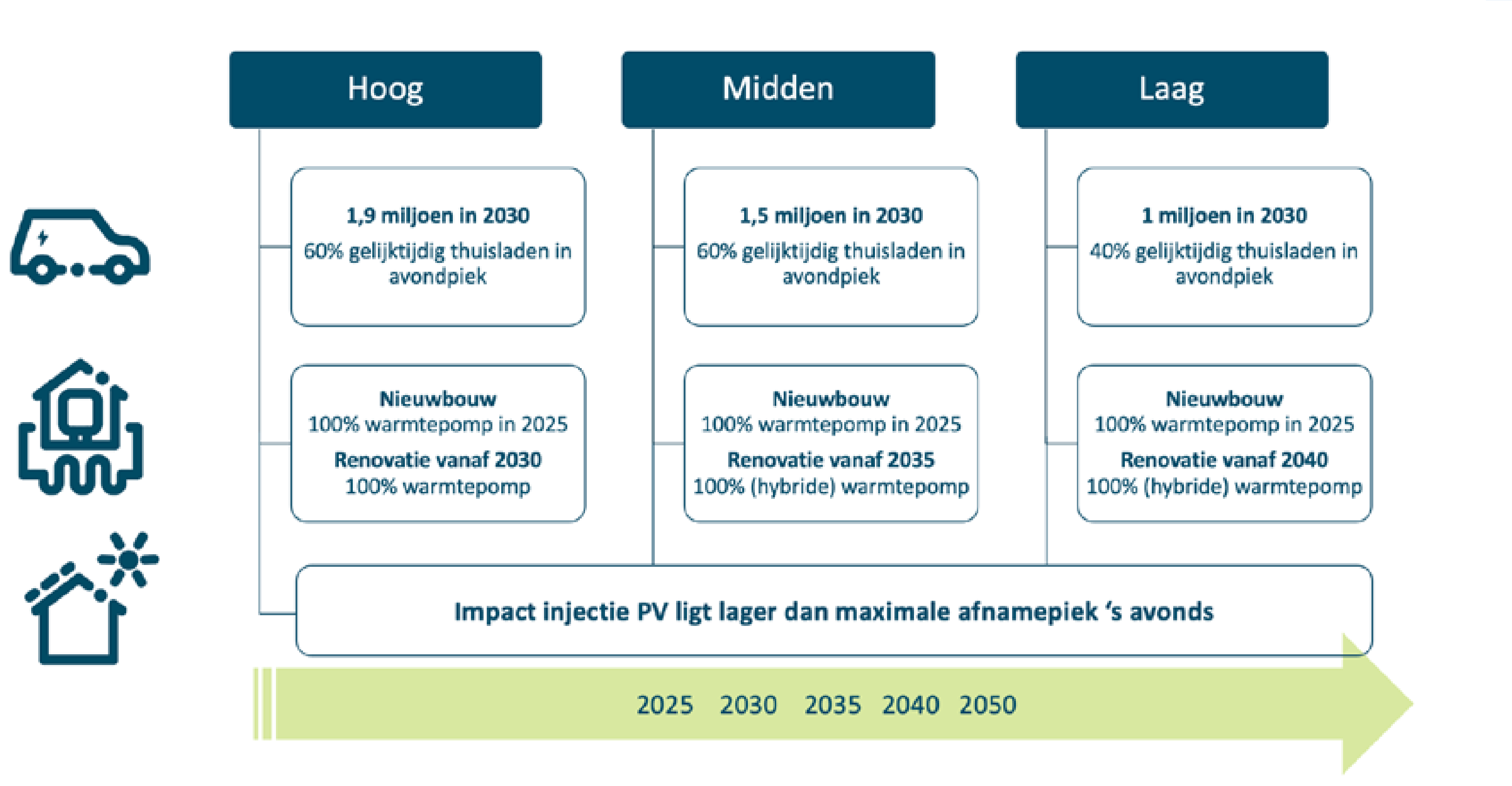
In order to determine the network impact, we translate the social context and forecasts explained in the previous section into concrete **scenarios**. The resulting additional grid load is simulated on top of the current network state. We do this first for the **low-voltage distribution grid**, then for the **high-voltage distribution grid**, and finally for the **transformer stations**.

The impact on the low-voltage distribution grid

Although the distribution network still has a capacity margin in most places, congestion limits that capacity in some places. On the distribution network, there are currently only congestions on typical longer **low-voltage feeders** in some areas, due to large PV injection at times of low consumption. This congestion occurs during strong sunshine and relatively low temperatures, because this is when the solar panels generate the most energy.



On top of the current network state, we simulated additional grid loads according to a high, medium and low-impact scenario. The low-voltage electricity scenarios are mainly determined by the increase in home charging for electric vehicles and the increase in heat pumps for residential heating, considered at the time of the (winter) evening peak. The scenarios examined are:



We consider the 'high impact' and 'low impact' scenarios to be extreme scenarios, which include other combinations of electric vehicles and heat pumps.

At low voltage, the highest load in almost all cases occurs during the evening peak in winter. This was why we left out the effect of decentralised production (PV) in the three scenarios. However, we made a separate analysis of the impact of additional decentralised production on the injection peak with the corresponding network impact.

We determined the impact on the low-voltage distribution network by simulating the times of maximum consumption peak (typically the evening peak) for the different scenarios. We then simulated times of maximum injection. Applying each of the scenarios to the entire Flemish low-voltage distribution grid, we applied dispersion for the distribution of additional electric consumption, based on statistical sectors (Statbel, no date). Among other things, this dispersion takes into account residential area, socio-economic factors, etc.

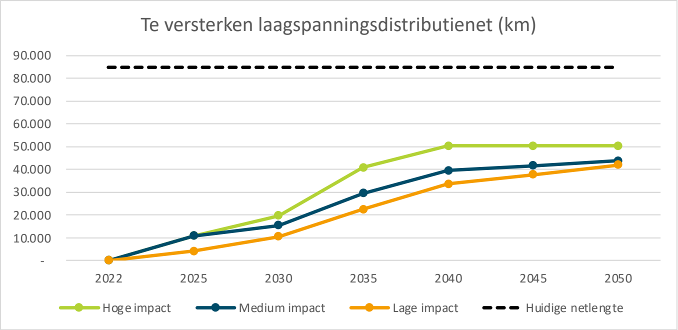
The three low-voltage scenarios were calculated for 2025, 2030, 2035, 2040 and 2050.

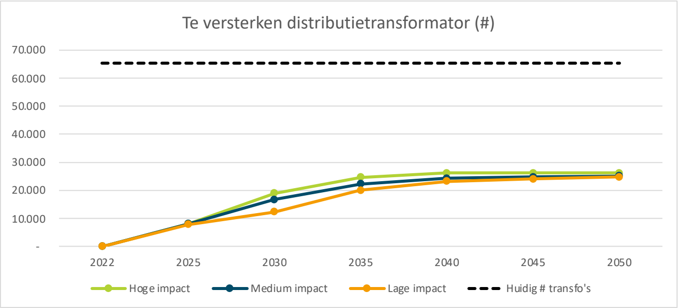
For these three scenarios, we calculated which grid elements (low-voltage cables and distribution transformers) will become congested and thus overloaded due to excessive current, or voltage being too high or too low. The measure to solve this congestion was determined in accordance with the investment policy.

Ultimately, we translated the network impact into grid lengths to be enhanced/expanded/converted, with corresponding connections. We do emphasise that enhance one kilometre of grid length does not necessarily mean that we must also build one kilometre of grid. There are several options, such as voltage conversion to 400V or the addition of low-voltage cables without overcoupling part of the customers from the old cable to the new cable, known as middle injection.

The distribution transformers to be replaced/enhanced give rise to the replacement of the existing transformer with a new one of higher capacity or the addition of new distribution cabinets. If the replaced transformer has a capacity of >=250 KVA and also has 400V as its secondary voltage, it can be recovered – depending on its rated capacity, age and condition.

These graphs show a clear trend similar to the anticipated evolution of passenger transport electrification. The impact of electric driving is certainly many times greater in the short term than the impact of electrification of heating.

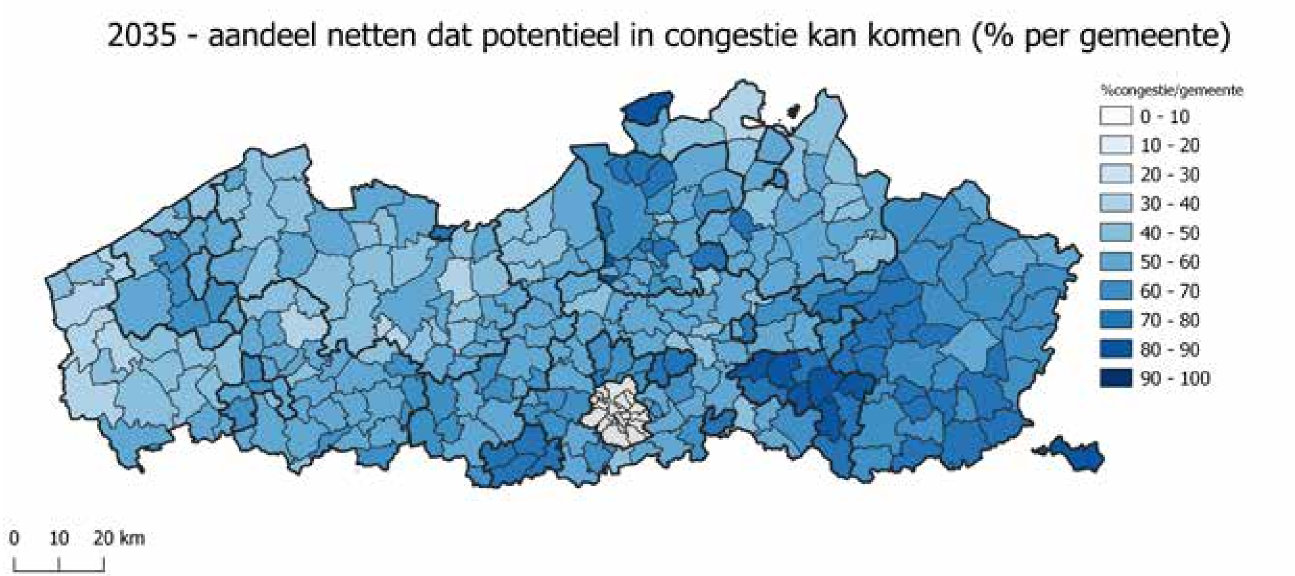




In addition, we examined the impact of more or less staggered charging. To this end, we considered 60%, 30% and a theoretical minimum of 15% simultaneous charging. For this theoretical minimum, we assume a maximum distribution when charging the electric vehicles during a full day.

The analysis of the distribution of charging tells us that the impact on peak consumption is major, hence the need for investment in the distribution network. Charging distribution – particularly outside the evening peak – will ensure that grid investments are less urgent toward 2050. In the short term, the impact of mitigation measures to distribute charging behaviour is likely to be limited. Therefore, within the time horizon for this Investment Plan (2024-2033), major simultaneity (~60%) is assumed.

Finally, the time of maximum injection peak (afternoon peak) was also simulated. Several simulations were run in preparation for the Investment Plan, including a scenario where the expected growth in solar panels is large.



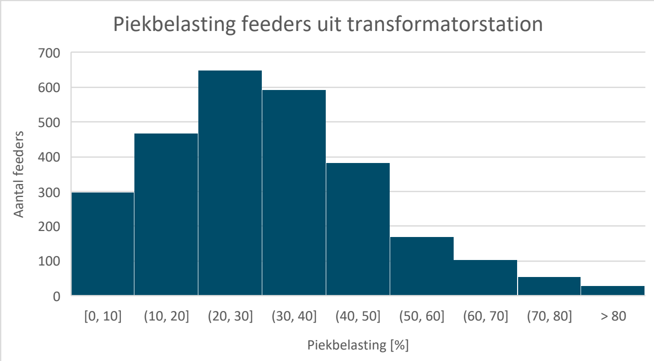
It follows from the results that – save for in a limited number of situations – the same network elements are impacted. Thereby, the impact of electric vehicles and heat pumps during the evening peak is significantly greater than the impact of PV on the afternoon peak. When developing the concrete cases for grid enhancement, Fluvius will systematically consider whether the enhancement for consumption are sufficient to accommodate decentralised production as well.

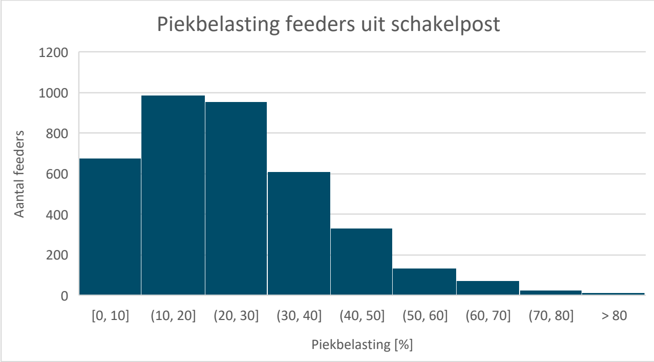
The estimation of the increase in PV has no impact on the planned investments, since the summer peak is secondary to the winter consumption peak. This does not rule out the possibility that locally larger spikes may also occur temporarily due to injection. After all, there is no uniform distribution of solar panels, nor electric cars, on every low-voltage cable.

The impact on the high-voltage distribution grid

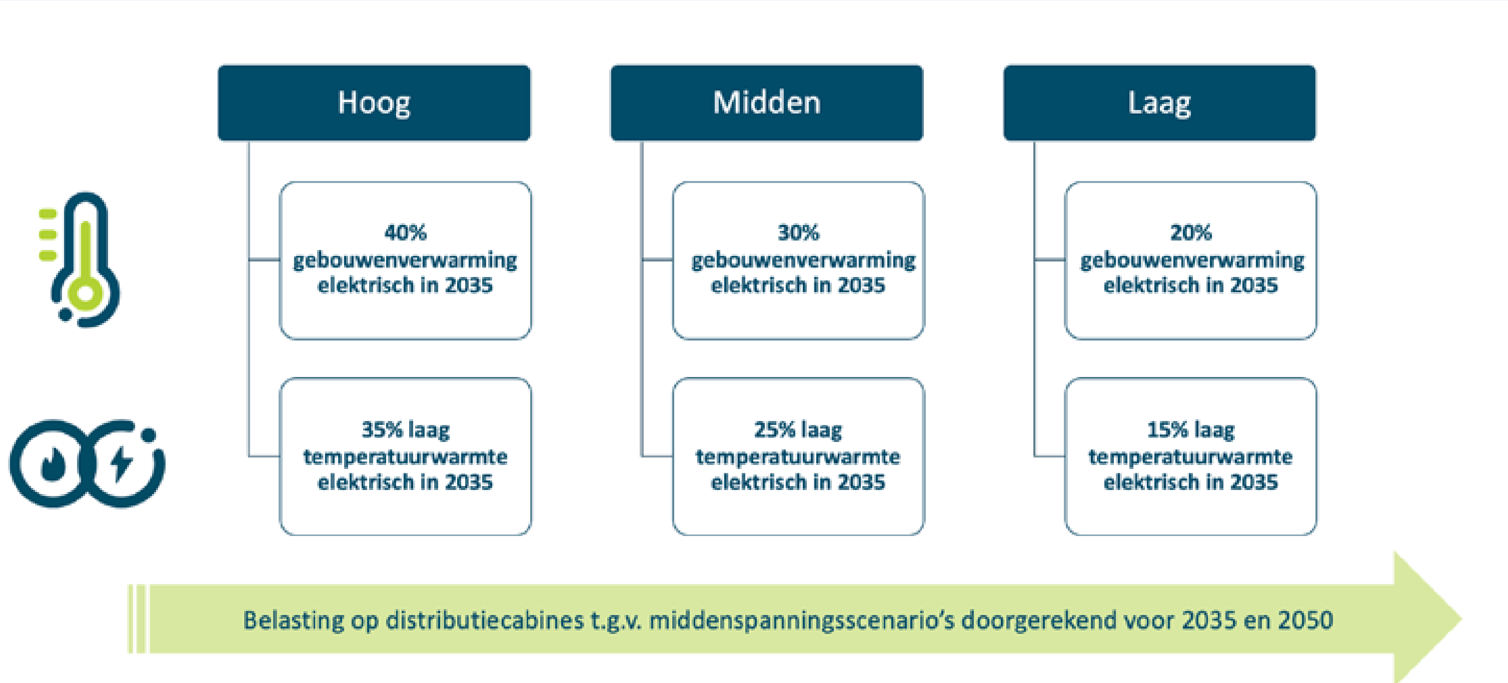
There is currently no congestion on the high-voltage distribution grid. The graph below shows the peak load on the various **high-voltage feeders** departing from transformer stations and switching stations.

Note that a large proportion of feeders are at less than 50% load. This is mainly a result of the redundancy designed on the high-voltage distribution network.



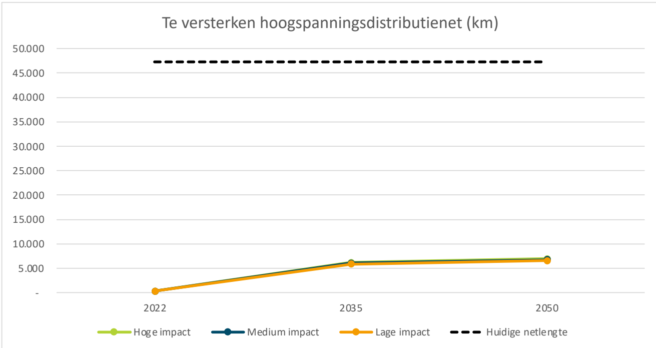


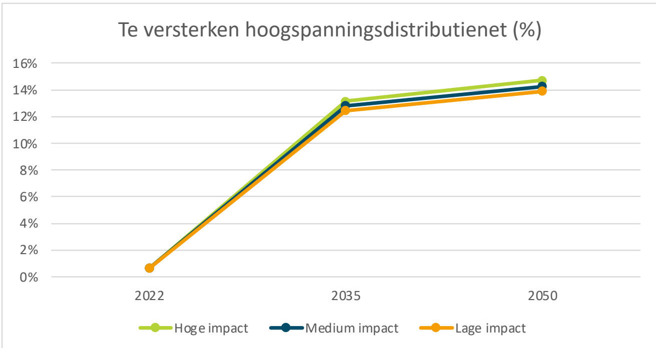
The future scenarios for high-voltage electricity are a combination of the aggregated impact on low-voltage, projections for charging at work and along motorways, electrification of (building) heating and of process heat in the industrial/service sector, and prospects for larger projects (wind development, data centres and charging infrastructure for public transport). We considered three variants in line with the electrification of heat demand:



We also calculated the load on distribution cabins resulting from the 2035 and 2050 low-voltage scenarios at high-voltage, adding the impact of electrification of heating and low-temperature process heat for professional customers.

The peak load at an interconnection point does not necessarily occur in the (winter) evening and varies by interconnection point due to the major regional impact. Some interconnection points are almost exclusively connected to professional customers. At other interconnection points, the proportion of residential customers is higher. Therefore, the simulations were run separately for each interconnection point, at the relevant peak time for that interconnection point.





Note that part of the high-voltage distribution grid to be enhanced consists of cables at less than 100% load. This is a result of the redundancy designed on the high-voltage distribution network. In the event of an incident (such as a cable failure), it can be re-switched to re-feed as quickly as possible and reduce prolonged high-impact incidents.

In particular, we also included the developments for charging infrastructure and high-voltage wind projects (see: *Charging infrastructure for electric vehicles* and *Onshore wind*).

More details on the calculation method used can be found in appendix: *Method for forecasting annual peaks high voltage feeders and stations*.

The impact on transformer stations

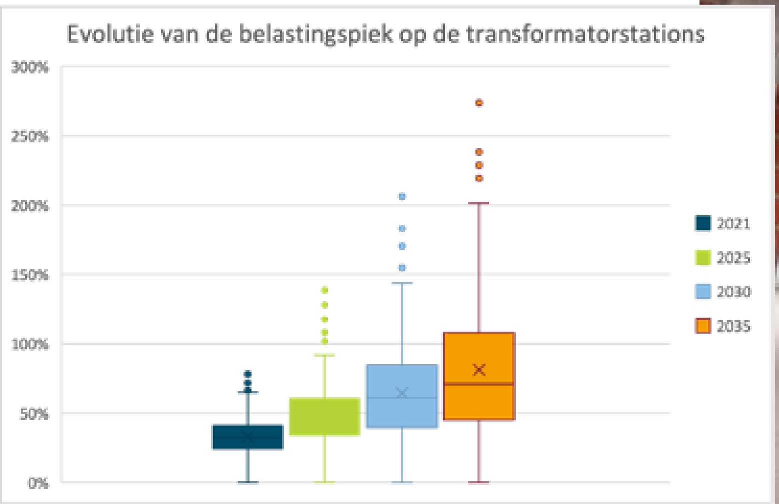
There is some congestion on the **transformer stations** and the transmission grid – mainly due to over-injection when there is a lot of wind and solar production. This congestion is occurring on assets owned and operated by the transmission grid operator and is impacting the distribution grid and distribution grid users. The appendix: *Explanation of bottlenecks in the distribution grid* further explains these and other bottlenecks in the distribution grid.

Based on the previous scenarios, we calculated that energy consumption on the distribution grid will evolve from about 32TWh to about 50TWh in 2035. This will also have an impact on the transformer stations.

We see the heaviest impact on transformer stations to which distribution cabins are predominantly connected and are thus residential in nature. In this process, transformer stations with low transformer capacities are overloaded first. The impact on industrial transformer stations remains limited – barring exceptions due to major customer requests.

The graph shows the evolution of the load peak at all transformer stations. A 100% load corresponds to the full installed power of all the transformers combined.

Taking into account the long lead times, prioritisation of transformer stations to be enhanced is recommended, followed by an accelerated proactive investment policy. This must be done in collaboration with the transmission grid operator Elia: within a 10-year time horizon, we must take measures for at least 80 transformer stations.



Electricity grid measures and investments

The network impact determined in the previous section shows that large-scale measures must be taken to enable the energy transition. Through a combination of investments and mitigation measures, we want to be ready for the challenges ahead.

In this section, based on our **investment policy**, we will provide an insight into the measures being considered and applied to resolve the anticipated bottlenecks. We will then explain how we consider **alternative solutions** complementary to investment. Finally, we will discuss the concrete fields of action and sites, and clarify that significant additional grid investments in the distribution grid are necessary, whatever future scenario unfolds. Here, we will determine the **'no regret' investments**: the necessary investments to provide the necessary capacity in good time, on the one hand, and to leave plenty of room to implement alternative solutions, in response to electrification, on the other.

Investment policy for electricity

Fluvius' investment policy is developed and/or updated taking into account external regulations and our internal basic principles. It is founded upon Value-based Asset Management. The investment policy balances cost, risk and operational performance over the full life cycle of the asset.

Planning and design of low-voltage distribution grids

Fluvius maintains a proactive policy in its design of low-voltage distribution grids and carries out grid enhancements where necessary. For each of the prompts listed below, a grid study is conducted that thoroughly examines the local grid situation:

- New subdivisions
- Customer requests for consumption > 25kVA or where no suitable distribution grid is present
- Customer requests for decentralised productions > 10kVA
- Voltage issues or indications of excessive load via grid protection, monitoring and simulations
- Synergy with other utility lines, other utility companies and road works
- Proactive replacements based on Fluvius' replacement policy
- Proactive enhancements based on grid simulations

Fluvius shall ensure in its grid design that low-voltage distribution grids maintain a sufficient margin, taking into account the criteria mentioned above. That margin must be there for the (partly uncontrollable) growth of residential connections, including the expected increase in heat pumps, solar panels and electric vehicles. Because the grids have only limited capacity problems today, there has been a rather limited need for grid enhancements to date. But with electrification, there will be a shift to more proactive grid enhancements, based on grid simulations or other parameters.

When designing **new low-voltage distribution grids**, we always try to estimate future capacity requirements, as grids have an anticipated technical life span of 50 years:

- For new subdivisions, where the car can park on the premises, a standard 400V distribution grid is sized based on home connections of 17.3kVA, so that each home can have a heat pump. An electric car can thus be charged with some simultaneity with a charging capacity of 11kVA. Each home also has a PV facility within this sizing.
- For a subdivision where separate parking/charging islands are provided, and the cars are in a car-free zone, we obviously do not include the home charging option for grid sizing purposes.
- For a subdivision or zones where there is a high-temperature heat grid, these values are adjusted downwards, as we expect a lower proportion of heat pumps here. The assumptions about electric vehicles and PV remain the same.

We consider the above assumptions when designing new subdivisions or grids. For our grid construction, we choose the standard cables that definitely meet the needs.

Existing low-voltage distribution grids are being replaced not only because of their age, but also based on a lack of performance in the broadest sense. Grids are enhanced when capacity is no longer adequate, or owing to voltage quality problems. They are replaced at high error rates. When works are planned for another utility line or by another utility company, we always evaluate the necessity of works on the low-voltage distribution grid. Certain old cable types (e.g. PILC) are more susceptible to damage while working. Therefore, they are replaced preventatively if any excavation in the immediate vicinity is deeper than 50 cm, even if the cable was in good condition before the start of works. A new cable, regardless of the voltage at which it is operated, always has four conductors. This allows it to be converted to 400V in the future.

Voltage problems on the low-voltage distribution grid

In recent years, there have been frequent local problems after solar panel inverters failed due to a violation of the voltage quality standard (EN50160). This issue often arises in long low-voltage distribution grids, which have historically been designed for pure consumption of electricity and where the installation of decentralised generation locally creates too high a voltage level. Fewer than 0.5% of PV customers within our operational area report any problems.

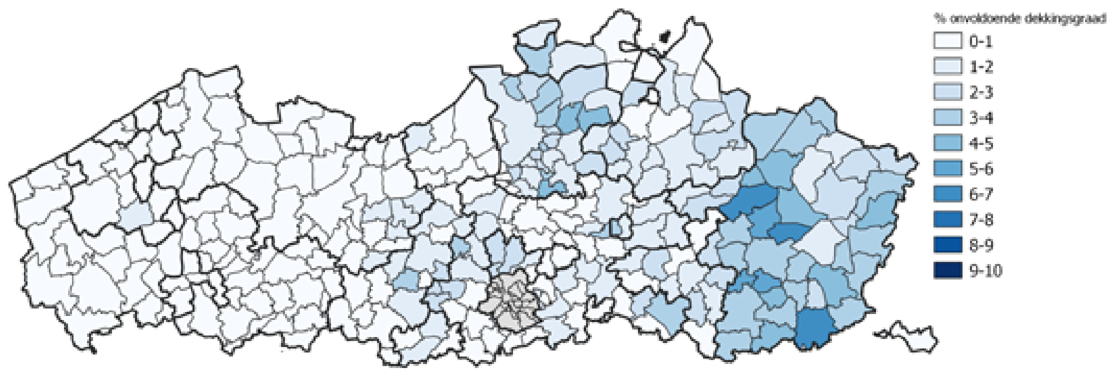
Any voltage complaint is, of course, regrettable. As a company, we make every effort to prevent complaints on the one hand and to resolve them as quickly as possible on the other. Fluvius is developing and using tools for managing, predicting and anticipating local grid problems on a macro scale. The possibilities for monitoring local grid situations will increase greatly in the coming years, not least thanks to the roll-out of the digital meter. This will allow us to take more and more proactive management measures.

Today, however, Fluvius still often has to work in reactive mode. Customers who are inconvenienced, for example, by a power outage or too low or too high a voltage, will contact Fluvius. Reports of voltage problems are investigated through an established process. We contact the customer and analyse their complaint. In the first step, we make an analysis of the complaint (potentially on-site). In doing so, we examine the local grid situation, measure the voltage at the customer and in the distribution cabin, and verify whether or not the problem is at the customer's indoor facility.

If voltage problems are caused by local congestion on the distribution grid, we provide compensation in the event of an inverter failure. This takes place in accordance with the conditions set out in the Government of Flanders' Energy Decree.

Voltage problems can be resolved with or without investment works, depending on the cause. The fact that, in some cases, investment works are required to resolve the voltage problems does not detract from Fluvius' proactive policy on grid enhancements. More details in the appendix: *Resolving voltage problems*.

The image below shows zones where we are investing in additional cables or distribution cabins in the near term to resolve local problems, including solar panel inverters dropping out due to a high variation in voltage. One of the major challenges here is finding available land or locations for the placement of distribution cabins. Unfortunately, that makes for longer lead times.



Monitoring 230V grids and making a 400-volt grid available to all grid users

Another challenge is the 230V grids that have historically been located mostly in urban and village centres. These grids are equivalent to 400V grids in terms of delivery reliability and safety. However, they have less capacity, so they become saturated more quickly.

Our new standard grids are 400V grids. In order to create additional grid capacity, or at the request of customers who need a 400V connection, we provide 400V grids where there is only 230V today. The operating voltage of 400V also contributes to energy-efficiency, thanks to lower grid losses. The grid losses per kWh transported are three times lower than those for a 230V grid with the same section.

By the end of 2022, there were 18,431km of 230V grid in service at Fluvius. This is a decline of about 170 km from a year earlier. In the coming years, we expect a further decline in the 230V grid.

Phase-out	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
3x230V grid	-403 km	-660 km	-652 km	-642 km	-642 km	-642 km	-642 km	-642 km	-642 km	-642 km

The phase-out of the 3x230V grid depends upon the number of 3-phase consumers involved.

The 230V grids are not homogeneously distributed throughout the Fluvius operational area. Thus, especially in the urbanised and western regions, we still see a great deal of 230V grid.

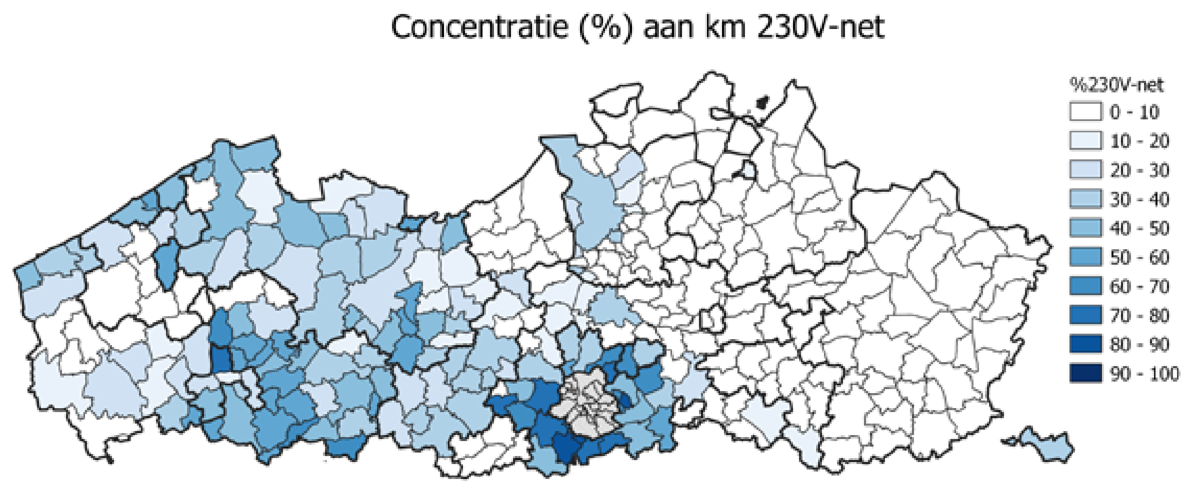


Figure 9: Concentration (%) of 230V grid km by municipality.

About 26% of our low-voltage customers are connected to a 230V grid, but this proportion varies greatly between different operational areas. Customers who are connected to a 230V grid and yet need 400V because of the installation of a charging station or heat pump can request 400V and will pay only an administrative fee since 2023. This administrative compensation by the customer serves as an incentive for avoiding unnecessary requests. In 2022, we received 1,953 requests from customers for the provision of 400V. In most cases, we chose to install an additional 400V cable.

Fluvius is proactively taking initiatives to make 400V available within an acceptable time frame. For example, there are still a limited number of distribution cabins that can only supply 230V today. For these distribution cabins, there is a chance of a longer lead time. These cabins will be converted as soon as possible and fitted with a transformer and low-voltage board with 230V and 400V. Last year, we provided 400V in more than 150 existing distribution cabins. Fluvius plans to have 400V available in all cabins by the end of 2025.

In 2007, a programme was launched to replace the underground cabins in the region around Brussels with overhead distribution cabins, which have an output voltage at 400V. Due to the urbanised nature and regulations relating to land use planning, it is difficult to obtain land or cabin space in the right location. As a result, it is often only possible to obtain a cabin room in new construction projects. Therefore, in the study for connecting the construction project, the low-voltage distribution grid will be adapted to current requirements.

In new subdivisions or expansions, for several years we have chosen to install a 400V grid. In works, we have been laying cables with four conductors for decades. The laying of a cable with four conductors operated at 230V creates additional spare capacity that can be utilised in the future by a conversion to 400V (+73%).

When Fluvius provides 400V in a street where a 230V grid is present today, we make a trade-off: do we install an additional adjacent cable at 400V, or do we convert the existing cable with its associated connections and customer facilities to 400V? In future years, an additional adjacent cable will usually be chosen. In late 2022, there were about 670km of 230V and 400V grids adjacent to each other on the same street. We expect this proportion to increase significantly.

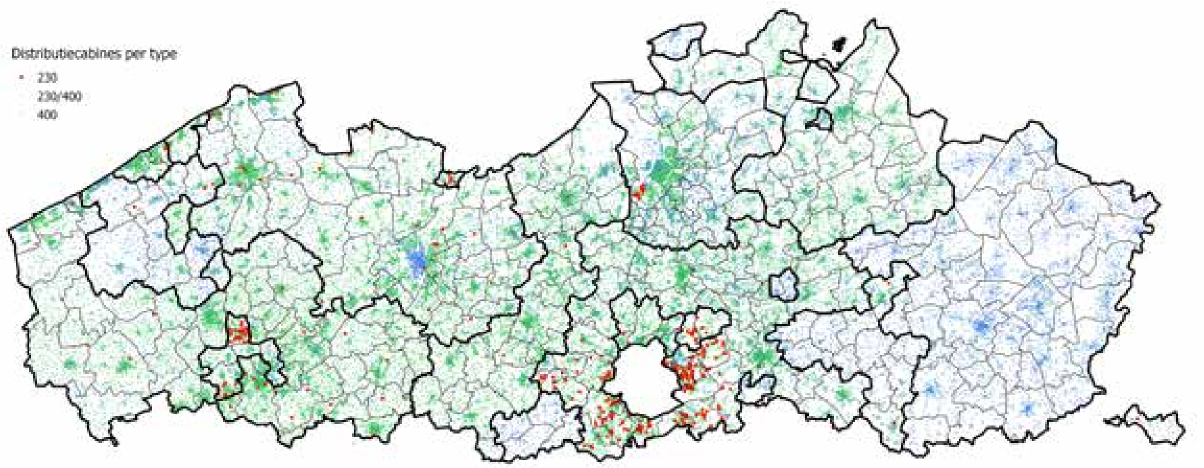


Figure 10: Concentration of distribution cabins capable of supplying 230V, 230V/400V or 400V. For historical reasons, these cabins are mainly located on the outskirts of Brussels.

Converting a 230V grid to 400V is only more cost-effective if only a limited number of three-phase users are connected. After all, converting appliances from 230V to 400V is not the easiest job, nor is adapting the indoor facility. Organisationally, this is quite an undertaking: customers' facilities must be converted in a very short period of time (the same day). This can only be done if all the customers are at home or their homes are accessible.

The concentration of three-phase connections varies widely geographically. In some regions (e.g. outskirts of Brussels), a three-phase connection was the standard connection in the 1980s-2000s. Because this is done in conjunction with sufficient distribution cabins (possibly expanded with an additional underground transformer), we do not yet have any capacity problems in that region.

Over the past few years, we have made an effort to adapt the grid whenever possible in road and sewer works and the adjustment to utility lines. Thus, a strong reduction in 230V has already been achieved since the start-up period in 2007.

In the appendix: *Monitoring of 230V grids and making 400V grid available to all grid users*, you can find some additional information on the monitoring of 230V grids, in line with the Electricity reporting model (VREG, 2022).

Planning and design of high-voltage distribution grids

High-voltage connections are always the subject of a specific grid study. Depending on the possibilities, the optimum connection scenario is always sought.

Fluvius is making proactive investments in backbone enhancements at those locations where high feeder peaks or significant voltage variations have been observed or are anticipated in the future. This way, we can avoid a situation where a request for connection to high voltage encounters a structural lack of grid capacity.

For any request for local production larger than 400kVA (PV, wind, CHP and others), we inform Elia of the request. We coordinate as to whether there is sufficient reception capacity at the transformation level and/or the higher-level grid. At a number of interconnection points with Elia, the traditional reception capacity has been used up. The provision of flexible reception capacity is recommended for making local production in those zones still connectible in the short term. We explain this further in the appendix *Explanation of the bottlenecks* in the distribution grid. In order to provide some longer-term solutions, investments by Elia that increase reception capacity are also being discussed.

In concentration areas for local production (typically wind turbines or CHPs in greenhouse horticulture), for specific projects we are investigating connection options at higher voltages (30kV or 36kV). That way, we can still make the total potential connectible at minimal cost.

Wind farms or clusters and other large-scale production facilities are rarely connected to the existing grid due to their specific location and capacity, among other reasons. They need to be connected to a sufficiently strong point. This requires a specific study for each project.

CHPs close to industry tend to be connectible in a shorter period of time, as the existing network offers more opportunities due to the presence of large consumers. In most cases, CHPs in horticultural and agricultural areas do require additional grid extensions and enhancements. In areas of CHP concentration, sometimes combined with wind energy, specific solutions are necessary in consultation with the transmission grid manager Elia. These include applying flexibility, connecting to higher voltage or expanding transformation capacity.

Fluvius proactively works together with various governments and stakeholders – wind project developers in particular – to map out the potential of a region and cluster zones. This way, we can study appropriate scenarios in a timely manner and prepare adequate investments. In doing so, we coordinate with Elia on the necessary investments in the transmission grid.

Digitalisation of the electricity distribution grid

Digitalisation of the electricity distribution grid for better grid management

Digitalisation and automation are not an end in themselves for Fluvius, but a necessary step for making better and faster decisions about the management of our distribution grid.

By further digitalising and automating our electricity distribution grid, we aim to ...

- continuously optimise management of our **individual assets** throughout their entire life cycle. We will do so by converting the data we obtain through digitalisation using asset analytics into insights about the actual condition of the asset. Indeed, this condition ('asset health') evolves in line with a great many environmental parameters and the load history, which may differ for each individual asset. This will allow us to make increasingly targeted choices between maintenance, renovation or renewal.
- Optimist the management of the **electricity system**, thanks to an increasingly fine picture of grid load. This will allow us to better deal with evolutions in consumption and production, over different time horizons. That will enable us to:
  - have a better idea of how, where and when the grid structure is or will become inadequate. Based on this information, we will optimise investments;
  - take network support services or flexibility services into consideration. These are further explained in the *Alternative solutions supplementary to investment* section.
  - be able to provide feedback to our stakeholders on the actions of the grid, so as to trigger appropriate investment decisions with them as well;
- ensure more efficient **implementation of operational tasks**, such as (planned or unplanned) grid-switches via remote operation on our high-voltage distribution grids following an incident or maintenance. Or also: the treatment of voltage complaints on low-voltage grids. We will do this by remotely reviewing the relevant measurement data, analysing the condition of the grid and remedying it where possible, before we arrive on-site.

These choices will allow us to maintain grid performance in an increasingly complex system. At the same time, we are deploying our available people and resources more efficiently.

Fluvius has long taken the initiative to turn digitalisation and automation into useful applications, and thus into social value. Remote metering and control in the highest grid planes (transformer stations and switching stations), for example, has long been the standard. Fluvius (and its predecessors Eandis and Infrax) also has more than a decade of experience in connecting local production facilities with flexible access. In doing so, Fluvius and Elia are working together to SMART manage potential congestion in the distribution or transmission grid.

The challenge for further expansion of digital capabilities? That would be industrialisation for far larger volumes and a wider variety of digital assets, data and application areas (= down to the high-voltage distribution loops and low-voltage distribution grids).

In order to enable this scale-up, we need to take three major steps, within parallel development pathways and with concrete objectives:

- Building up a critical mass of digital assets in the grid.
- An integrated data platform as a foundation for data access and use cases.
- Implementation of concrete use cases: first through a pilot project on part of our grid, but always with further upscaling in mind.

Building up a critical mass of digital assets in the grid – roll-out of digital meters and cabins

Digitalisation begins with providing sufficient digital assets in the grid itself. In so doing, we can measure more in the grid (digital asset as a sensor) and automate certain operations (digital asset as an actuator).

Remote monitoring and remote management are already in place today at almost all transformer stations and switching stations. Thus, the highest grid plane of our distribution grid (the backbone) is already strongly digitally equipped.

In the underlying grid planes (high-voltage distribution loops and low-voltage distribution grids), we are greatly increasing the critical mass of digital assets. We are focusing here on **digital distribution and customer cabins** on the one hand, and **digital meters** on the other.

New distribution cabins will be digitally equipped as standard. This means that the cells in each new distribution cabin are equipped with remote measurement, operation and signalling. For prefab cabins, this involves all new cabins since 2021. More complex builds (e.g. built-in cabins) required a number of additional intermediate steps. The goal here is to have every new cabin digitally equipped by default from late 2023.

Customer cabins, for connections with request dates from 1/1/2022, will also be digitally equipped. Technical regulations and connection contracts have been adapted for this purpose.

We are digitalising **existing distribution cabins and customer cabins** in synergy at the time they are renewed, in response to a necessary aggravation or in line with normal life cycle management based on our Asset Management touchstones (e.g. for obsolete cabins with a higher risk score). There is therefore no active conversion policy for accelerating the digitalisation of existing cabins prior to end of life. That way, we will not unnecessarily ruin the value of existing assets, and yet will build a critical mass of digital cabins in distribution loops sufficiently quickly.

With this approach, focused on the digitalisation of new and to-be-renovated cabins, we anticipate installing 1,000 digital cabins per year in the distribution grid. By 2030, 12.5% of cabins in distribution loops should be digital.

We do have an active roll-out policy for **the digital meter**, with roll-out targets per customer segment as explained in *Accelerated roll-out of digital meter*.

The digital meter helps increase efficiency in regular market operations (e.g. remote reading of meter readings). It also provides the following grid management capabilities:

- **As a sensor**: these measurements add value to refine the understanding of grid load:
  - Voltage per phase, at the level of the connection, per quarter of an hour
  - Power taken from the connection per quarter-hour)- The consumed or injected kWh value exchanged, per day, or per quarter of an hour
  - Peak capacity consumed or injected by the connection, and time of it

  This allows us to feed our grid calculation models more and more with real data instead of estimated data (e.g. estimating peak consumption for a connection based on annual consumption).

- **As a necessary basis** for developing alternative methods to manage grid capacity. See *Alternative solutions complementary to investment* for this.

Integrated data platform as a foundation for enabling access to data from different sources

The digital sensors capture a lot of measurement data. In order to turn these into useful analyses, insights and applications, data from different sources must be combined. It often needs to be combined with other data not originating from sensors. For example: measurement data from digital meters should be easily linked to local grid data (topology, cable parameters, etc.), and from the applications ('digital twins') that simulate these grids, in order to get a good picture of the grid state.

Fluvius has a number of specialist core applications that contain data for their specific application. But we lack a foundation that allows us to flexibly combine data and perform complex analysis across these silos.

This was why Fluvius started a number of internal projects. We will build an integrated platform, as an intermediate layer between data sources and applications.

The central project in this (with the internal working name Athena) has been running since mid-2022 and will run until the end of 2024. Objective: to build a Fluvius data platform (including organisation and governance) on which data becomes combinable and datasets reusable. This is a coordinated, product-oriented approach, in compliance with all legal requirements – such as GDPR.

This data platform will help us and the market enable new applications based on combined market, asset and process data and will allow for rationalisation in the applications and their management costs.

With a view to efficiency, this project requires not only an IT architecture, but – as with all business transformation projects – a vetting of the enterprise architecture (the architecture of processes, applications, information and organisation).

Fluvius will thus lay the foundations for achieving speed in further digitalisation and to make data more accessible to more than just IT-skilled profiles (which are scarce on the market).

Useful applications of integrated data platform: first three use cases

We identified three use cases that are now being developed. Thanks to the further development of the IT architecture, they will be the first to be fed from this higher-level integrated data platform:

Refinement of proactive grid planning: we are refining our view of the future load on the high and low-voltage distribution grid, based on current grid situations and generic assumptions for continued growth, by supplementing it with further data.

Thus, on the one hand, we will refine our view of the current grid load by using digital meter data to refine the voltage image across a grid cable.

On the other, we need to enrich our generic assumptions about future grid load with available local information (e.g. concrete plans by a local authority to make streets car-free, which would require no charging stations on this street). We are launching a project to structurally set up the capture of this local information and its processing in our grid calculation applications by the end of 2024, making our processes more efficient and reducing the risk of errors or forgetfulness. In practice, the process of capturing this local information to get a better idea of investment needs is very much in line with concrete investment and implementation planning. After all, there is always a strong interaction with a local authority's plans regarding the layout of the public domain, both in terms of the need for investment (how much capacity should the grid have in the new situation?) and its timing.

Proactively dealing with incidents or complaints: we are utilising the information from the digital meter and the digital cab better, and we are combining it with the relevant grid data, for use in the event of disturbances on the grid – including the LV grid. This is needed, among other things, to properly assess the actual network condition more quickly and remotely, avoid useless trips, gather information without customer intervention and discover the extent of the failure in order to immediately send the appropriate services to the site.

Grid condition communication: we will share information about our grid condition that is useful to the market. Initially, in the second half of 2023, we will make the available connection capacity on the high-voltage distribution grid available as open data, per high-voltage distribution cable segment (this is an indicative value for a concrete connection request that must be confirmed each time by a study). This application is ahead of the development of the integrated data platform mentioned above. We will have them retrospectively fed from this platform so as to make their management more efficient.

We desire the same transparency for the low-voltage grid. In order to offer this efficiently and reliably, we must first develop the integrated data platform.

What about the flexibility pilot projects (see *Developing services and measures to increase flexibility*)? For the grid areas involved, we will enable visibility into the necessary grid load data from which the need for flexibility arises.

In addition, Fluvius is undertaking a number of other actions, independent of the integrated data platform, to achieve some direct benefits from the digitalisation of assets. We refer to the *Energy-efficiency of electricity* appendix here, on the placement of the open point in a distribution loop. As explained in this appendix, judicious placement of the open point can reduce energy losses, prevent voltage problems, and enable rapid re-powering after a failure for a larger number of customers.

Digitalisation of the electricity distribution grid at customer request

Today, we have already remotely metered and operated some customer and distribution cabins at the request of customers. Some examples:

- Switching from power supply transmission grid to distribution grid for a port terminal, in order to enable maximum decentralised production and reliable operation.
- Remotely operated circuit to ensure redundancy of power supply in line with process needs.
- Maximising decentralised production in line with grid situation.
- We are studying the question of replacing diesel-powered emergency groups with batteries in line with grid conditions.

Alternative solutions complementary to investment

Distribution grids today are largely designed to stay within capacity limits in a number of specific worst-case scenarios. As soon as it is clear that a particular grid section is in danger of becoming overloaded – either because of some form of congestion or because of too high currents or too high or too low voltage – we provide additional grid enhancements. In the coming years, the available capacity margin will be accelerated by electrification. As a result, congestion may occur, which is highly place and time-specific.

As a result of electrification, Fluvius must invest in a strong(er) electricity network. On the other hand, any measure that ensures better utilisation of available grid capacity and smoothing out peak loads is welcome. This means postponing or even cancelling investments, which helps keep overall distribution grid costs under control.

Alternative solutions will evolve significantly in the coming years. Further *digitalisation of electricity grids* will enhance the potential of alternatives. Digitalisation offers an accurate knowledge of the (local) grid situation, a better level of detail when looking for solutions, and more and better data for evaluating overall solutions.

Classification of measures for better utilising the distribution grid

The starting point for better utilisation of the distribution grid is a better understanding of the actual load. Digitalisation of power grids is making a significant contribution. The new and additional data supports any alternative measure for better utilising the capacity of the distribution grid, alongside standard investments in capacity increase/grid enhancement. These measures can be classified into the following categories:

- **Dynamic management** of grids: ensures better utilisation of existing physical infrastructure. Starting to manage grids dynamically and re-switching them according to load makes (temporary) residual capacity visible, deployable or better utilised.
- **Tariffs**: a more cost-reflective tariff such as the capacity tariff encourages the end user to stagger or more closely align consumption with their own production and thus self-consumption.
- **Market-based flexibility and/or support services**: sometimes, the grid manager cannot actively adjust undesirable grid situations with its own assets and passive incentivisation of customers is insufficient. At these times, it is useful to have customers actively contribute at times when grid capacity is insufficient. The choice to participate is free and lies with the grid user.
- **Technical flexibility**: participation here is mandatory and is driven by the grid manager. We consider technical flexibility only when the use of market flexibility proves not to be an option, for example in emergency situations or when the purchase of market-based flexibility is not economically efficient.
- **Local automatisms**: to deal with highly local phenomena, it is useful to have local automatisms built into grid-connected applications. This prevents different customers from being impacted by local phenomena. It also allows for reactive action to avoid local problems in the future. This is thanks to other mitigation measures or grid enhancements.

Fluvius' vision for flexibility

In order to achieve the climate objectives, the share of renewable energy must grow, and electrification must accelerate. Given the intermittent nature of renewable production, there is a need for solutions to match up supply with demand. This can be done, for example, by providing flexibility. This same flexibility can also be deployed at specific locations in the electricity grid where overloads or congestion occur as a result of electrification.

In other words, flexibility can be used for a variety of purposes, including portfolio management (by BRPs, customers, etc.), balance maintenance through frequency-related balancing services for the transmission grid manager and local application for grid management purposes of both the transmission grid manager and distribution grid manager. The latter category includes congestion management, which prevents voltage and/or current from exceeding the design limits of the asset.

Fluvius' role in this is twofold. Fluvius facilitates participation for all grid users in flexibility services for both portfolio management, balancing services and grid management by the transmission grid manager. Fluvius is also actively pursuing flexibility itself as a local application for grid management by the distribution grid manager, in particular for congestion management. Through both roles, we are pursuing the social optimum and optimising total system cost.

Flexibility provides added value both for the customer, the grid manager and society:

- The customer gets a connection faster, can deploy more decentralised production, or can use their (existing) assets to support the grid manager in building out the grids. This is how they generate added value.
- The grid manager can choose the most cost-effective solution to defer investment and better utilise its existing capacity on the grid. In doing so, we free up resources to deploy them where the societal benefit is greatest. This may involve temporary or semi-definite solutions, with the temporary solution being recurrently evaluated and reaffirmed.
- There is also added value to society. The distribution grid is not an inhibiting factor for climate objectives or economic growth. In addition, further solutions can strive to reduce disruption, optimise planning and further control costs.

That makes flexibility a necessary piece of the puzzle in this matter. It should help Fluvius continue to meet its customers' expectations in the full energy transition.

What is important here is that grid managers find a solution in flexibility alternatives that meets capacity needs in as certain a manner as upgrading the grid infrastructure. Market solutions to fill those needs are virgin territory for distribution grid managers and are de facto higher-risk solutions. This form of certainty will inevitably form part of the flexibility products that Fluvius intends to develop. Of course, the degree of certainty will depend on several factors, such as the availability of other solutions or local market potential.

The evolution towards fully-fledged alternatives is a growth process. It allows for this anticipated certainty to be built in and discovered as we go along, but also allows us to avoid market growth and development being impossible until all the guarantees are fully met. Nonetheless, that growth trajectory must include looking at solutions that can be implemented in the short term.

Developing services and measures to increase flexibility

Given the present growth trajectory in the development of market flexibility services, we are prioritising the development of explicit (market) flexibility to avoid congestion at transformer stations. This is with the participation of customers connected to all grid areas – both low voltage and high voltage. In a yet-to-be-developed market, this offers the greatest market potential for problems that are already emerging and involve the greatest investment costs and lead times. However, when developing explicit (market) flexibility[6] for congestion management at transformer stations, we aim to provide solutions for congestion on the high-voltage distribution grid as well.

We do not believe that explicit market flexibility can provide a solution for preventing low-voltage congestion. We do believe that most of the value in participating in flexibility for low-voltage customers lies in balancing services, portfolio management – including individual optimisation – and flexibility services to avoid congestion in the 'higher-level grid'. That means we should not exclude low-voltage customers from this market, because there is insufficient grid capacity available due to insufficient grid investment.

Moreover, the solution to avoiding congestion is to look locally. This is why only a very limited number of grid users connected to low voltage can help avoid this low-voltage congestion. Test projects by distribution grid managers in our neighbouring countries and initial impressions in academia also point in this direction (Martín Utrilla, Cossent, & Chaves, 2022). The potential and availability of low-voltage flexibility to resolve low-voltage congestion will gradually become apparent. They could contribute on a potentially large scale towards avoiding high-voltage congestion.

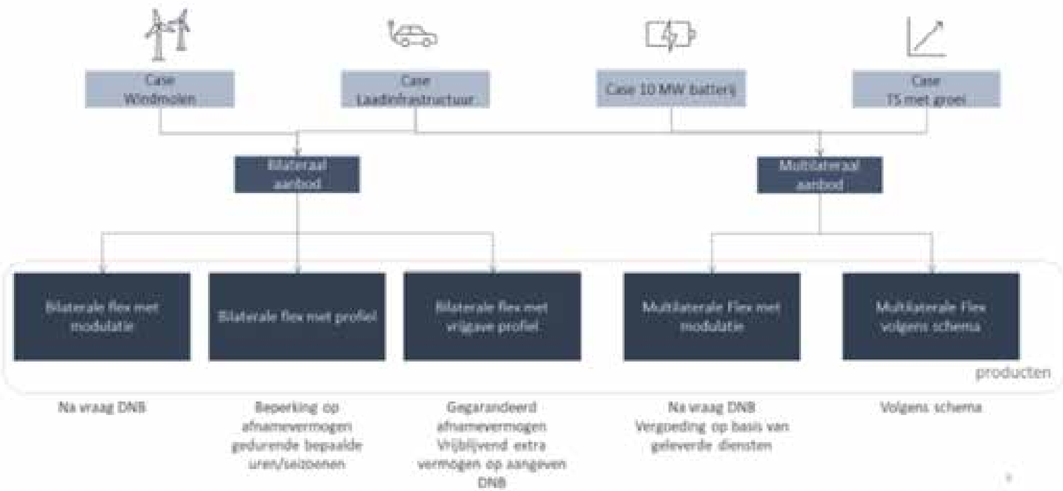
Over the past year, we have continued to shape the specifications for the market-based procurement of flexibility and the rules for the procurement of support services. Following stakeholder consultations, a new version was submitted for consultation, after which – subject to approval of these rules by our regulator – we can proceed to market testing.

6 Consultation specifications for the procurement of market flexibility, support services and grid losses 2023 | Fluvius

Various market products are being developed to cope with congestion that may occur in subsequent time periods:

- On the one hand, congestion predicted with reasonable probability in long-term analyses as part of the annual preparation of the Investment Plan. This means at least one or more years in advance, usually influenced by organic growth;
- On the other hand, we are dealing with congestion created by concrete requests for significant new connections or the significant enhancement of existing connections in an area of the distribution grid with limited residual capacity. Due to the legal obligation upon network managers to provide the customer with a quote, in the short term this may lead to a longer lead time for the implementation of the connection (due to necessary investments in the distribution network) or even rejection of the customer's request;
- Finally, congestion may occur that is linked to the operational management of the grids and to the management of planned and unplanned outages in particular.

As part of this consultation, the following proposed market products with an accompanying roadmap were developed. The proposal focuses on the first two time periods above:



Consideration framework for grid investment versus flexibility

For some of the investments in additional capacity, it makes sense to weigh the potential investment cost up against another component. That component is the potential that customers can actively contribute – through the market or regulations (through technical flexibility) – towards avoiding or deferring the investments in question. Fluvius has a number of important concerns in this regard:

❶ **It is best to limit the time for flexibility or support services (contractually)**

Not only is there a highly evolving market, each new development (synergy, customer demand) also requires a re-evaluation. For market (stability) itself, a minimum term is also desirable, from which it follows that a balance must be sought between flexibility services and grid investment. Even when investments are needed but cannot be made in a timely manner, flexibility may provide a temporary solution.

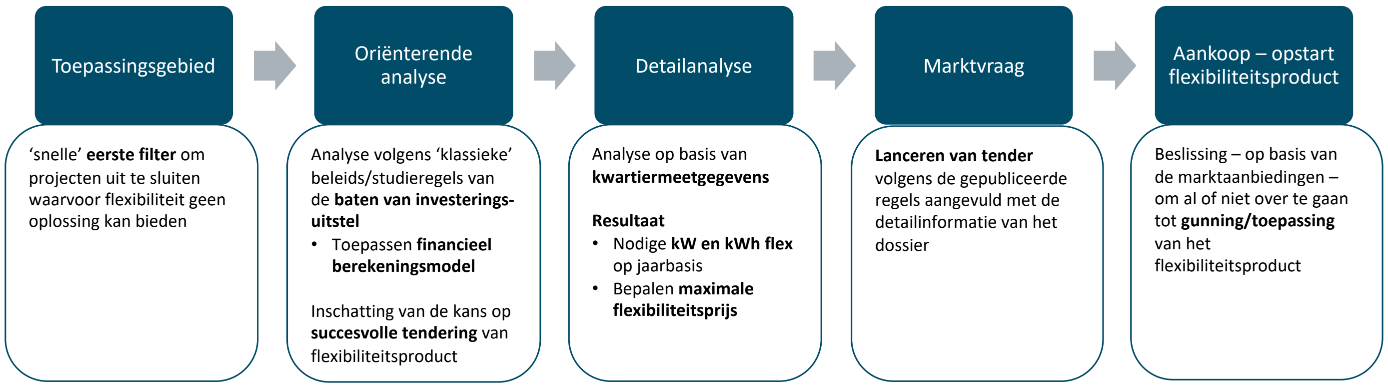
There are a number of situations where a review due to a re-evaluation may be relevant:

- The contracted flexibility is no longer sufficient: Growth on our grids continues apace. At the time of contracting market flexibility, certain new investment cases (e.g. new customer demand) were not yet known. In such an event, Fluvius should reassess the situation when there is clear growth, or there is new and significant customer demand.
- There is a significant evolution in pricing: An accretion of flexibility in a particular zone may lead to a significant evolution in pricing over the initial period due to the ratio of supply and demand. In addition, by stacking multiple flexibility services at both TSO and DSO, participation in flexibility of certain assets may evolve from a cost recovery fee to a marginal incremental cost fee. Increased supply may be a driver for this.

❷ **Flexibility should be technology and customer-neutral to the maximum extent**

Economically meaningful cases for the distribution grid manager will first manifest themselves at the higher grid levels. But this should not be a barrier to participation of any customer (including e.g. low-voltage customers) in flexibility products. Once a customer is technically capable of providing the flexibility service and the location is relevant, participation should be possible.

In order to weigh up the extent to which flexibility is an alternative solution for a grid investment in accordance with Article 4.1.19 of the Energy Decree for each investment case, a consideration framework is used. If the evaluation using this consideration framework shows that the purchase of flexibility products makes sense, then the process for purchasing flexibility is initiated.



We distinguish five stages within the consideration model.

An initial evaluation takes place within the first two phases. This aims to filter out projects where flexibility has little added value, both technically and economically. This is why we consider these aspects:

- it does not involve investment cases linked to **remediation** or **assets with known underperformance**;
- a minimum investment cost: if this is too small, the potential benefits of flexibility are also scant and investment is preferred. Indeed, with minimal effort, in addition to the overhead cost of flexibility cases, the potential grid risk is completely eliminated;
- an initial exploratory analysis indicates **no major crossings of grid boundaries**. After all, these occur when there is a structural lack of grid capacity, which can only be solved through investment.

Consequently, in the cases below, Fluvius will in principle always opt for grid investment:

❶ Remediation

Fluvius will proceed with the remediation (replacement or replacement with extension) of cables according to their life cycle management. Life cycle management is based on cable technology and capacity and the performance of the cable(s). Potential triggers: the technology (e.g. PILC cables), the capacity (e.g. 15 -35 mm^2 cables vs. current standard 150 mm^2), frequent spontaneous failures within a certain length, or cables that will be difficult to reach in the future due to, for example, axis shift of roads. An important note in this matter is that work is started after both remediation needs and enhancement needs have been identified. The schedule for this work is then optimised, taking into account, among other things, customer and synergy demands.

In summary, then, these are situations where Fluvius has already identified a certain operational and business risk. We therefore included them in the life cycle management for these types of assets. Market flexibility has no impact on those existing risks, hence it is not a solution.

❷ Congestion on low voltage

Market-based flexibility as an alternative to investment in the low-voltage distribution network is limited mainly by the small construction cost to resolve the problem, the limited flexibility market and uncertainty regarding growth scenarios and supply stability. Test projects by distribution grid managers in our neighbouring countries and initial impressions in academia also point in this direction (Martín Utrilla, Cossent, & Chaves, 2022).

At this time, therefore, we are not focusing on purchasing flexibility for low-voltage distribution grids. The same applies to the distribution transformer, since it involves a limited cost and an asset that can be redeployed to another location in the distribution grid if compliant. Therefore, the asset should not be considered systematically scrapped.

To be clear, we do not exclude low-voltage access points from participation in the supply of flexibility as an alternative to investment in higher-voltage (high-voltage) grids.

❸ Multiple cables or use of larger sections

In this case, there is always a minimal investment need (for example, due to a remediation). This means that much of the cost (for example, trenching costs) must be borne anyway. Since the financial impact of a thinner section or cable in the model is an order of magnitude lower than the investment for the entire case (the exact percentage depends on the length, section and number of cables), we consider it very unlikely that flexibility can yield savings here. Therefore, we will make no further analysis or calculations to initiate the demand for market flexibility for these cases.

❹ Synergy

Synergy has a significant impact on the cost of investment. However, it is important to note that not all work is automatically carried out with synergy. A specific customer demand, for example, does not necessarily involve synergy. Moreover, it is unlikely that there is full synergy across the entire length of the route.

The trade-off considers both short-term and long-term synergy, or a combination of the two. Fluvius does not rule out all cases with synergy at this stage. Only cases where short-term synergy is present, without any prospect of future synergy, are excluded. We are considering including more cases (e.g. based on length, investment size and synergy potential), to avoid excluding any potential profitable cases.

However, we note that if there is already synergy in the next year, it is very difficult to justify a meaningful business case for deferring investment, especially if there is no forecast for future synergy benefits.

The third phase also adds **information on the required flexible capacity** (capacity, volume, duration and number of activations) through detailed analysis. In the trade-off, the classic investment scenario is always weighed against one or more scenarios where flexibility plays a role in whole or in part.

Within the financial consideration model, Fluvius takes into account the differences in costs associated with the solution scenarios. Among other things, we talk about:

- **Standard investment costs**: all costs associated with classical investments (equipment, contractor costs, wages and overhead/supervision);
- **Time aspect**: we consider a particular time period until a certain synergy opportunity, a maximum deferral period in growth scenarios, etc. In each case, flexibility is considered over a certain predetermined period;
- **Synergy**: knowledge of synergy opportunities, both in drawing up the case and in the future, has a strong impact on the added value that flexibility can bring. Synergy can mean, on the one hand, that investment deferral is not an option, and on the other, that a synergy opportunity can be exploited later by deploying flexibility in the interim;
- The current **financial parameters** such as WACC, inflation and discount rate.

The **cost-benefit analysis** evaluates whether the flexibility solution for Fluvius is the most cost-effective solution to resolve the congestion problem. This involves identifying the costs and benefits of the various solutions (market flexibility, technical flexibility or classical investments) over a full life cycle.

The final result of the model gives the budget available to purchase flexibility from the market, based on the time period chosen and in line with the market flexibility needed.

The results of the modelling may still lead to a choice other than a flexibility purchase. This is the case, for example, when the purchase of flexibility is economically inefficient.

Only after tendering is the market price known and the final trade-off between market flexibility, technical flexibility or investment is made. We may charge for the uncertainty risk associated with market flexibility at that time, if necessary.

Because the actual market price is not known until after tendering, the final trade-off between market and technical flexibility and investment can only be made after that. As indicated by VREG[7], estimation of available flexibility and corresponding commitment by flexibility providers may be difficult/risky in this case, and may lead to a brake on the provision of market-based flexibility. As a result, an important part of its potential is at risk of being lost. This is why Fluvius wants to launch multiple successive market demands for shorter deadlines: for a customer demand, when studies are resumed, multiple times at already contracted zones, etc. These market demands are not tied to the publication of the Investment Plan. As a result, the cost price for market-based flexibility is not fully known at the time of consideration in the Investment Plan. Therefore, a new methodology is needed to estimate the cost of flexibility, regardless of the type of flexibility:

- Consumption: based on experience from market testing
- Injection: 120% x allowance for reserved technical flexibility (see Energy Decree Article 3.1.34/3)

Only during the operational phase can the consideration of extraordinary circumstances take place. Because only after launching the most recent market demand does Fluvius have sufficiently accurate information to weigh up market-based and non-market-based flexibility.

This version of the consideration model is used in identifying relevant cases for market testing. After the specifications for market flexibility are adopted, this trade-off framework can be applied more widely. The consideration model and its decision parameters will be adjusted gradually and frequently based on the results. We must strike a balance: in the number of cases that go through all or part of the model, but also in the number of cases that effectively lead to a flexibility purchase. To that end, the necessary feedback loops will be provided. We regularly re-evaluate flexibility needs and the associated contracts. And we review the decision parameters to ensure that as many cases as possible lead to market demand. In doing so, we limit our efforts for cases that do not ultimately lead to market demand. These parameters should also allow for the proper handling of the uncertainty inherent in future estimates.

In the appendix on *Flexibility* , you will find a decision tree that explains previous steps in detail, with the various options in each step. Note that we follow this decision flow when evaluating different investment cases when the Investment Plan is prepared. We do the same when we identify the risk of congestion in the planning phase, so that more frequent market requests can be launched subject to approval of specifications for flexibility and support services. This approach is similar to that for customer cases.

7 https://www.vreg.be/sites/default/files/document/cons-2023-01_consultatiedocument.pdf

Electricity grid investments

Regular investments and additional investments for the energy transition

Based on internal investment policy, forecasts and trends related to projects (backbone works, road works) and external requests (subdivisions, customer requests, municipalities), the numbers for **regular investment works** are determined for each asset.

Investments for wind projects and larger charging infrastructure will be discussed and budgeted for based on actual projects by the developers involved.

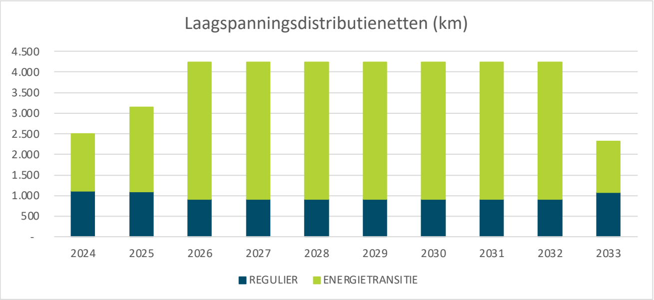
In calculating the network impact, we note that the anticipated electrification will have a significant impact on the distribution grid. The need for **additional grid investment for the energy transition** will depend heavily upon the actual impact and timing of electrification and the breakthrough of mitigation measures that stagger usage over time.

Since the energy crisis, there has been a decline in load on the distribution grid. Despite the downward trend in decreased volume and asynchronous peak, we do continue to observe larger local peak loads. Moreover, we expect a significant increase in electrification in the coming years as a result of the energy transition. Therefore, we are maintaining the same strategy as last year and retaining the 'no regret' investment budget for the period 2023-2032.

The reasoning behind the 'no regret' investment budget? Despite the uncertainty about future scenarios, we have budgeted for the necessary investments that are sufficiently ambitious until 2032 to get the grids ready in time (including for scenarios with faster electrification), and that are not redundant given the further electrification we expect after 2032 (including for the scenarios with less rapid electrification). Many market participants are anticipating major electrification and European ambitions are high. This is why we are positioning the 'no regret' investment budget between a medium and high scenario for electrification. In doing so, we deliberately chose not to fully align our investments with the high scenario. This leaves ample opportunity for alternative mitigation measures for grid investments, including flexibility.

The Investment Plan is not something static for the next 10 years, but rather a cyclical thing. This has the advantage that the proposed 'no regret' investment budget can be adjusted both up and down annually based on actual trends, additional policy measures and the development of future insights. We will monitor market, policy, regulations, user behaviour and grid load to make the necessary optimisations at each iteration. It is true that in sizing the grids we are building today, we take into account the current simultaneity of load. We are not taking account of any future developments.

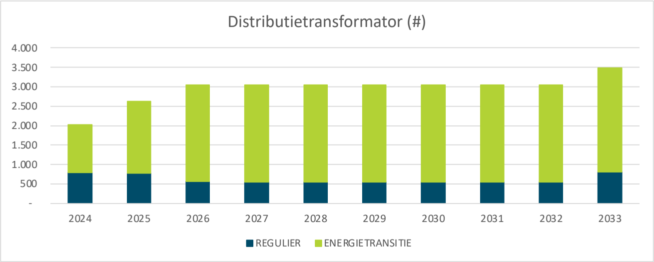
The regular investments and additional grid investments for the energy transition are shown in the following graphs.



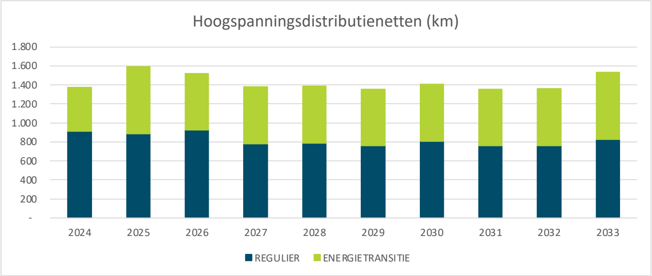
In order to enable electrification for low-voltage customers, additional enhancements to the low-voltage distribution grid are needed. Within the time horizon of this Investment Plan (2024-2033), it is unclear what the effect of yet-to-be-developed mitigation measures will be. We are making a conservative estimate, taking into account a high network impact. Towards 2050, we are providing room for mitigation measures, which may reduce the additional investments in low voltage.

Based on the investment policy, older low-voltage cables are being replaced and expansions are coming, by adding one or more new cables at 400V. To enable low-voltage customers to electrify, we will need to upgrade or expand at least 40% of low-voltage cables (30,000 km) by 2032. The long-term need for grid enhancements depends heavily upon the implementation of mitigation measures that help spread consumption.

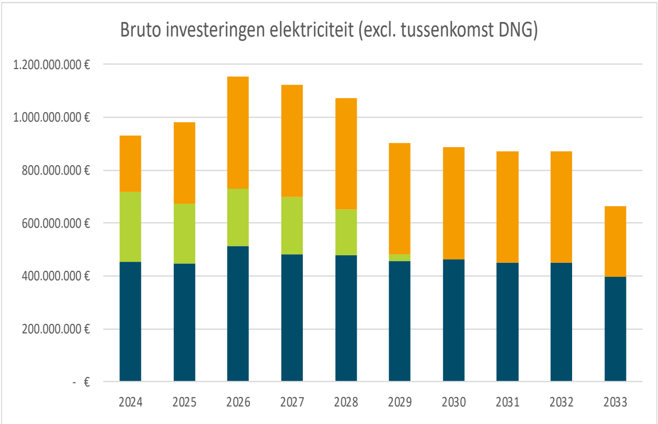
The enhancement of the low-voltage distribution grid will impact approximately 750,000 connections, which will be adjusted as needed. A large proportion of these connections will be overcoupled to a new grid, with potential connection cable enhancement. In addition, many connections to existing low-voltage distribution grids also need to be enhanced. Some of the outdated connections are already being adjusted based on the risk analysis when converting to the digital meter. The high volume of connections presents an additional challenge due to the limited availability of technical personnel and equipment.



Investment in the low-voltage distribution grid involves enhancing nearly one in three cabins connected to the distribution grid. When we contrast this with the pure distribution cabins, we know we need to adjust 50%. An enhancement is sometimes carried out by installing a distribution transformer with a higher nominal capacity. If possible, the distribution transformer will be recovered to enhance other sites with a more powerful recovered distribution transformer. Distribution cabins will also be added at certain locations, with an accompanying expansion of the high-voltage distribution grid. An additional challenge here is obtaining the necessary land or cabin space.



The high-voltage distribution grid is historically stronger and better built out, making the network impact less drastic compared to low voltage. Nonetheless, the high-voltage distribution grid will not only be placed be under higher load as a result of electrification for customers on the high-voltage distribution grid, but also by electrification for low-voltage customers connected to the high-voltage distribution network via distributions cabins. In addition to the regular investment works, about 13% of the high-voltage cables (6,000 km) will be enhanced towards 2032. Older high-voltage cables with smaller sections are to be replaced and existing high-voltage distribution grids are to be further expanded. Mitigation measures can and will also have an effect at high voltage. The contribution of this is difficult to assess today: on the one hand, professional customers have long had an incentive through pricing to minimise peak load. Often, it rather more the energy component (commodity) that is decisive, so this potential is already largely being fulfilled. On the other hand, concepts to be implemented – such as market flexibility – will still have an impact.



In order to prepare for higher (peak) consumption on the electricity grid, Fluvius intends to invest an additional four billion euros into the electricity grid towards 2032. Of this, three billion euros are for enhancing the low-voltage distribution grid and one billion euros for enhancing the high-voltage distribution grid. For the period after 2032, we will build upon the electrification scenarios, providing an additional budget of 270 million euros in 2033 to be on the safe side, pending sufficiently effective mitigation measures.

The additional investments will be built up gradually over the first three years to build up the necessary operational capacity. By 2025, we expect to have the full capacity needed. However, the implementation of the necessary grid investments will be a challenge, in which Fluvius aims to fully assume its role within society. This challenge can only be met if the necessary resources are also provided on a financial level and there is sufficient availability of technical personnel and equipment, not only at Fluvius, but throughout the sector as a whole.

In order to avoid a **sharp** increase in the necessary grid investment by 2050, we must invest with policy-makers, stakeholders and the free market in the development and implementation of mitigation measures, as described in *Alternative solutions complementary to investment*. More detail around electricity investment budgets can be found in appendix: *Investment budget for Electricity*.

Grid investment in the backbone

An overview of accomplished and planned backbone investments can be found in the appendix: *Data Tables for Electricity*. This appendix also provides some more detail on the backbone investments for which flexibility is or has been considered.

The impact on the gas grid

In order to meet future heat demand, Fluvius is advancing the following priorities in line with the assumptions mentioned earlier:

1. Connecting to a **heat grid** where feasible;
2. Electrification through an all-electric **heat pump** where homes allow for it (new builds or major renovation);
3. Potential application of a **hybrid heat pump** if extensive renovation is not possible, but you still want to switch quickly to heating technology with reduced CO_2 emissions.

Fluvius has made a clear choice for construction in subdivisions. In 2022, we consulted on our amended project regulations, such that since 1 January 2023, we no longer construct a gas grid by default. With this, we aim to anticipate the connection ban for new build homes starting in 2025. That way, we also ensure that future maintenance costs for the gas grid are not increased for no reason.

In time, our customers will switch to alternatives that are in keeping with the concept of a climate-neutral Flanders. In order to achieve this, the necessary preconditions must be met, such as a higher renovation rate and additional grid investments for heat or electrification. Customers will still connect to the existing gas grid, in part as a result of the phase-out of fuel oil. We are still seeing an increase in connection rates and not yet a decrease in (residential) gas consumption.

In the short term, the effect of any additional gas connections will be limited and insufficiently significant to warrant any additional investment. In the longer term, we are assuming a decrease in gas (peak) consumption. For the gas distribution grid, we are therefore adopting a '***keep it running***' scenario. Of course, our existing gas customers can continue to rely on the gas distribution grid.

Consequently, within the time frame considered in this Investment Plan, we see **no significant network impact**. In the **longer term**, we are assuming a **lower utilisation rate** of the gas distribution grid, due to the electrification of heating that we explained earlier in this paper. The speed at which this will happen will depend upon (future) policy choices.

More details on the calculation method used can be found in appendix: *Method for forecasting peak consumption of gas receiving stations*.

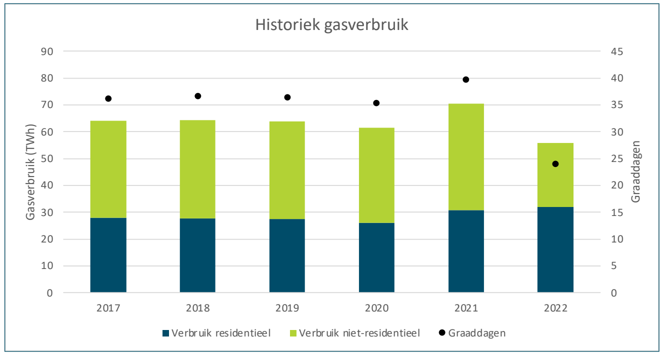
Connection rate and gas consumption

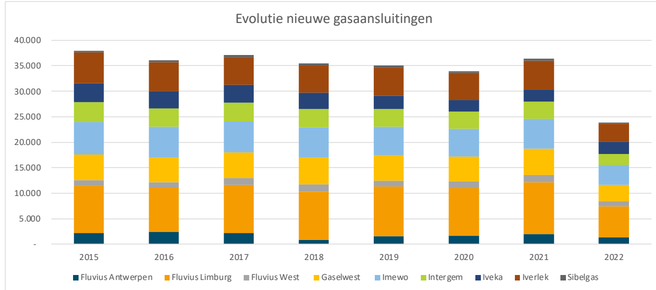
Flanders has a well-built and well-maintained gas distribution grid. This is the result of strong investment in the expansion of gas grids, responding to connectivity rate targets (= is there a gas grid in the street?). The graph below shows the evolution of this connectivity rate and the connection rate (= is the customer connected to the gas grid?). As a result, the connection rate continues to rise, while the connectivity rate has stagnated since 2018. More details on the connection rate can be found in appendix: Connectivity rate and connection rate.

2018:
Afschaffing doelstellingen
aansluitbaarheidsgraad voor DNB's
(o.a. op vraag van Fluvius)

Although connection rates continue to rise, residential gas consumption remains stable when the severity of winters is taken into account on a degree-day basis. This can be seen in the graph below.

In 2022, we observed for the first time a drastic decline in the number of new connections. If we compare it with previous years, we see a 30% decrease for buildings where a gas connection was implemented. This decline is present across the entire operational area (to a greater or lesser extent).





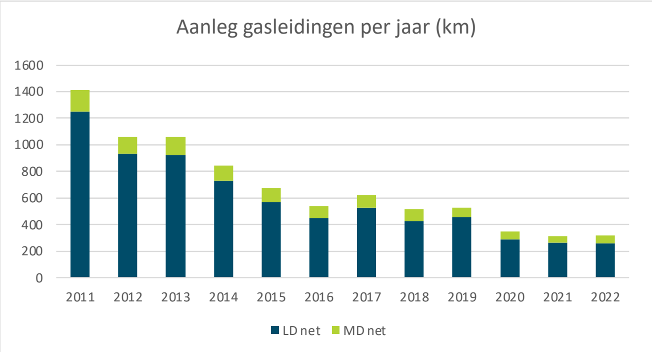
The impact on gas receiving stations

Based on the preceding assumptions, we estimate that the evolution of the load peak at gas receiving stations will be fairly stable in the next few years, before commencing a downward trend. However, the extent and speed of this downward trend will very much depend upon future policy decisions. A detailed overview of the expected evolution of peak consumption can be found in the appendix: Data tables.

Gas grid measures and investments

The network impact determined in the previous section shows why Fluvius is not planning any further expansion investments over the next ten years – except for specific customer requests, for biomethane injections or for relocation works within the framework of road and sewerage works at the request of domain managers.

The graph below illustrates how investments in the gas distribution grid have been phased out over the years. At the current level, we are merely maintaining the quality of service.



Current and future investments in the gas distribution grid are therefore:

- necessary to continue meeting customer expectations in a **safe, sustainable and reliable manner** – including avoiding gas leaks – for as long as natural gas is needed;
- **well-considered** and framed by a variety of **flanking measures** such as condition-based maintenance, targeted leakage level measurements and increased pressure monitoring, such that replacement investments are made judiciously and only when necessary;
- **compatible** with a possible use for **other gases**, without making a prior assumption about the future of the gas grid;
- aimed at **reducing methane emissions**.

Finally, alongside previous investments, the following programmes complete the investments in the gas distribution grid:

- the **conversion** from low to high-calorific gas;
- the roll-out of the **digital meter**.

There is no policy framework today for phasing out existing gas grids. Within the current legal framework, access to the gas grid cannot be refused, with the exception of new major projects and new builds in the future. Therefore, there is no basis today for providing funds in the Investment Plan for the phasing out of the existing gas grid, nor for the accelerated depreciation of assets. At Fluvius, we have already anticipated the upcoming legislation by adjusting our project regulations. In new subdivisions, we have no longer been installing a gas grid since 1 January 2023.

In the following, based on our **investment policy**, we will tell you what measures Fluvius is considering and applying to maintain the quality of service. We will then explain the role we see for **new forms of gas**. Finally, we will discuss the **concrete areas of action & attraction**.

Investment policy for gas

The anticipation of declining gas consumption in the longer term is reflected in Fluvius' investment policy. The main focus is the maintenance and replacement of existing assets to ensure safety and maintain operational efficiency. As a rule, only (very limited) investments in grid extensions are being made in response to specific customer demands.

Replacement investments based on condition and risk profile

The replacement programme for gas grids is drawn up annually based on the condition of the pipeline and the local situation. In doing so, we take into account potential opportunities, such as road or synergy works.

Old gas pipelines made of grey cast iron will be replaced as soon as possible owing to an increased risk of gas leaks. These involve limited remaining grid lengths. In addition, fibre cement gas pipelines are being remediated in synergy works. We routinely analyse grid performance to set appropriate priorities and ensure that there are no pipeline segments with excessively high leakage ratios. No systematic replacement programme is planned for gas pipelines made of ductile iron, PVC, steel (cathodically protected or otherwise).

If necessary, we will decide based on local situations and/or opportunities to remediate, depending upon the condition of the pipes.

Gas cabins will be replaced based on their risk profile and in line with our asset management touchstones. We prepared a long-term replacement programme for gas cabin remediation.

In both main line remediation and connection works, Fluvius will look at the condition of the **gas connection**. If it is found that this connection no longer meets the set criteria, it will be replaced.

A number of **odorisation facilities** no longer comply with Vlarem legislation and ATEX legislation. We established a remediation policy to make these facilities systematically compliant.

Resolving pressure problems in the medium and low-pressure grid

Fluvius wants to maintain its level of service. In each case, we examine whether we can do so without any additional investment. We do so by fully utilising pressure tolerance margins, combined with more focused monitoring of pressures (with pressure loggers). In some cases, this may give rise to a case for investment.

These are smaller local investments, such as a small medium-pressure expansion, the installation of new distribution cabins for additional supply for the low-pressure grid, several small interconnections on the medium and low-pressure grid or the conversion of low-pressure grids to a higher pressure level of 100 mbar.

Digitalisation of the gas grids

Fluvius is required by law to install **digital gas meters**. In addition to replacing old gas meters for performance reasons or within the framework of the Royal Decree on metrology of gas, we will be replacing all existing gas meters in the coming years. This will take place according to an established roll-out schedule. When a meter is replaced, we check that the quality of the connection is still adequate. If necessary, we renew the connection. The installation of digital meters will increase gas investment budgets in the coming years.

Appliances for **cathodical protection** must be checked bimonthly by law. A cost-benefit analysis showed that it was cost-effective and added value to read these devices remotely. Fluvius has a plan to equip all of these devices with a remote management module by the end of 2025.

A limited number of **gas reducing stations** and **receiving** stations that are not yet being remotely managed are also scheduled for digitalisation. This should increase security of supply and efficiency.

Today, pressure monitors are already being read via GPS connection. With the phase-out of 2G technology, to ensure safe operation, we need to replace the monitors with devices using 4G technology. This replacement is planned for in the 2024-2025 budget.

Consideration for methane emissions

Although new investment in the gas grid will be limited, the existing gas grid will be operational for quite some time, bringing natural gas to users for many years to come.

Europe is presently taking several legislative initiatives to curb methane emissions in gas distribution. These initiatives will potentially have an impact on our organisation, both in terms of investment policy and operational policy. We are anticipating further clarity over the course of 2023. Fluvius is monitoring this legislation and preparing a potential organisational adjustment.

Moreover, Fluvius continuously adapts its (maintenance and repair) techniques in accordance with evolving 'best available techniques' for reducing methane emissions.

Green molecules

Heat grids and rapid electrification alone are not enough to cover all the demand for heat in all buildings in Flanders in 2050. In order to achieve this, the necessary preconditions must be met, such as a higher renovation rate and additional grid investments. Electrification and heat may not be able to cover all the demand for energy for industry either.

It is suspected that fossil natural gas will not be simply phased out unless there is an adequate climate-neutral replacement. The potential long-term future role of gas grids is linked to the availability of green molecules and the development of specific applications. Today, it is impossible to make statements with any certainty about the availability, role and price of green molecules and thus the possible future function of existing natural gas distribution grids. Therefore, premature decisions about the long-term vision for gas grids should be avoided. By keeping open the option for future reuse of (parts of) the natural gas distribution grid, we are also safeguarding the possibilities for green gases or blends and are not mortgaging those possible technological evolutions.

Fluvius aims to actively participate in pilot projects for biomethane, power-to-gas and green hydrogen. Of course, we will continue to monitor evolutions in the market, technology and regulations. In subsequent iterations, we will adjust our starting points as necessary, based on the most recent information.

Biomethane

Biomethane is a climate-neutral gas, and thus a major opportunity to green the gas in the grids. The European Commission aims to produce 35 billion m^3 of biomethane by 2030, as part of the REPowerEU plan (EU, 2022). Biomethane is already available now, can be produced locally with local raw materials and requires no modifications to consumable appliances. Furthermore, biomethane has a significant impact on European climate ambitions, gas supply security and the financial gas market. Biomethane can help Flanders take an important step toward climate neutrality in the short term. In Flanders, according to a study by Valbiom (Gas.be/Valbiom, 2019), there is potential for more than 7TWh of biomethane. This is about 10% of the current gas consumption through the distribution grid. At present, four production facilities are already connected to the Flemish distribution grid. In mid-2023, four new facilities will be under construction and feasibility studies are underway for ten facilities. Flow rates vary depending on the site between 0.4 and 2.8 million m^3n/year. In the next few years, we expect a maximum of 2-3 additional facilities to be started up each year.

Today, the investment climate for new biomethane injection projects is uncertain. Profitability is currently good due to high gas prices, but we do not know how those gas prices will evolve in the future. As a result, few potential producers are taking the risk to invest.

Nevertheless, we expect there will be an increase in biomethane injection, in part due to European measures, pressure from governments' climate ambitions, and the link to climate objectives for the waste and agriculture sectors. However, legislation on the reuse of biomass-derived waste streams inhibits collective facilities, preventing certain potential from being unlocked.

The phasing out of certificate support for CHP offers the sector an opportunity to consider biomethane as an alternative to CHP: the investment in a facility to purify biogas into biomethane is smaller than the investment needed to replace the CHP.

Biomethane will also play a continuing role in the medium and long term, after the anticipated decline in gas consumption. This can be done, for example, as a raw material for industry or to replace the remaining natural gas in gas grids with climate-neutral gas.

Hydrogen

Green hydrogen is produced on a very limited basis today. In the future, gas distribution grids could also distribute green hydrogen. This can be done by blending certain (fixed) percentages into the existing gas grid, or by converting grids to 100% hydrogen. It remains unclear which scenario will be best for which applications. This makes the efficiency of hydrogen for the different competing applications decisive.

Fluvius expects the cost of converting the natural gas grid to hydrogen to be limited. In fact, the vast majority of the gas distribution grid consists of 'hydrogen-ready' materials (e.g. polyethylene).

Hydrogen can be a major replacement for natural gas for industry, and it is probably easier to distribute to this target group than to households. In larger industrial zones, it is probably easier to completely ‘retrofit’ whole sections of the existing natural gas grid into a hydrogen grid at one time. This situation does not involve dealing with (tens of) thousands of individual customers with different customer profiles, wishes and resources, with a need to approach persuade each individual customer to retrofit their facilities at the same time. Large industrial clusters and business parks are often home to companies with similar activities and customer profiles. This is an important aspect, because a single gas grid cannot be used to serve natural gas and hydrogen customers at the same time.

The green hydrogen will only become available incrementally, and in the initial phase will probably go mainly to heavy industry on the transmission grid. In the longer term, we anticipate impacts on distribution grids, possibly first for industrial grids here too, and later for residential customers (IRENA 2022). The Government of Flanders assumes that a quarter of Europe's renewable electricity will be used to produce green hydrogen by 2050 (Government of Flanders, 2020).

Among larger industrial companies, we see several initiatives emerging for making use of hydrogen.

It is useful for Fluvius to keep a finger on the pulse here. We are following the development of hydrogen, and are participating in pilot projects. This will mean we are ready for the implementation of the feasible solutions with hydrogen in the Flemish distribution grids in Flanders.

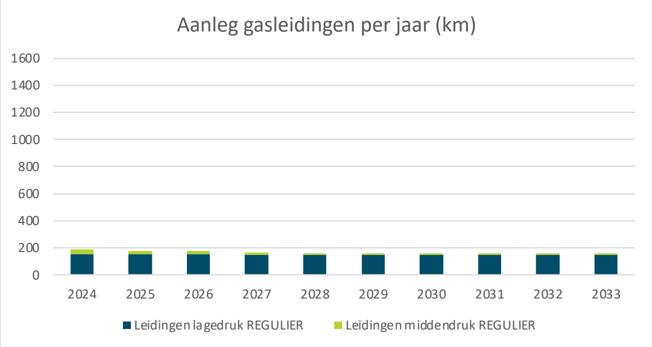
Investments in the gas grid

Project on the conversion from low to high-calorific gas (L/H)

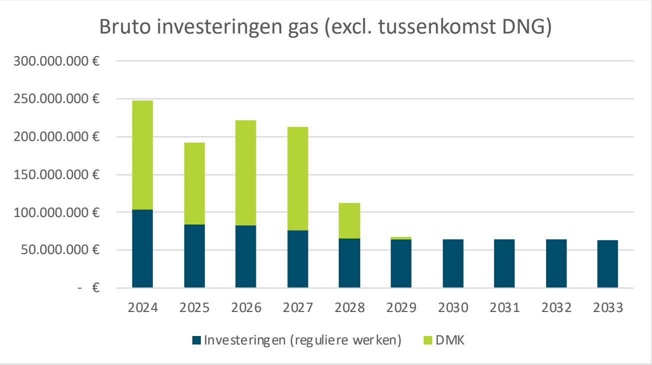
The Dutch government will systematically reduce the production of low-calorific gas in the coming years and stop it completely in 2030. Some of our customers are feeling the effects of this. The L/H conversion should be completed by 2029. By combining this with the roll-out of digital meters, we will be ready as early as 2024 and achieve savings of about 30 million euros.

Regular investments

Based on internal asset management policy, forecasts and trends related to projects (backbone works, road works) and external requests (subdivisions, customer requests, municipalities), the numbers for regular investment works are determined for each asset. The following graph shows the numbers for low and medium-pressure pipelines.



Due to the expiry of a number of policy rules and investment programmes (the roll-out of digital gas meters and the conversion from low to high calorific gas), the investment budget for the gas grids will continue to decline in the coming years. Toward 2033, the current budget for regular investments will almost halve to 63 million euros annually. These investments are necessary to ensure safety and maintain operational efficiency.



More detail around gas investment budgets can be found in appendix: *Investment budget for Gas*.

Grid investment in the backbone

An overview of the limited number of planned and implemented backbone investments can be found in the *Data tables for Gas* as an appendix.

Conversion of investment plan into executable works

If the Investment Plan and additional budgets are approved, Fluvius will convert the requested overall investment budget into concrete initiatives and projects. We will do this according to the local situation, the policies set out and the priorities. Before implementing these plans in concrete terms, we obviously coordinate them with the relevant domain managers, cities and municipalities. We also engage with other utility companies to maximise any opportunities for synergy.

Impact for spatial planning

The layout of the public realm is the guiding factor in determining the appropriate priority for grid adjustments. In a proactive approach, spatial planning guides our determination as to when grid capacity is actually needed.

Fluvius aims to integrate this input into the planning process and, thus providing the necessary coordination with spatial planners. After all, a proper sizing of the low-voltage grids will be in line with the future use of habitation and the use of the public realm. In order to incorporate this information into our planning, we will consult with municipalities.

This will give us an insight into:

- zones planned for the use of existing open spaces and zones where residential density will increase;
- local policies of cities and municipalities regarding potential charging cables on or above the footpath;
- the establishment of parking zones where publicly accessible charging infrastructure is provided;
- car-free streets or districts;
- non-zone conforming constructions where the intention is to demolish residential buildings.

Since the above information is not available as structural data, we need to acquire it by engaging in dialogue with municipalities. However, we are working on better securing this information through some pilot municipalities, so we can incorporate the refinement directly into the grid simulations in the next iteration. At the start of a new legislature, municipal councils, as part of their PMC (policy and management cycle), prepare a multi-year plan for the entire legislature +1 year. This is how we know what road and sewage works cities and municipalities want to carry out.

Road and sewage works

Given the far-reaching nature of road and sewage works, Fluvius adapts distribution grids during these works. That way, there is no need for subsequent interventions on a renewed road surface. The lead time for road and sewage works (from decision to end of implementation) is 5 to 8 years. This means the coordination must take place long before the works start. It is necessary to avoid interventions on a renewed road surface. We also want to avoid having to relocate recently installed pipelines because of road layout changes.

We shape this coordination through bilateral alignment with municipalities and cities, but also structurally through the partnership under the banner of Synductis. Through Synductis, there is planning consultation with supra-municipal domain managers such as AWV, Infrabel or De Vlaamse Waterweg.

Synergy works

Fluvius aims to limit disruption to the public realm. To this end, we have made agreements with cities and municipalities that were laid down in the VVSG code for work on utility lines (including black-out periods) and the AWV guidelines for work on roads.

In order to reduce disruption to the public realm, there has been voluntary collaboration between utility companies in Flanders for years, within the Flemish Council of Network Managers (VRN). Key areas of action:

- managing the process for collaborative working in synergy where the initiative comes from a utility company;
- managing the process for collaboration in synergy where the initiative is a road or sewage work;
- agreements for distribution of contractor costs for works in synergy.

In order to make collaboration between utility companies uniform, allocation ratios were agreed upon within VRN in addition to process agreements. These allocation ratios divide the cost of earthworks in proportion to the impact of the pipeline, the type and number of different utility lines.

Since we want to work proactively with this Investment Plan, we also need to detect synergy with other utility companies early and graft our operations onto these accordingly. As a founding member of Synductis, we want to go beyond the classical synergy model, where a synergy request is made to all utility companies via GIPOD (Generic Information Platform for the Public Domain) for each individual work. We aim to seek synergy opportunities for the next five years, based on our policy rules and planned investments. This allows Fluvius to coordinate its operations with planned road works and minimise disruption to the public realm. In addition, this also ensures an increased implementation rate, as available contractor capacity is optimally used for works in synergy. Of course, we must maintain flexibility here for work specific to customers. We cannot require companies and individuals to delay their connection request until after the prohibited period.

The formal process for synergy operation as set up on GIPOD will of course continue to be respected and applied by Fluvius. Not only is this a legal requirement, it also includes works by network managers who are not members of Synductis or VRN.

Netsimulatie i.f.v. weerhouden 'no regret'-aanpak

We vertrekken van de werken die in de hoogste belastingsgraad komen op basis van de weerhouden scenario's. We beperken ons bewust tot de hoogste belastingssegmenten zodat we steeds 'no regret'-investeringen uitvoeren.

Alignering met wegenis- en rioleringswerken

Via Synductis-werken doen we al een eerste afstemming waarbij de timing zal worden bepaald door het wegeniswerk. Uitzonderingen zijn hier werken waar investeringen noodzakelijk zijn omwille van klachten of congestie.

Optimalisatie met collega's nutmaatschappijen

Met Synductis-vennotren die langetermijnplannen willen delen, zoeken we naar een optimale afstemming. Gezien de uitrolplanning of de beschikbare budgetten geënt zijn op de eigen visie en strategie, is het niet altijd mogelijk om de werken 100% in synergie uit te voeren. We streven ernaar om voor de komende jaren een voldoende groot pakket aan gemeenschappelijke werken vast te leggen.

Afstemming met de gemeente of stad

Op basis van bovenstaande pakketportfolio stemmen we af met steden en gemeenten. Binnen deze korf wordt de finale prioriteit bepaald door de stad of gemeente, die meer zicht heeft op de ontwikkelingen van de ruimtelijke ordening. Zo vermijden we netinvesteringen die overbodig worden door aanpassingen van gemeentelijke plannen, bv. bij autovrije zones zonder mogelijkheid tot thuisladen, collectieve verwarmingen met hoge temperatuursnetten, ...

Attracting long-term resources

One of the bottlenecks to the energy transition is the lack of suitable human resources. Fluvius is setting up various actions to attract sufficient people with the right competencies in both the short and long term.

In order to generate sufficient intake in the long term, we will work more closely with education. Therein lies the beginning of the solution to the lack of technically skilled personnel.

It starts with choosing a technical direction. To encourage that, STEM disciplines were created in education. We are seeing that this is not yet having the desired effect. The number of pupils is not yet sufficient to provide for all the technical profiles required by the market (wider than the energy sector, of course).

Fluvius is collaborating with Green Energy Park (GEP) to introduce children to engineering and all its possibilities as early as primary school. GEP's demo site allows school groups to watch demonstrations, organised in collaboration with Fluvius. The topics covered include electricity grids and the various grid components associated with them. This is how we want to give young people hands-on experience of technology as early as the age of 11 to 12 and get them excited about a STEM route at secondary school.

Engineer profiles are also needed to develop and manage increasingly complex networks. Fluvius is working with universities to get young people excited about engineering. In doing so, Fluvius emphasises that the energy transition presents some wonderful challenges for engineers.


CROSSWISE

Conclusions

Residential customers

For residential customers, we see no reason to adjust the assumptions in the 2023-2032 Investment Plan. The main reasons for the increase in peak consumption on the electricity distribution grid remain the growth of electric mobility and the use of heat pumps instead of fossil fuel boilers. Both factors still fall within the scenarios we put forward. This means maintaining the same level of funding for adapting low-voltage grids and distribution cabins. We are also maintaining the goal of enhancing 30% of low-voltage distribution grids. There, the availability of 400V to the end customer is a priority.

For the high-voltage distribution grid, we are seeing an acceleration in both renewable production and consumption. The number of projects for new wind turbines is seeing a significant rise.

Among our industrial customers, we are seeing greater growth in solar panels, due to amended legislation. Owing to the energy crisis, many companies have already started some proactive projects to install more solar panels on their sites and buildings.

For electric freight transport, an adjustment is needed this year. Whereas there were still some doubts about electric trucks last year, confidence in this technology has soared. Despite the limited supply on the market, a number of pilot projects are in development for gaining experience with electric trucks. In preparation, there is a strong emphasis on the availability of renewable energy, whereby decentralisation of production and local battery storage could reduce the impact on the distribution grid. Fluvius is actively participating in pilot projects and studies to gain insights and make the right choices. There is also increased demand from the government to provide the necessary charging infrastructure and take action to shape the TEN-T network. This will lead to additional grid expansions. The load on the distribution grid will increase once there are more electric trucks.

Availability of energy

In order to assess the investments needed for the interconnection points with Elia properly and in a timely manner, we jointly set up a study pathway. Based on different load profiles, we are gaining some common insights. This allows us to make informed decisions. A temporary peak load is acceptable within certain operating limits. Fluvius has initiated some projects to improve our grid calculation applications, so that we can perform better load studies. Simultaneously with this pathway, we have launched some pilots for procuring market flexibility. We have also been participating in a pathway by Vlaio to gain a better understanding of the still relatively unknown energy transition among companies. For example, we are collecting data on grid impact, based on load profiles and the potential for flexibility.

Electricity grids

Since the energy crisis, there has been a decline in load on the distribution grid. Despite the downward trend in decreased volume and asynchronous peak, we do continue to observe larger local peak loads. Moreover, we expect a significant increase in electrification in the coming years as a result of the energy transition. Therefore, we are maintaining the same strategy as last year and retaining the 'no regret' investment budget of 4 billion euros for the period 2023-2032. For the period after 2032, we will build upon the electrification scenarios, providing an additional budget of 270 million euros in 2033 to be on the safe side, pending sufficiently effective mitigation measures.

Customers

We are also ensuring that our customers can actively participate in the energy market. Through our customer portal, customers with a digital meter can gain an insight into their energy consumption and how to optimise it. Later this year, high-voltage distribution grid customers will be able to consult overview maps showing available grid capacity on the Fluvius portal. In other words, a customer can immediately see what power is indicatively available.

Public domain & Synergy

Unfortunately, the Investment Plan requires many interventions in the public realm, which will cause some inconvenience. In order to minimise this disruption, Fluvius is implementing the Investment Plan in synergy as much as possible. We give the highest priority to synergy with road and sewage works. We then work with drinking water companies to find the optimum implementation period, obviously in consultation with municipalities. This alignment is necessary to successfully implement our Investment Plan. With this information, we can anticipate planned developments and avoid investing in charging station capacity on car-free streets, for example.

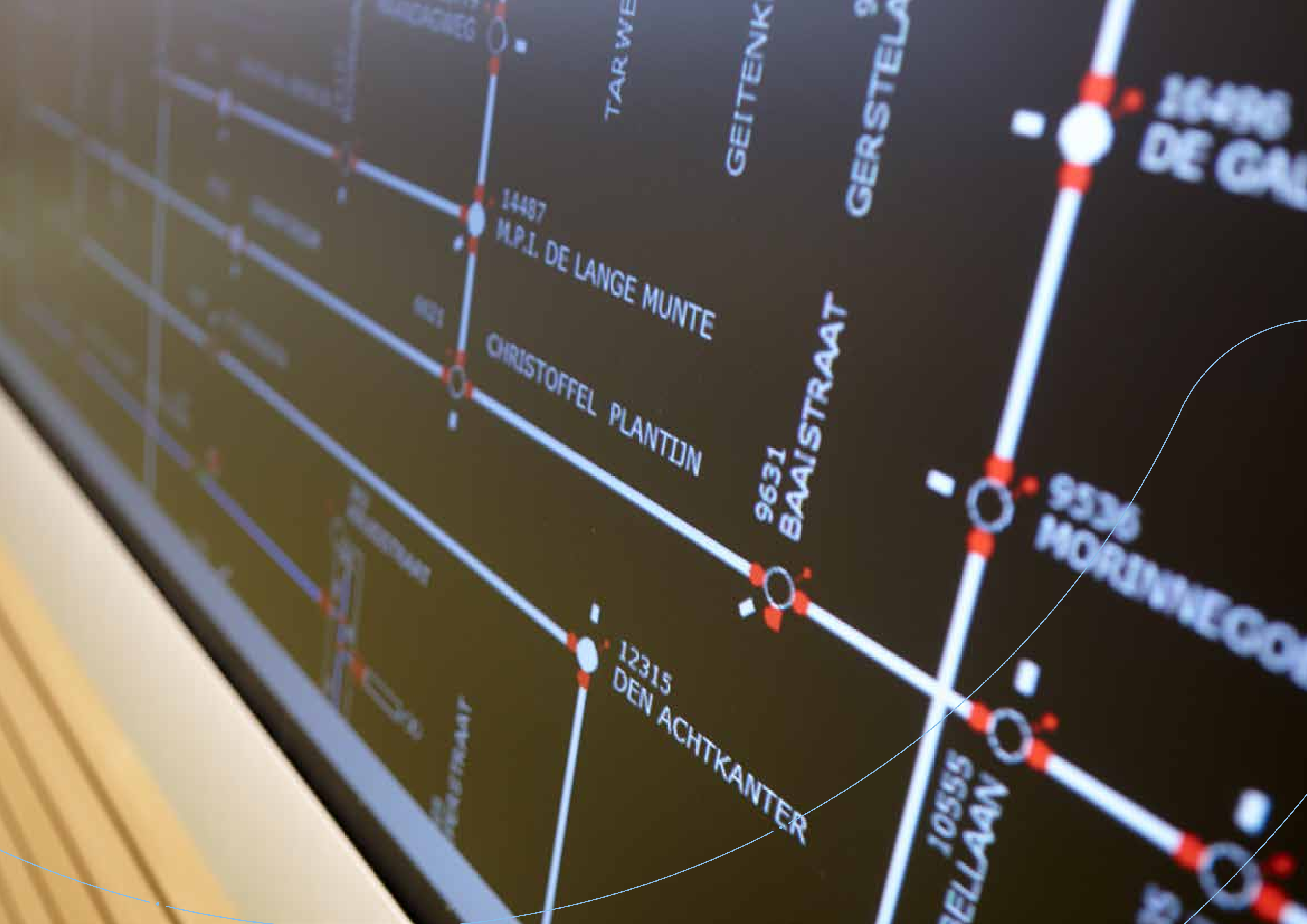
Gas grids

For the gas grids, we are using the same strategy as last year: the 'Keep it running'. Fluvius strives to reduce costs, but we are continuing to invest so as to ensure safety and continue the roll-out of the digital meter. Construction in new subdivisions has been discontinued. We are closely following legislation on methane emissions and are limiting these emissions as well. In September 2024, we will also complete the switch to high-calorific gas, meaning Flanders will then only be supplied with this type of gas. For example, Fluxys can use grid capacity for natural gas that is released for H2 or other applications.

Resources

It will take time to scale up Fluvius' regular operations to the volumes needed to implement the Investment Plan. As a result of the war in Ukraine, the energy transition is accelerating, increasing demand for materials and equipment and decreasing supply. Fluvius is making every effort to reach good agreements with suppliers and contractors and is striving for a long-term perspective.

Finally, we are also taking initiatives to rely upon competent technicians. We are doing so through internal training as well as through collaborative partnerships with all stakeholders involved.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CHRISTOFFEL PLANTIJN
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BAAISTRAAT
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DEN ACHTKANTER
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Appendices

Appendices on Electricity

Resolving voltage problems

Depending on the cause, voltage problems can be resolved with or without investment works.

Resolving voltage problems without investment works (operational actions)

If the problem is on the distribution grid, a range of measures are possible depending on the cause. In doing so, we first look at operational measures that can be achieved in the short term.

Importance of phase balance for voltage quality

Unbalanced load distribution among the phases of a low-voltage distribution grid has a major impact on voltage quality. The impact of a single-phase load on the voltage profile along a mains cable can reach up to nine times higher, compared to an equivalent three-phase load. Thus, for proper voltage management, it is important that the three phases of the mains cables be balanced in load.

A voltage problem on the low-voltage distribution grid due to an unbalanced load can be resolved by rearranging the single-phase connections across the different phases. With an above-ground 400V low-voltage distribution grid, there is also the possibility of placing a zero-point transformer on the grid, which will reduce the imbalance.

Increasing or decreasing the voltage level

Through '*compounding*', it is possible to automatically regulate the voltage of the high-voltage distribution grid at the transformer station, according to the load (typically based on a current measurement). Compounding should initially create reception capacity for decentralised production on the high-voltage and low-voltage distribution grid. Compounding counteracts voltage rise due to injection and prevents voltage limits from being exceeded and inverters shutting down. On the other hand, compounding means that in situations of high consumption, the voltage can be regulated as high as possible, i.e. the voltage does not need to be reduced just to create some margin for injection. In those situations, a higher voltage results in lower currents and consequently a reduction in energy losses.

We are currently testing compounding at four transformer stations. We are doing this with a view to a further roll-out across multiple transformer stations whose load profiles qualify for compounding. In order to be able to apply this technique, the voltage regulator at the transformer station must allow for automatic regulation. This is not the case at all the transformer stations.

By increasing or decreasing the voltage level at the beginning of the distribution grid, a voltage problem further down the line can be resolved. At low load or high injection, the voltage is adjusted downwards. At high load, the voltage is adjusted upwards. Low load (or even feedback) in this context occurs in situations of low consumption and high decentralised production (especially small-scale PV).

At a distribution cabin too, the voltage can be controlled by a manual increase or decrease through the distribution transformer, whereby the voltage for the entire low-voltage distribution grid will go up or down. In an above-ground low-voltage distribution grid, there is also the possibility of installing a voltage regulator, in which the winding ratio is automatically changed according to the input voltage. This keeps the output voltage constant insofar as possible, around its set value.

Resolving voltage problems with investment works

For heavily loaded grids, heavily loaded grid sections can be relieved by re-switching. If this is insufficient or not possible in providing a long-term solution, we must plan some investment work. The potential investments are diverse and each has advantages and disadvantages, maintenance costs and investment costs.

We simulate the different alternatives and choose the techno-economically optimum solution:

- **adding low-voltage cables** with overcoupling for some of the customers from the old cable to the new cable. For example, by adding an underground cable, by adding a cable on an above-ground network – with or without replacing support poles – or by de-duplicating single-sided grids laid, where a grid is laid on both sides of the street instead of only on one side;
- **adding low-voltage cables** without overcoupling for some of the customers from the old cable to the new cable, known as middle injection.
- **adding new distribution cabins** in places where low-voltage distribution grids are too long and problems are occurring with voltage drop or voltage rise. This is particularly the case in (rural) areas with typically longer low-voltage distribution grids, often above ground.
- New since last year is the introduction of an **overhead cable with a section of 150 mm²**. With this type, we can perform middle injections, but we can also overcouple home connections to this. Thus, this cable is also an alternative for longer grids in a rural setting.

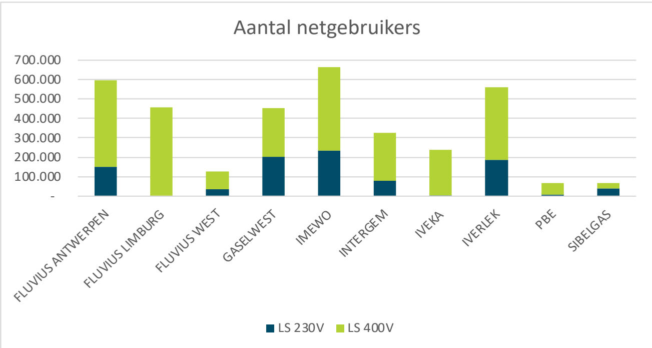
Monitoring 230V grids and making a 400-volt grid available to all grid users

In the reporting model for Electricity (VREG, 2022), the regulator asks for a number of specific elements regarding the monitoring of 230V grids and making 400V grids available.

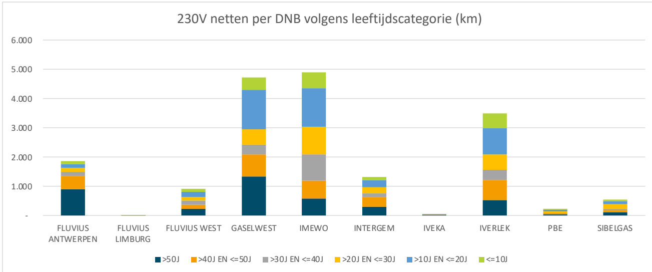
Length of the existing 230V and 400V grids

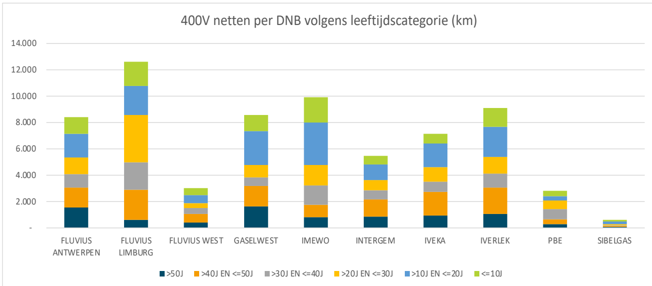
	230V grid (km)			400V grid (km)
	3-wire	4-wire	Total	Total
Fluvius Antwerp	4	1,917	1.21	8,754
Fluvius Limburg	4	34	38	12,627
Fluvius West	334	590	924	3,015
Gaselwest	12	4,772	4,784	8,770
Imewo	362	4,617	4,978	10,331
Intergem	23	1,317	1,340	5,647
Iveka	6	40	47	7,278
Iverlek	128	3,440	3,568	9,393
PBE	233	6	239	2,862
Sibelgas	8	583	591	655
Final total	**1,113**	**17,318**	**18,431**	**69,330**

Number of users connected to the 230V and 400V grid

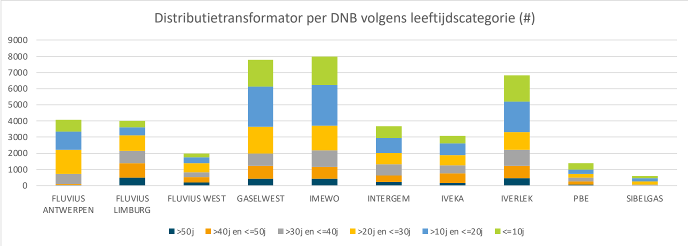


Age of low-voltage cables and distribution transformer





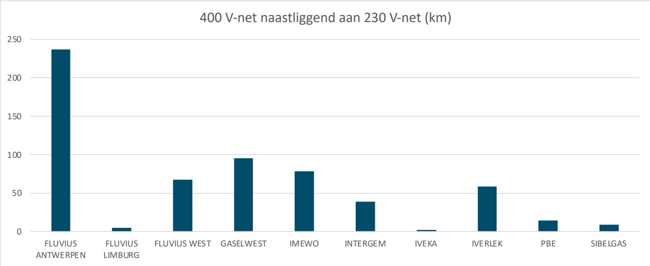
List of distribution transformer types and low voltage boards (230V/400V)



Detailed estimate for replacement of the 230V grid

Phase-out	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
3x230V grid	-403 km	-660 km	-652 km	-642 km	-642 km	-642 km	-642 km	-642 km	-642 km	-642 km
Fluvius Antwerp	48	89	86	84	84	84	84	84	84	84
Fluvius Limburg	0	0	0	0	0	0	0	0	0	0
Fluvius West	14	22	22	22	22	22	22	22	22	22
Gaselwest	70	109	108	106	106	106	106	106	106	106
Imewo	86	141	139	138	138	138	138	138	138	138
Intergem	107	170	169	168	168	168	168	168	168	168
Iveka	0	0	0	0	0	0	0	0	0	0
Iverlek	73	119	118	116	116	116	116	116	116	116
PBE	0	0	0	0	0	0	0	0	0	0
Sibelgas	5	10	9	9	9	9	9	9	9	9

Length of the 400V grid laid adjacent to the 230V grid



Detailed estimate for replacement of the 230V grid

	2024	2025	2026
3N400V grid	+2,724 km	+3,578 km	+4,023
Fluvius Antwerp	338	441	470
Fluvius Limburg	540	723	654
Fluvius West	82	109	118
Gaselwest	333	429	566
Imewo	502	634	790
Intergem	165	205	347
Iveka	201	268	225
Iverlek	427	565	653
PBE	95	132	117
Sibelgas	59	72	83

Use of the non-periodic rate for conversion from 230V to 400V

DNB	2022
FLUVIUS ANTWERP	119
FLUVIUS LIMBURG	0
FLUVIUS WEST	30
GASELWEST	499
IMEWO	580
INTERGEM	237
IVEKA	3
IVERLEK	424
PBE	6
SIBELGAS	55
Total	**1,953**

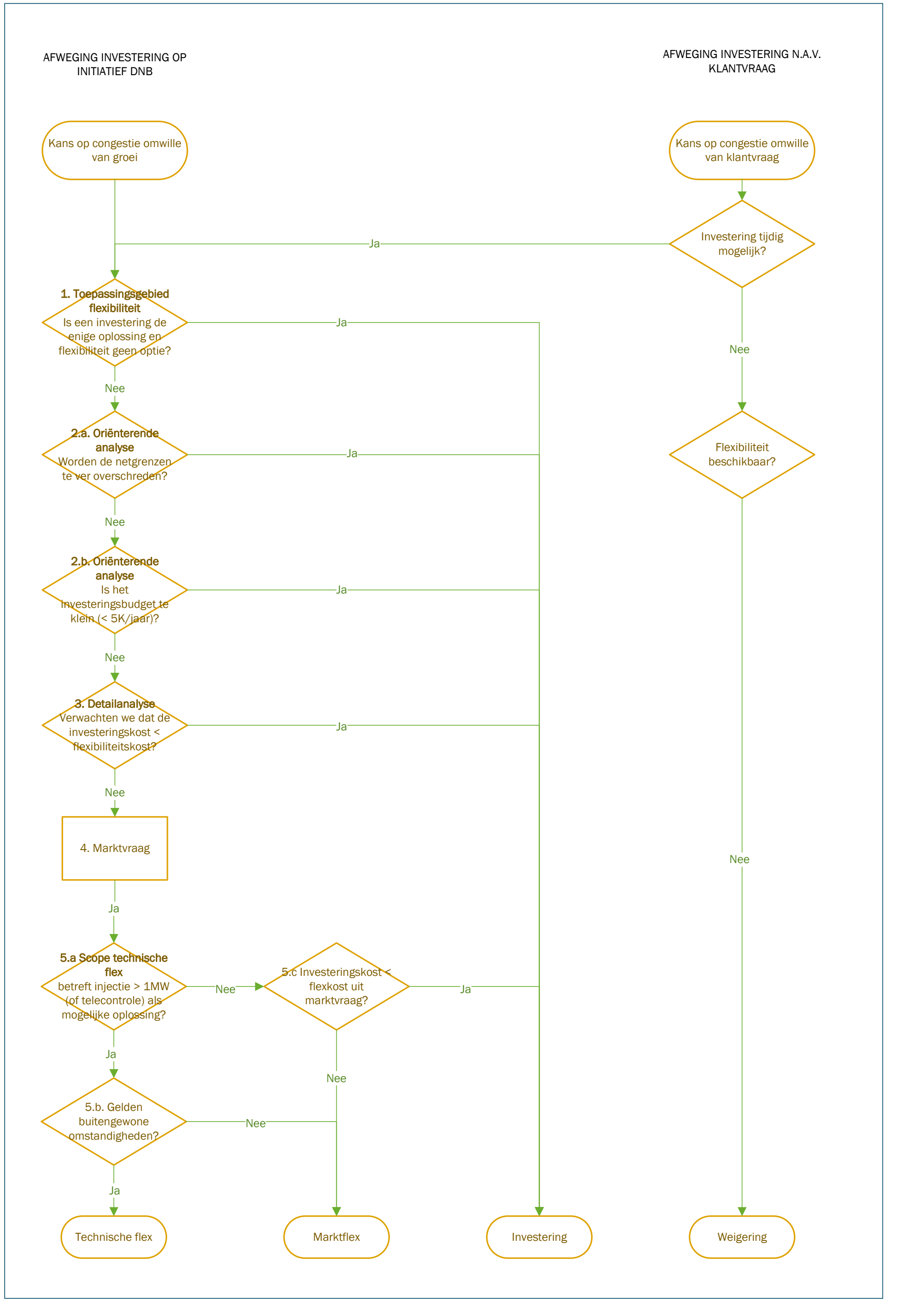
Estimate of number of grid users per DNB having a 400V grid available (10 years)

DNB	2033
FLUVIUS ANTWERP	99%
FLUVIUS LIMBURG	100%
FLUVIUS WEST	99%
GASELWEST	99%
IMEWO	98%
INTERGEM	99%
IVEKA	100%
IVERLEK	98%
PBE	99%
SIBELGAS	97%

Flexibility

Decision tree for flexibility consideration framework

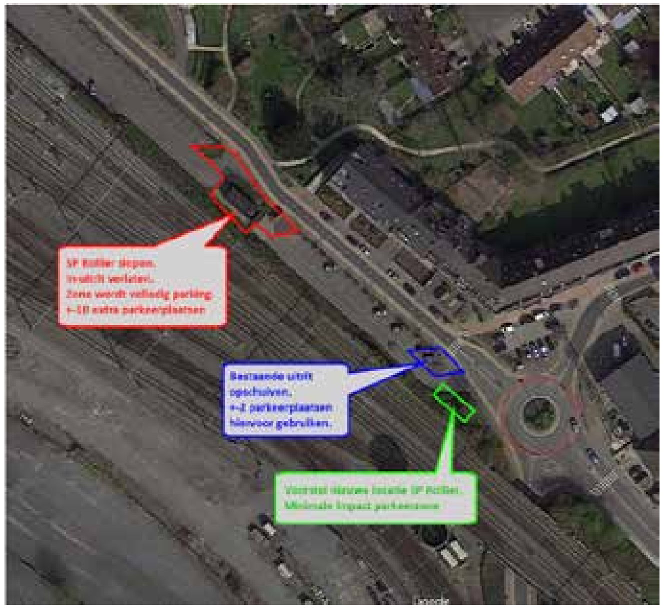
The decision tree below details the steps we take when considering grid investments versus flexibility.



On the basis of a concrete example, the various steps will be gone over in detail below: the remediation and enhancement of Rollier switching station.

Rollier switching station, in the municipality of Denderleeuw, was studied as a result of both risk analysis (due to the current condition of the building and the equipment installed) and anticipated organic growth that could lead to congestion without additional measures.

In order to ensure the continuity of the electricity grid and make the best use of the public realm, the new switching station will be provided at a different location and will be called the Stationsplein switching station.



The first part of the investment following the risk analysis is necessary for safety reasons and concerns the switching station itself.

The second part of the investment resulting from the organic growth concerns the potential investment involving the laying of a new additional feeder cable with section 400 mm^2 over a length of 3,200 metres and connected to a new cell to be installed at the TS Essene transformer station.

Step 1: flexibility scope

In this initial step, we check the scope as the first rough filter: can flexibility provide a solution at all? To answer this question, we examine the various criteria that rule out flexibility solutions:

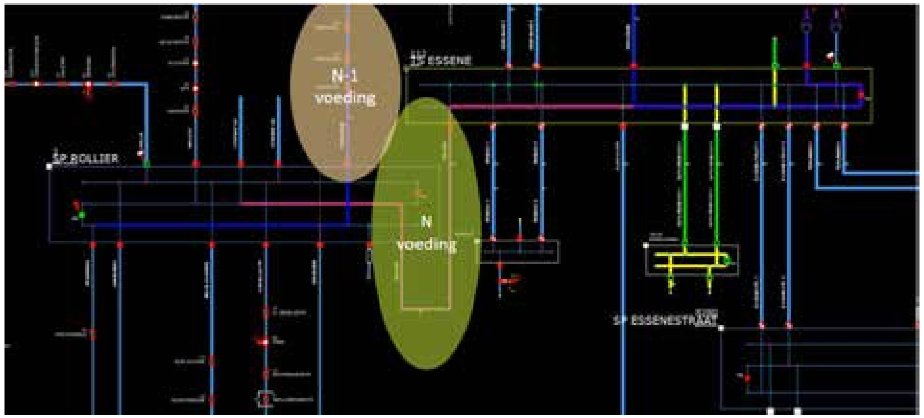
- Remediation: the investment in the switching station itself involves pure remediation and is therefore not considered. The cable investment does not involve remediation, so it will be considered.
- Congestion at low voltage: this refers to congestion at high voltage and therefore not congestion or works at low voltage.
- Multiple cables or use of larger sections: it concerns the laying of a new cable and therefore is not a saving in the number of cables or cables with smaller section.
- Synergy: this does not involve synergy work, so further deferral of investment is possible.

Based on the above, the cable investment meets the criteria included in the consideration framework for a grid investment versus flexibility. Consequently, we can proceed to the next step, within the exploratory analysis.

Step 2: exploratory analysis

The exploratory analysis consists of 2 sub-steps: we first (step 2a) check whether the enhancement need is not too great and flexibility can indeed provide a solution to the enhancement need. Next (step 2b), we consider whether the investment cost is sufficiently high to have potentially sufficient benefits from flexibility, taking into account costs related to deploying flexibility.

In the current situation – when there is no grid incident (N situation) – there is a peak load on the existing feeder cable of 190A, while this cable can be loaded up to 390A. In the event of failure (N-1 situation), another cable takes over the supply and is loaded to 335A, although this cable in turn should only be loaded to 320A. See the schematic diagram below for feeding in different situations:



The latter feeder's protection will only turn off at currents higher than 400A for 0.7 seconds. Since the peak load of 335A is higher than the permitted load (320A) and lower than the protection setting, in this N-1 situation we risk overloading the cable – however, without a shutdown in the grid where flexibility can thus provide a solution.

In order to determine the annual depreciation cost of an investment, a mathematical model was developed that uses the total investment cost to estimate the annual depreciation. For this case, the annual depreciation is 10,032 euros – higher, therefore, than the minimum limit of 5,000 euros/year that we maintain.

The investment includes a new cable over a length of 3,200 metres and an additional cell at Essen transformer station.

INVESTMENT COST	
Cost	
Cost of equipment	€243,386
Cost for contractors (construction)	€142,471
Indirect costs	€115757
Total investment	**€501,614**
Annual depreciation	€10,032

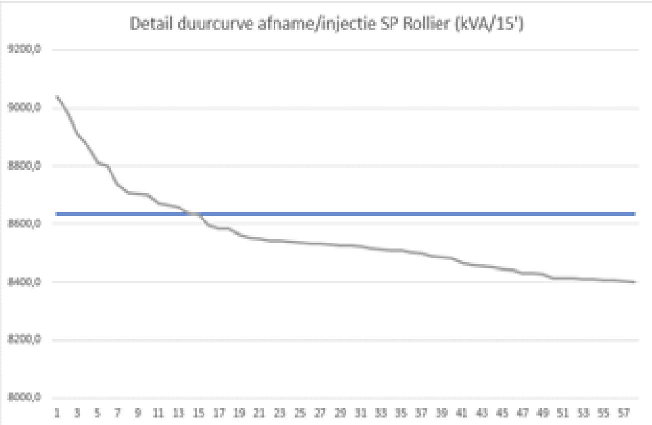
Step 3: detailed analysis

Since the outcome of the previous exploratory analysis is positive, the detailed analysis is performed in this step. In doing so, we identify what the actual flexibility need is in terms of controlled energy volume, based on time series analysis, capacity and frequency. These parameters are then used to consider whether flexibility is more advantageous than investment.

The annual depreciation cost of the investment had already been determined in the exploratory analysis and amounts to 10,032 euros. If we want to avoid (or delay) this investment, then the alternative with flexibility must cover 100% of the potential risk, just as the investment would.

With growth, the frequency and size of overloads will increase incrementally. This makes it necessary to regularly revisit the consideration of 'do we have enough flexibility offerings relative to the potential overload?'. This is especially the case when new grid users are connected.

Today, this means that the supplying feeder Teralfene can be overloaded 14 quarters of an hour per year with a maximum of 500kVA when the grid is re-switched, in what is known as an N-1 situation.



When determining the cost of flexibility, we assume potentially one activation per year, for 14 quarters of an hour (= 3.5 hours) and a capacity of 500kVA.

Since we do not currently have any insight into potential market prices, we are making several assumptions. Even though we have no information from previous market demands, we can still evaluate whether flexibility is more beneficial than investment.

- We set the reservation fee at 3,000 euros per year.
- The present market price is set at 110 euros/MWh.

These assumptions should be further refined in the future through market testing.

FLEXIBILITY PARAMETERS			
Capacity – upper limitCapacity – lower limitAnnual number of activationsAverage activation duration	0.5 MVA0 MVA13.5h	Desired flexibility	1MWh
+ reservation fee + current market price/MWh	3,000 €110 €/MWh	Pricing for desired flexibility	€3,096

What do these parameters mean? If the investment is deferred for 5 years and the overload is not increasing in an N-1 situation, flexibility is 24,214 euros cheaper than the grid investment.

The flexibility alternative thus yields annual savings of 4,842.8 euros or 24,214 euros when considered over a 5-year period, as long as no parameter adjustment is required:

RESULT	
TOTAL flexibility budget over period from 2022 to 2027 at 0% synergy	€39,085
Approach according to flexibility budget PER YEAR (period from 2022 to 2027) – not discounted	€7,817
Aggravation or flexibility (*)	+ €24,214

(*) '+' flexibility is cheaper – '0' break even – '-' reinforcement is cheaper

Step 4: market demand

The market demand launch follows on from the foregoing analysis, with concrete parameters to place the desired flexibility product in the market.

Because a new version of the specifications for flexibility services was recently submitted for consultation, no market tests have yet been conducted. Subject to approval of these rules by our regulator, Fluvius will be able to proceed to market testing based on the analysis as explained here.

Step 5: deployment of flexibility

Finally, we make the ultimate decision to actually purchase the flexibility service, based on the information from market demand.

If technical flexibility – control of decentralised production units with a remote-control cabinet – can provide a solution (step 5a), there will be an assessment of whether exceptional circumstances are involved (step 5b) and consequently whether technical flexibility or market flexibility will be deployed.

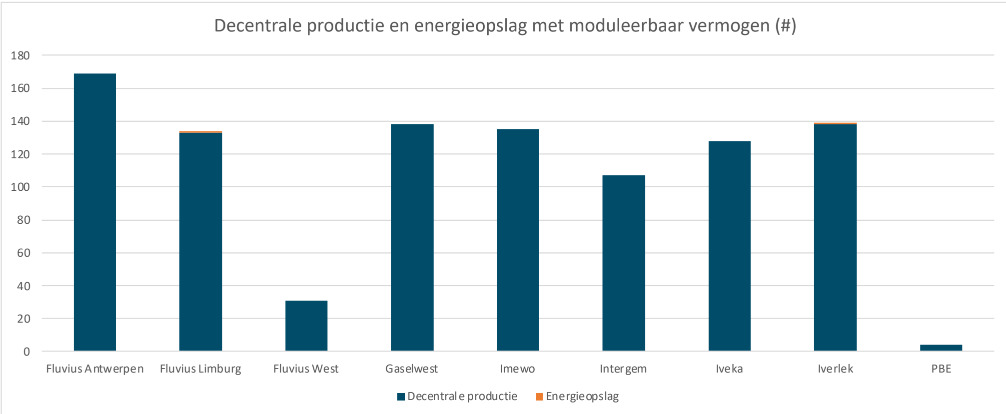
Our example involves a congestion problem in consumption, where technical flexibility cannot provide a solution. If market demand were to indicate that flexibility is actually more advantageous than investing (step 5c where the parameters from the detailed analysis are updated based on market demand information), this case is eligible to proceed to market testing of flexibility services.

Volume reporting of activations of flexibility services

The Energy Decree Article 4.1.19. §1 asks for volume reporting on activations of flexibility services on the electricity distribution grid in the past two years preceding the submission of the Investment Plan.

In the past, VREG took six decisions for connection with flexible access (AmfT), where the installations connected have a permanent access restriction in N condition. The ability to connect generation facilities under AmfT was introduced at the time at the request of the grid manager, as an alternative to a refusal to connect in situations where local congestion could occur under normal operating conditions. In a previous revision of the Technical Regulations, this possibility was removed, which means that no new connections with flexible access will be made.

The Energy Decree defines technical flexibility as flexibility at the request of the electricity distribution grid manager, where participation is mandatory in the context of operating the distribution grid. Production facilities or electricity storage facilities with a capacity greater than 1MVA (Type B) or remote control are eligible. Below is a list of all the installations eligible for technical flexibility.



Fluvius provides a remote control cabinet at facilities for decentralised production and energy storage systems with a capacity > 1MVA or at smaller facilities in the event of potential grid congestion, see TRDE Art. 2.2.54. In Fluvius' operational area, there are 1,303 production installations (total installed capacity 3GVA) and 4 energy storage systems where adjustment of facility capacity is possible. Below is a summary of the modulations of these facilities over the past two years:

		Fluvius Antwerp	Fluvius Limburg	Fluvius West	Gaselwest	Imewo	Intergem	Iveka	Iverlek	PBE	Sibelgas
2021	number of shutdowns	8	-	-	-	14	-	12	-	1	-
	average duration	3h31	-	-	-	7h17	-	5h43	-	3h30	-
	average capacity reduction (MW)	5	-	-	-	4	-	8	-	2	-
	Non-produced energy (MWh)	196	-	-	-	378	-	519	-	7	-
2022	number of shutdowns	18	-	-	1	21	13	9	-	-	-
	average duration	19h21	-	-	1h00	34h41	33h10	4h00	-	-	-
	average capacity reduction (MW)	6	-	-	4	5	8	10	-	-	-
	Non-produced energy (MWh)	2,256	-	-	4	3,852	3,262	371	-	-	-

List of decentralised production and energy storage

For a listing of decentralised production facilities and energy storage systems linked to the distribution grid, please refer to the relevant details on Fluvius Open Data.

Method for forecasting annual peaks high voltage feeders and stations

We calculate the load prediction for the high-voltage feeders (= high-voltage cables) based on the following factors:

Current annual peak and average load

- The **feeder peak** for both **consumption** and **injection** is determined on the basis of the measurement data recorded and related to the nominal load capacity of the feeder. This takes place for all metered feeders. These include both feeders that depart from a transformer station (TS) and feeders that do so from a switching station (SS). Peak currents due to interruptions were filtered out.
- The annual **average load/flow** in a feeder (Inom gem [A]) is a value not yet provided in our standard reporting. To overcome this, we analysed purely industrial and purely residential feeders. For these feeders, the annual average was determined manually and the ratio relative to the feeder peak was calculated. The conclusion: the average value is about 45% of the feeder peak. However, the variation around this average can be major for industrial feeders. This value is also not available for switching stations. Based on random sampling, we determined the average value to be 60%.

Future annual peak based on growth scenarios for consumption and injection

- **For each feeder**, the underlying load types were determined pro rata (residential or industrial). In recent years, given the increase in decentralised production, we have instead seen a decline. Due to increasing electrification – see simulations – we predict an increase emerging. Based on the scenarios in this Investment Plan, we determined the growth in consumption and injection by load type. Given that we are converting the 2032 scenario to a growth per year, with the following result, we have:

Load type	peak consumption growth / year	peak injection growth / year
Residential	7.5%	12.0%
Industrial	0.8%	3.0%

- The peak load at **transformer stations** was also determined based on the scenarios in this Investment Plan.

  In particular, for injection peaks, we included wind projects. In doing so, we took into account the respective implementation period and the chances of success. We divided the expected growth in PV pro rata to the consumption peak among the different transformer stations.

The reporting model requires a list of high-voltage feeders under the management of the distribution grid manager that have a load > 100% in an N-1 condition for the grid. However, these situations do not occur. However, there are several feeders where in N-1 condition, the injection peak could still cause an overload. But in all these situations, remote control cabinets are set up that are controlled at the time of N-1 to avoid this kind of overload in N-1.

Explanation of the bottlenecks in the distribution grid

In the following, we address the main local issues. For any problem at the level of a transformer station (TS), Fluvius coordinates with the transmission grid manager Elia, as a transformer station is the interconnection point between transmission grid and distribution grid. In addition, Elia owns the transformers at almost every station. Often, Elia also owns the building and some high-voltage cells (such as arrival cells and coupling cells).

Reception capacity for decentralised production

The reception capacity for decentralised production available at the interconnection point level is determined by two aspects:

1. The capacity available on the feeder transmission grid (upstream grid)
2. The capacity available from transformers between the upper grid and the distribution grid (interconnection point)

Upstream grid

The map below summarises the bottlenecks on the upstream grid. This map shows all the transformer stations. For transformer stations coloured orange, reception capacity restrictions apply. The constraint for these and for the transformer stations coloured green may change, depending on customer demands and investments.

Figure 11: Upstream grid

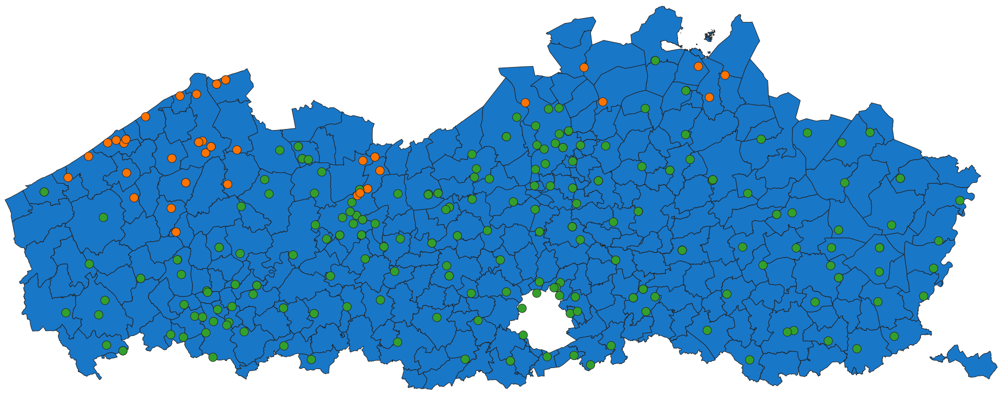


Figure 11: Upstream grid

In northern West Flanders, a vast area is feeling the impact of planned connections of offshore wind turbines. In anticipation of the Ventilus project – this is a 380kV corridor with a capacity of 6GW between Stevin and Avelgem – and the implementation of additional projects, congestion on the upstream grid is possible in the future. It is up to the upstream grid manager to manage this congestion, for example with investments or the purchase of flexibility. This may possibly result in tuning the capacity of the production facilities during the congestion periods. These modulations are performed by the manager of the grid to which the modulated customers are connected, on behalf of the upstream grid manager.

At the port of Ghent, there are two areas of higher congestion.

At the western port (Rieme, Ertvelde), we expect some congestion after the decommissioning of a feeding 36kV cable. A new interconnection point at the Kluizendok, with an additional feeder cable towards the northern port section, would eliminate this bottleneck. However, there is no concrete date yet for the implementation of this project, so pending any investment, this will cause some congestion.

At the eastern port, there is mainly a restriction on connecting decentralised production with a high short-circuit contribution, such as CHPs. However, it is still possible to connect these facilities, provided that the necessary measures are taken to limit the short-circuit contribution. After replacing the limiting high-voltage station on the 36kV grid, this issue should be remediated.

There are also some bottlenecks in the north of the province of Antwerp. The first zone is located near the 36kV network, around the Lillo substation where there is also a restriction on facilities with a high short-circuit contribution.

The second zone is located on the 70kV grid in the North Campine. Congestion may occur in the future there with further growth of decentralised production in this region and in the absence of timely investments in the upstream grid, for example an upgrade to 150kV.

Interconnection point

The map below shows an overview of the current percentage of injection load for the various interconnection points between the transmission grid and the distribution grid.

A load higher than 50% in many cases means that if one of the feeder transformers fails or is undergoing maintenance, congestion may occur and production cannot be fully received. In some cases where only one transformer is set up (as in Hoogstraten), this leads to a complete shutdown of the facilities. In addition, projects are still underway, making enhancement necessary. After all, these projects take up all residual capacity.

The table shows the percentage of injection load for the highest-loaded interconnection points. This percentage of injection load is expressed against the nominal allowable injection capacity for the transformers. This is generally 90% of the installed rated capacity, according to Elia's technical guidelines.

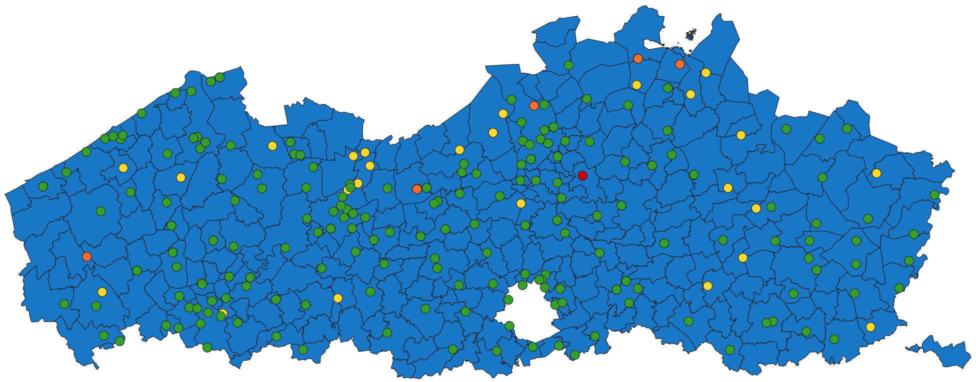


Figure 12: Interconnection point load in injection (green < 25% load, yellow 25%-50% load, orange 50%-75% load)

Table 3: interconnection points with multiple transformers

Interconnection point	Percentage of injection load	Absolute injection
TS KOEKHOVEN	70%	-63MW
TS NOORDSCHOTE	64%	-23MW
TS RIJKEVORSEL A	59%	-47MW
TS 7E HAVENDOK	55%	-62MW
TS GISTEL POST 36 11kV	50%	-18MW
TS RAVELS	46%	-37MW
TS STASEGEM POST	46%	-19MW
TS KETENISSE	45%	-41MW
TS GERDINGEN 1	42%	-15MW
TS SITE ADEGEM	41%	-16MW
TS ST. PAUWELS-HOOGSTR.	40%	-24MW
TS GENT DESTELDONK	34%	-23MW
TS TESSENDERLO 2	33%	-30MW
TS GHENT ST. KRUIS-WINK.	33%	-11MW
TS HALEN	32%	-29MW
TS RIEME-OV5 LGB-RO	32%	-16MW
TS ERTVELDE 36 12kV	31%	-11MW
TS MOL VAARTSTRAAT	31%	-42MW
TS TESSENDERLO 1	31%	-28MW
TS WILLEBROEK	30%	-22MW
TS KENNEDYLAAN 150 36	30%	-62MW
TS RIEMST	30%	-27MW
TS MEERHOUT	29%	-26MW
TS ZEDELGEM 4 – 12kV	26%	-14MW
TS BEVEREN-WAAS 15kV	26%	-24MW
TS TURNHOUT OUD EN NIEUW	26%	-28MW
TS YPRES NORTH	25%	-19MW
TS KERSBEEK	25%	-18MW

There are currently five interconnection points with multiple transformers where control of decentralised production is possible in the event of maintenance or failure of one of the feeding transformers.

Table 4: Interconnection points with 1 transformer

Interconnection point	Percentage of injection load	Absolute injection
TS LIER PROD	80%	-36MW
TS HOOGSTRATEN 36KV	69%	-78MW
TS BEVEREN-WAAS 30KV	64%	-63MW
TS LOKEREN VIJGENSTRA	53%	-53MW
TS SIFFERDOK R.O.	50%	22MW
TS RIJKEVORSEL B	45%	-7MW
TS EEKLO NOORD 36KV	41%	-46MW
TS ST.DENIJS-BOEKEL	31%	-3MW

Residual consumption capacity

This map again shows the various interconnection points between the transmission grid and the distribution grid. For the green interconnection points, connection requests for consumption were always able to be granted. At the orange interconnection points, concrete connection requests for consumption may not be fully granted due to congestion on the upstream grid or at the interconnection point itself, pending solutions.

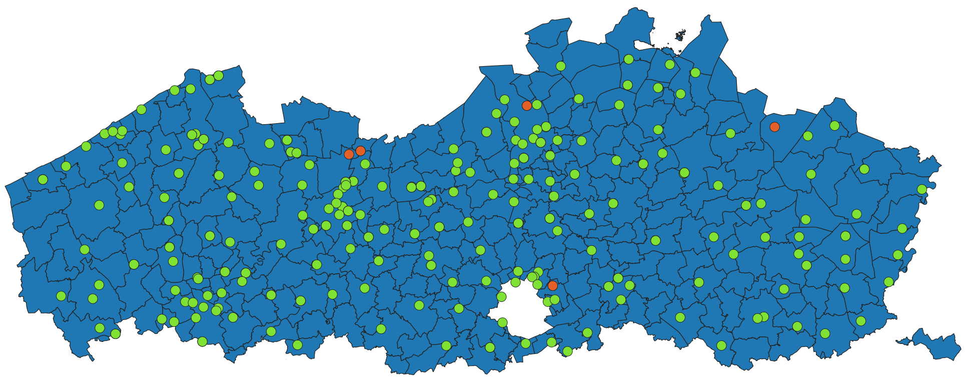


Figure 13: Restriction on interconnection point load for consumption (green: no restriction, orange: temporary restriction applicable – interconnection points Rieme/Ertvelde, 7de Havendok, Lommel, Zaventem

Bas-Warneton – Wijtschate

The Bas-Warneton transformer station is being enhanced both with regard to high-voltage transmission (Elia) and high-voltage distribution (lead: ORES and part-owned by Fluvius). Commissioning is scheduled for 2024. Initially, the installation of the high-voltage distribution equipment was also planned for 2024, but for practical reasons, that equipment was installed earlier, in 2022. It will enter service in 2024. Moreover, this equipment is Schneider PIX, the production of which will cease in 2023.

Once the transformer station at Bas-Warneton has been enhanced, the transformer station at Wijtschate will be taken out of service. It is in urgent need of replacement. There will be a new switching station, powered by the transformer station at Bas-Warneton, which will take up the existing spaces at the transformer station at Wijtschate.

Westrozebeke

In the future, the transformers for the Noordschote transformer station will be supplied as a satellite from Wortegem and Koksijde. In fact, Elia will abandon the 70kV voltage level in the region, as several grid elements have reached the end of their service life. Due to the long supply line from Wortegem, voltage problems may occur in Westrozebeke at higher loads in N-1 situations until well beyond 2025. Today, this is not yet causing problems, as the current peak load is below 70MVA. The problems will only start to occur from about 85-90MVA upwards.

The load at this point may increase until the problem level is reached. Direct customers (trans-HS) can still increase about 13MVA according to their contractual capacity. The potential increased load from electric vehicles is also a factor. However, this is uncertain. Consequently, it is economically and socially irresponsible to make any adjustments at all in Westrozebeke at this stage. We decided to keep an eye on changes to the electrical load in Westrozebeke (on an annual basis) and to take possible corrective actions based on that analysis.

A corrective action that would be achievable in the relatively short term is the connection of a high-voltage capacitor battery at the Westrozebeke transformer station. Other solutions will involve fundamental modifications to the electricity grid, which will take a number of years to complete.

Elia will monitor this issue by carrying out long-term studies. When doing so, it will take into account the further phasing out of the 70kV grid in the region and uncertain load increases in the future. Consultations with Fluvius are taking place in order to identify the best solution.

Bruges Pathoekeweg

The new 36kV grid, which currently only receives locally generated power, can create synergies with the DNB 36kV grid for the ‘replacement’ of Elia's grid between Zeebrugge and Bruges. However, the higher periodic tariffs charged by the distribution grid manager relative to those of the transmission grid manager are preventing us from achieving synergy in consumption and injection on that grid.

Finally, a new 36kV substation will be established in Pathoekeweg. It will be fed by two 36kV cables from the existing local transport network and one 36kV cable from the existing distribution grid (at which locally generated power is received).

Bruges North

The site where the current Bruges North transformer station is located needs to be remediated. Since the required capacity can be distributed from the nearby Bruges Waggelwater transformer station, the transformer station will be abandoned and replaced by a switching station with power supplied from the Bruges Waggelwater transformer station.

Port of Ghent Left Bank Kluizendok

In the port of Ghent, we can see both the reception capacity and the capacity for off-take being taken up more rapidly. In order to receive the energy from additional local energy generation facilities (such as new wind turbines), the congestion in the transmission grid at Ertvelde must be resolved.

New and specific applications at Kluizendok also require the creation of a transformer station at Kluizendok, for which Elia has not yet taken the final investment decision. Taking into account the amount of time needed in order to realise a new transformer station and the capacity constraints for both injection and offtake, this decision is urgent. Fluvius and Elia are working out interim solutions to ensure that new customers can still be connected. We are already constructing part of a future local transportation network. This will initially fulfil the function of a distribution network and will free up additional capacity in the short term. In the medium term, that capacity will remain insufficient.

Local generation of electricity in Temse

In 2013, we estimated the potential for locally generated energy in the Temse/Melsele region within the 15-kV perimeter around the Burcht transformer station to be 59 MVA. We provided detailed studies for connection requests totalling more than 30 MVA. However, these did not lead to concrete realisations. We are continuing to monitor developments in this region.

Port of Antwerp – Left Bank of the Scheldt

A large portion of the locally generated energy (mainly by wind turbines) in northern zone was connected via the Ketenisse transformer station (15kV). In the event of congestion on the transmission grid, local installations for power generation can be modulated.

Further connections in the more southern zone are made to the existing Beveren-Waas transformer station, at 30kV and 15kV. In the event of congestion on the transmission grid, local power generation facilities can be modulated.

Antwerp – 7e Havendok

Owing to the rapid increase and high concentration of decentralised production at transformer station 7e Havendok, if one transformer is switched off, the injection may be so high that the remaining transformers switch off. To avoid this situation, we are moving to separate operation of the transformer station.

Moreover, the remediation of this transformer station is urgent. We identified that the high-voltage equipment was in a worse condition than expected. There are no further expansion opportunities and a shortage of reception capacity for injection and consumption. Meanwhile, arrangements were made with Elia for the location of the new building for this transformer station.

In addition, a new industrial subdivision will be built on the former Opel site, where four customers have since applied for connection (total 25MVA). Two of these customers, given their connection capacity, should be connected directly to TS 7e Havendok. However, that is not possible, since there are neither any free cells nor any room for expansion. A new SP Next Gen switching station could feed these customers on the one hand in anticipation of the revamped TS 7e Havendok, and on the other receive further growth in the second phase of the subdivision. Construction of SP Next Gen is scheduled to begin in 2024.

Antwerp Tabaksvest

Following the incident in the Nieuwevaart transformer station with double busbar cells, we took several measures to reduce the risk an incident of that type. One of the measures agreed upon by Elia and Fluvius is the implementation of a new post concept with single busbar cells. Construction defects on the double busbar equipment had led to incidents involving shutdowns in recent years. As a preventative measure, we have already performed an upgrade on the affected equipment group.

The Tabaksvest transformer station is one of the first projects in which this single-busbar concept has been applied. Because of equipment problems, among other things, completion was delayed by 1 year until 2023. This principle will continue to be applied by default, with the exception of those projects already in design/implementation, or extensions to existing double busbar installations.

Antwerp Petrol

In the region between Nieuw Zuid in Antwerp and the Hobokense Polder, a large load increase is expected. This increase is due to the development of the Blue Gate industrial zone, an upgrade of an existing customer to 15MVA and concrete plans by the Port of Antwerp to provide shore power at the Scheldt quay. As a result of this increase, investments will need to be made in additional outward cells at TS Petrol and, over time, there will be a need for additional transformer capacity. Discussions with Elia have been initiated for that purpose.

Antwerp Damplein

An enhancement to the Damplein transformer station will be necessary following the installation of charging infrastructure for De Lijn. Coordination is under way with De Lijn on the roll-out schedule of the electric buses. In that regard, we will continue to monitor any need for further enhancement work. Fluvius will coordinate the corresponding enhancement measures with Elia.

Zaventem

In the region around Zaventem, as in the wider region around Brussels (Ternat), we received many requests for the connection of data centres. They are usually trans-HS connections, because of the large capacities (on the order of 20MVA per connection). As a result, the Zaventem transformer station is taking up a great deal of capacity as well as physical space.

The connections tendered for are actually on the way, as a result of which both the 11kV and 36kV voltage levels in this region will be full. Capacity in Zaventem could be increased through additional investments in the transmission grid, but that will not solve the problem of insufficient physical space at the Zaventem transformer station. We carried out a joint study with Elia to identify alternative solutions. We looked at the feasibility (permit issues) of various alternatives for a new transformer station. Several locations ultimately proved unfeasible, so we are expecting the final decision with a six-month delay this year. The site in question is south of the E40 motorway.

Muizen

In a recent project, Elia replaced the three 20MVA transformers in the transformer station in Muizen were replaced with two 40MVA transformers. This has increased the total installed capacity, but the available capacity in the event of an incident is therefore still limited to 40MVA – although the cyclical residential load is quite high and typically exceeds this value during the winter peak. Indeed, the power made available at this interconnection point was stated to be 42.6MVA. Today, temporary overloads of the transformers allow the necessary power to be made available in the event of an incident. To allow for further load increases to occur, this transformer station will need to be enhanced by the installation of two additional transformers. Ongoing load developments are being closely monitored.

Sint-Katelijne-Waver

We examined the remaining capacity for connection of additional locally generated energy in the horticultural region of Sint-Katelijne Waver. This region is partly fed from Lier/Duffel on 15kV and partly from Mechelen/Putte/Heist-op-Den-Berg on 10kV. The available capacity for additional CHPs is mainly located at the borders of the area. Enhancements to the backbone may create some targeted additional margin, but will only be scheduled once we receive specific requests for enhancement. The potential for reactive capacity control will be further explored for that reason.

Putte

In the region around Putte, there is great potential for new applications in decentralised production. However, the capacity of Putte transformer station is limited due to insufficient expansion possibilities and the short-circuit capacity of the switchgear imposes limitations. In order to solve these problems on the ground, a new building is being constructed on the same site for a completely new transformer station.

Heist-op-den-Berg

Elia plans to convert from 70kV to 150kV at the Heist-op-den-Berg transformer station. The change in primary voltage will require major modifications to the CAB injection. In addition, the reconstruction of the N10 will probably require the relocation of 21 of the 24 high-voltage cables coming from the Heist-op-den-Berg transformer station, at the request of the implementing party, AWV. This involves a section of 9.5km in length and will also require some intersections with side streets to be partially reconstructed. As a result of these works, the differential bundles to various switching stations would also be addressed in synergy.

Meer – Hoogstraten

Additional requests for the connection of locally produced power in the Hoogstraten area will continue to be received at the Hoogstraten transformer station. However, the available reception capacity at the Hoogstraten transformer station is already largely used up. In addition, in the north, receiving additional locally produced energy is threatening to cause voltage problems in the 15kV grid. This makes the previously envisaged establishment of a transformer station in Meer necessary. Several scenarios were examined with Elia for this purpose. In doing so, we aimed to open up both additional reception capacity at 36kV and to strengthen the 15kV grid. Meanwhile, 120 MVA of locally produced energy has been ordered for connection to the Hoogstraten transformer station during the past 10 years. The distribution grid constructed for that purpose had a function as a future local transport grid. However, given the investments already made in the case of 36kV, we will be going off-track in order to set up a transformer station in Meer. The existing distribution grid will not be required to function as a local transport grid. Fluvius and Elia decided to enhance the transformer station in Hoogstraten from Rijkevorsel with additional transformer capacity, to further expand the 36kV from the transformer station in Hoogstraten, to supply the existing Riyadstraat switching station with 36kV and to provide a 36/15kV transformer on- site to avoid voltage problems on the 15kV grid in the region. The plans for this have been undergoing further development. The final investment decision by Elia for additional transformer capacity in Hoogstraten will be necessary in order to connect additional locally generated energy in the region. Given the completion deadline for this additional transformer capacity, this decision and/or mitigation measures are pressing.

Merksplas

The capacity of the Koekhoven transformer station, established in 2016, was fully utilised by local producers (CHP) and customers after just over two years. Elia invested in a second transformer. The extra capacity was quickly taken up by new customer requests. We are therefore monitoring further developments at that location very closely.

Campine E34

In the Campine E34 region, from Vorselaar to Retie, there is enormous potential for the local generation of energy using wind turbines. Fluvius, in consultation with the province and Elia, determined how best to receive this potential when it becomes a reality. We also determined how specific (granted) applications would still be connected as quickly as possible. To that end, we have already connected some projects in the vicinity of Retie to existing interconnection points (36kV). We also looked at whether we could install an interconnection point near Turnhout, but that turned out to be impossible.

After working together to analyse the technical and economic feasibility, Fluvius and Elia decided to build a 36kV hub on the existing Poederlee site to receive the energy from the majority of the wind projects. We will continue to connect the remaining wind projects to the existing interconnection points.

Pending further realisation of these wind projects, we are connecting the projects in the Poederlee area that have already been ordered to a 15kV supply, using a 15/36kV transformation. As part of that process, we will ensure the necessary facilities are provided in order to connect to the 36kV hub that will become available in the future.

Ravels

An investment for strengthening work at Ravels transformer station that involves the installation of a second transformer as a subtransformer of Beerse no longer forms part of Elia's plans for 2023. Elia is investigating this option further, as additional connections of systems generating power locally are experiencing an increasingly higher probability of modulation under normal operating conditions. This will be closely monitored so that the necessary mitigation measures can be taken in a timely manner.

Boutersem

We received a request for an exploratory study for 19 wind turbines, with a generator capacity per wind turbine of 3.6MVA in four clusters (located along the E40 between Bierbeek and Hoegaarden). Together with Elia, several alternatives were elaborated upon: connection to 70kV, connection to a 10kV distribution grid and a combination of these. Connecting the various clusters to the distribution network requires a major cable-laying operation that is not economically justified and impose a cost upon further growth. A connection to 70kV also appears to be unachievable for the customer. Because a voltage level of 70kV is available, Elia is not considering a 36kV solution, although it is an alternative given the geographically dispersed clusters.

Developments in this region will continue to be monitored. A new study for the connection of 13.2MVA of wind energy will be received on the 10kV grid from Tienen for the time being.

Lommel

In 2017, Fluvius received two major applications for decentralised production at the Kristalpark site in Lommel. LRM (Limburg Investment Company) had set itself the target to generate 75MVA of PV energy and Limburg Win(d)t wanted to install 68MVA of additional wind capacity, which comes to a total of around 140MVA of additional production.

The available capacity on the 26kV grid is fully occupied by the wind turbines. The requested 75MVA PV installation was diverted using a direct line to a neighbouring Elia customer and will not therefore be connected to the distribution grid.

To provide the remaining reception capacity of 70MVA of wind energy, several alternatives were developed – taking into account whether or not all clusters would actually be realised. If only part of the clusters are developed, we will choose a different investment (simpler cable laying).

Enhancing the transmission grid in this region is a necessity. A new branch line (the Meerhout-Van Eyck line) is being built, with an associated injection transformer in the direction of the 150kV station at Kristalpark in Lommel. On the fringes of these works, Fluvius will also take over some smaller customers who are still connected to a lower voltage level on the transmission grid. We are consulting with the affected customers.

As soon as the 150/26kV transformers at the post in Lommel have reached the end of their service life (in around 2035), the voltage level of 26kV will be converted to a voltage level of 30kV, as planned. We are developing the plans, taking into account further developments involving individual customers in this region. We also take into account the fact that the 26/15kV transformers in Balen will reach the end of their service life 5 to 10 years earlier than the ones situated in Lommel.

As a result of some larger requests from customers on both the distribution and transmission grid, consumption capacity has been fully taken up. As a result, no additional consumption can be connected before the enhancement work has been carried out (which is scheduled to be in service after a scheduling update in 2031). Elia and Fluvius are exploring some additional interim mitigation measures.

Wind Master Plan for the region of Genk South

The total project included in the wind master plan for the Genk South region involves 98MVA of additional wind turbines. Of these, 80MVA are located on the Genk-Zuid industrial estate and 18MVA in the municipality of Bilzen, in the vicinity of the Kieleberg industrial park. The transformer station in Langerlo has insufficient reception capacity for this power. If necessary, the 18MVA of power generated in the municipality of Bilzen can, if necessary, be received at the Bilzen transformer station.

We abandoned the idea of building a new transformer station on the Genk-Zuid – Kieleberg industrial estate axis. An expansion to the existing 70kV transmission grid does not fit within Elia's long-term vision.

We planned investment works to receive the power generated by the portion of the wind turbines that has already been licensed. These investment works include the establishment of a switching station in the Genk South region and the associated cable laying that is currently underway.

In time, the transformer station at Langerlo will be enhanced with an additional transformer. The power supply for the new switching station in Genk South will also come from this transformer station, to receive additional locally generated energy.

Gingelom

Several applications as part of a wind cluster in the vicinity of Landen (near the language boundary) are proving difficult to accommodate: connection in the short term is impossible. We investigated some alternatives, including a connection from Hannut or Avernas. After further detailed analysis and discussions with Elia and RESA (the distribution grid manager in Hannut), it was decided – when detailed studies are requested – to receive the power generated by this wind cluster at Hannut. The transformer station at Hannut is actually being remediated and has sufficient reception capacity.

Windcluster Tongeren – Riemst

The wind plan for Limburg has identified the potential to site 27 wind turbines on the Tongeren/Riemst border, in order to provide 80 to 90MVA. Since this power cannot be received on the existing 10kV distribution grid and interconnection point, we decided in consultation with Elia to build a new 30kV station next to the existing 10kV station in Riemst (Herderen).

Since a number of specific projects have already been requested and the ideal implementation period of the 30kV station is not compatible with the permit periods of these wind projects, we looked for an intermediate solution. This consists of an intermediate transformer with limited capacity that transforms the voltage of 10kV present at the transformer station in Riemst up to 30kV. The transformer to be used is leased from Elia and offers a capacity of up to 21MVA in the initial phase. That capacity has already been taken up.

If there are any additional requests which, when combined with the power from phase 1, exceed a threshold of 30MVA, Elia and Fluvius will implement the fully-fledged 30kV station. Its capacity will be increased to 110MVA, through a new transformation from the 150kV grid.

For now, Fluvius has received only an exploratory study request to implement wind turbines with a total capacity of 108MVA. We are consulting with Elia on proceeding with the construction of a full 150/30kV transformer station. Given the high uncertainty about permits and the implementation deadline, no investment decision has yet been made.

Energy-efficient electricity

In the Electricity Reporting Model (VREG, 2022), the regulator asks for further information on the assessment of the energy efficiency potential of the electricity infrastructure.

When trying to devise the most effective way in which to run a distribution grid without sacrificing quality, it is often necessary to make a trade-off between different aspects that come under the heading of 'efficiency'.

On the one hand, a grid manager wants to control the energy consumption associated with grid operation (especially grid losses). On the other hand, efficiency also means the efficient use of available infrastructure so that the need for new investment in enhancing the grid remains under control.

Both objectives are not always achieved by the same measures. It is often necessary to evaluate which approach makes the most sense.

For example, grid losses through cables will decrease if a grid manager chooses to systematically invest in higher voltage levels. However, these higher voltage levels may entail a higher investment for customers and the energy losses on the customer's side due to transforming the voltage must of course also be taken into account.

On an individual case basis, it is therefore not always possible to achieve both goals (to reduce grid losses and make efficient use of available capacity) at the same time. In each case, it is necessary to consider what is the most appropriate measure will be, within what parameters, in order to achieve the highest overall efficiency once all costs and benefits have been analysed.

As part of the European *Fit for 55 package*, the Energy Efficiency Directive is also being revised. In that context, the principle of *energy efficiency first* is being put forward. The 'energy efficiency first' principle implies taking cost-effective energy efficiency measures into account as much as possible when shaping energy policy and making relevant investment decisions. This points to the increased focus on energy efficiency that is also expected of grid operators.

In some cases, reducing energy losses is also a side effect of interventions/investments that are made in pursuit of another main objective. That is why measures to reduce energy losses should always be considered within the context of the Investment Plan as a whole.

Energy efficiency in distribution cables

Cable section

The lower the resistance of the cable, the lower the grid losses. However, thicker cables require a much larger investment.

In about 30% of the replacements of an existing high-voltage cable or the expansion of the high-voltage distribution grid, Fluvius chose to make use of a higher section than was strictly necessary. We do that in order to reduce grid losses. This leads to a higher investment cost in the year of construction, but we recover that higher cost in the longer term.

Fluvius has a clear policy that establishes the principles for choosing the section of new cables. Our tool takes into account three aspects: grid losses, voltage drop and the load capacity of the cable.

Each time a new cable is installed (e.g. when expanding the grid or replacing defective cables), this tool calculates the optimum section of the cable, based on the current and predicted load.

New since last year is the introduction of an overhead cable with a section of 150 mm^2. We are aiming to achieve a reduced energy loss thanks to the thicker section, and a lower overhead cost because we are consequently reducing the number of different stock items. In doing so, we are also making provision in advance of the increase in energy consumption resulting from electrification.

Eliminating imbalance

When the energy flows in grids are not equally distributed across the different phases, this involves phase imbalance. This phenomenon occurs mainly on our low-voltage distribution grids and to a less extent on our high-voltage distribution grids.

Phase imbalance is therefore mainly caused by unbalanced distribution in the case of customers with a single-phase connection on a low-voltage cable, or in the case of customers with a three-phase connection who do not have equal load distribution at their indoor facility. This imbalance can occur with consumption situations or when power is being injected into a low-voltage grid by decentralised production facilities (mainly solar panels).

The imbalance causes greater energy losses in our low-voltage distribution network, causing the cable load to reach its maximum more quickly, which may or may not result in voltage problems.

On the one hand and as a preventative measure, we try to spread out single-phase customers when making new connections. On the other, we raise awareness amongst electrical installers to distribute the customers' load equally across the different phases in the case of customers with a three-phase connection. In addition, we recommend the maximum use of three-phase inverters in the case of three-phase connections, which also simplifies the sizing of the indoor facility. As far as locally generated power of > 5kVA is concerned, the customer must in any case have a three-phase connection and the production must be distributed as evenly as possible across the phases. Fluvius provides information about this on its website. We also inform sectoral organisations about it by holding webinars. We regularly send newsletters to the sectoral organisations and federations and participate in joint events by various sectoral organisations and federations. We also inform the industry and electrical technicians by means of our own Partner Events (of which we organised four in 2022).

Application of higher mains voltage

A higher operating voltage leads to lower currents at the same power, which means lower grid losses.

Making a 400V grid available to all grid users

Increasing the operating voltage of the low-voltage distribution network to 400V would contribute to energy efficiency, thanks to the lower grid losses.

Use of 30kV or 36kV

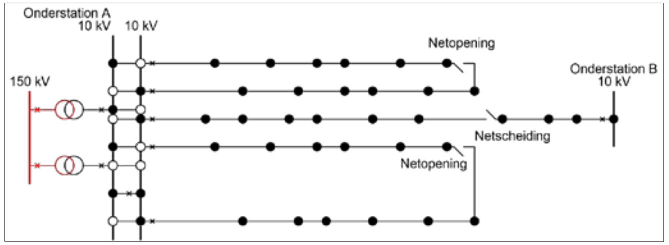
When connecting new customers, both for injection and consumption, a deliberate choice is made between the different voltage levels. When production is connected to the high-voltage distribution grid, we try to connect this production as close to the point of consumption as possible. That way, we can reduce power flows and the associated grid losses. If there is a possibility of connecting the production to a 30kV or 36kV grid, we work out the optimum choice depending on the capacity being connected.

Moving away from lower high voltage levels

At the Port of Antwerp, 11.3 km of high-voltage distribution grid is still being operated at 6kV. We have a remediation policy to ensure that we move away from this level of voltage in the foreseeable future.

Targeted selection of open point in distribution loops

Judicious placement of the open point reduces energy losses, prevents voltage problems, and reduces repair time in the event of a failure. In addition, the cable will not be subjected to as high a load and is therefore less subject to ageing. As a result, less investment in cables is required. In a high-voltage study, we assume a theoretical calculation in which we determine the open point in order to optimise the following parameters together – grid losses, voltage drop, selectivity. However, the final location of the open point depends upon local factors, including accessibility and the condition of the cabin and cabin equipment.



A method is currently being developed to quantify avoided energy losses more accurately, particularly in situations in which decentralised producers are present. We do this by calculating energy losses, based on time profiles of both consumers and decentralised producers.

On the one hand, thanks to the roll-out of the digital high-voltage cabin, the number of measured points in the high-voltage distribution grid will increase. This will provide a better understanding of the load, and consequently a more effective assessment of the location of the optimum open point. On the other hand, the degree of remote operation (the ability to switch remotely) is increasing. Dynamic switching of the high-voltage distribution grid thus allows the open point to be moved under varying load conditions, taking into account energy losses, voltage drops, etc. The accessibility of the open point becomes less important here, since switching can be carried out done remotely.

Energy efficiency at transformer stations, switching stations and distribution cabins

Use of energy-efficient distribution transformers in distribution cabins

Energy-efficient distribution transformers incur fewer losses. Purchasing them is more expensive, though.

When purchasing distribution transformers for new electricity cabins or to replace existing transformers, Fluvius chooses a transformer that is energy-efficient. The transformer must comply with Regulation (EU) No. 548/2014 of the Commission (ecological design of transformers).

Moreover, Fluvius gives suppliers an additional incentive, by awarding the tender based on the 'Total Cost of Ownership' (TCO). This allows us to purchase the most stringent loss levels possible, taking into account the *best available technology*.

The tendering process is carried out jointly for Fluvius-ORES-Sibelga. Moreover, the specification is also used by RESA.

Transformers are not proactively replaced for the sake of lower loss levels. The cost of doing this is too great relative to the losses avoided.

Segregated operation at transformer stations

A transformer station with two or more transformers and two or more rails can be operated in different ways as standard:

- Solo: one transformer feeds all rails. A second transformer is in reserve for use in the event of an incident or in maintenance situations;
- Parallel: multiple transformers power the rails together;
- Segregated: each transformer feeds part of the transformer station.

Transitioning from solo to segregated operation is one way to increase reception capacity for locally generated power. In solo operation, the capacity of one transformer determines the reception capacity. In segregated operation, the sum of the transformer capacities determines the reception capacity. The capacity is therefore greatly increased. If one transformer is lost, the injection must be limited to the capacity of the transformer remaining in service.

However, increasing the total transformer capacity means that the load on the individual transformer will be reduced. This also means that the load losses decrease because they are proportional to the square of the current. In contrast, iron losses increase with each transformer in service, regardless of load.

Transitioning to segregated operation is therefore advantageous whenever declining load losses offset increasing iron losses. Since transformer stations subjected to especially high loads are operated in a segregated manner, this is the case.

The trend within Fluvius to switch to segregated operation therefore not only ensures an increasing reception capacity, but also smaller energy losses.

Connecting decentralised production in the most effective possible way

Historically, electricity grids were built in a tree structure to bring the energy produced at large power plants to customers via the transmission grid, the local transmission grid, and the high and low-voltage distribution grid. This grid structure was not designed to efficiently integrate a significant capacity of decentralised (renewable) energy production and the market forces associated with it.

Energy generation based on solar and wind also has different requirements, given the variable energy supply.

Energy efficiency can be improved by reducing grid losses and ensuring that the largest possible quantity of the energy injected is consumed locally, instantaneously and preferably at the same voltage level.

Of course, the impact of this measure is largely influenced by external factors over which Fluvius has little or no control. Amongst other things, these include the development and location of decentralised energy production facilities. Fluvius wants to accommodate all decentralised (renewable) energy projects, large and small, on the distribution grid at the lowest possible social cost.

Potential offered by digital meters

The digital meter also initially provides a more effective understanding of personal energy consumption. In this way, it also creates awareness among individual grid users, which in turn contributes to the energy efficiency of the electricity system.

Thanks to the digital meter, the individual behaviour of each grid user can be better accounted for more effectively. This enables consumption/injection to be monitored more effectively and investment decisions to be taken in a more targeted way. That way, we can make more effective use of our assets (cables, transformers, etc.). We always consider the energy efficiency aspect when choosing the final solution.

Data Tables – Electricity

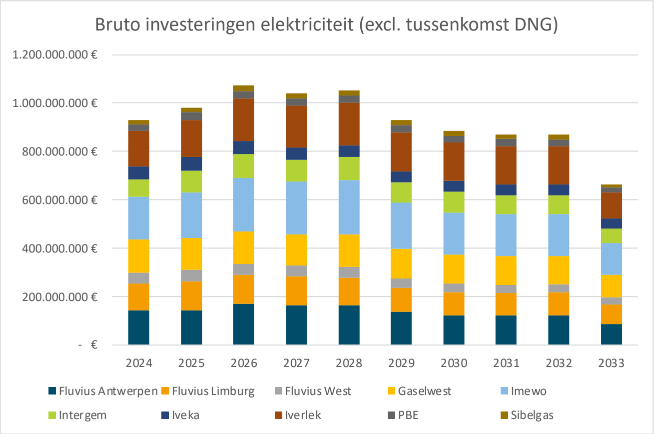
In the Electricity Reporting Model (VREG, 2022), the regulator requests that the data tables below be completed:

- Fluvius Antwerp 2023
- Fluvius Limburg 2023
- Fluvius West 2023
- Gaselwest 2023
- Imewo 2023
- Intergem 2023
- Iveka 2023
- Iverlek 2023
- PBE 2023
- Sibelgas 2023

Investment budget for Electricity

In the Electricity Reporting Model (VREG, 2022), the regulator asks for details of the investment budget for the short (3 years) and long term (10 years). On the right, you can find a summary for each DNB. This is an indicative proposal based on the scenarios in this Investment Plan. The final investment budgets will be submitted later this year after validation by the Management Committee and the various Boards of Directors.

The full annex of the investment budget reporting model will be provided upon submission of the Investment Plan to the regulator, after validation by the respective Boards of Directors.



Appendices on Gas

Connectivity rate and connection rate

The table below shows the connectivity rate and connection rate for each distribution grid manager. Forecast for connection rate and connectivity rate is no longer applicable since the 10 March 2017 amendment to the Energy Decree.

2022					
DNB	Total number of dwellings	Number of connected or connectible dwellings	Number of connected dwellings	AB%	AG%
IMEWO	679,014	640,898	447,506	94.4%	69.8%
INTERGEM	342,585	318,209	223,601	92.9%	70.3%
IVERLEK	594,453	549,987	389,129	92.5%	70.8%
GASELWEST	530,044	477,748	334,190	90.1%	70.0%
IVEKA	280,526	254,697	191,023	90.8%	75.0%
FLUVIUS ANTWERP	602,506	581,830	431,284	96.6%	74.1%
SIBELGAS	69,434	66,313	51,279	95.5%	75.5%
FLUVIUS LIMBURG	471,483	427,261	297,533	90.6%	69.6%
FLUVIUS WEST	94,206	83,786	61,758	88.9%	73.7%

Detailed plan for the natural gas distribution grid

MD grid diagram

LD plans by municipality

Detailed list of natural gas distribution grid with planned pipeline construction

The Energy Decree Article 4.1.19. §1 asks for a detailed list of natural gas pipelines whose construction is planned in the following three years, by street and, if necessary, with indication of house numbers. Given that connection rate target figures in residential areas were removed from the Energy Decree in 2017, no additional natural gas pipeline construction is provided for by default. Additional construction at the request of customers is confidential information and is just being made available for public consultation.

Method for forecasting peak consumption of gas receiving stations

We determined the load forecasts for the gas receiving stations (GRS) according to the following procedure:

Determination of peak consumption by GRS

- Processing all relevant daily peaks from last winter, as made available by Fluxys. Non-relevant daily peaks include consumption at weekends, during holidays, etc.
- Determination of the anticipated peak at Teq -11°C for each GRS by linear interpolation and manual detection of outlying points (e.g. due to switching).

Determination of the evolution in peak consumption by GRS

- The above exercise was repeated for all historical winters since 2016-2017.
- The resulting GRS peaks (at Teq -11°C) were plotted over time and given a trend line to determine the trend of consumption at a GRS. This extrapolation is used to forecast future peak consumption through 2026.

- Forecasts for 2027 and beyond were based on 2026 peak consumption, adjusted by a factor reflecting the assumptions of this Investment Plan. In doing so, we used a fixed assumption for each GRS, for each of the consumption groups listed below on the natural gas distribution grid:

Consumption group	Hypothesis
Domestic consumption	0.4% reduction/year
Industrial process heat consumption	Constant
Industrial heating consumption	14% reduction in current demand and 30% greening by 2032

- As a result of the conversion from low to high-calorific gas, we considered all the GRSes that are involved in this conversion together. The amalgamation and disappearance of GRSes throughout the conversion project creates an erratic pattern of predicted peak consumption, making an estimate of long-term evolution highly volatile.

Determination of the evolution in peak consumption by RS

We determined peak RS level consumption by distributing the peak consumption of the GRS proportionally among each RS – depending on the extent to which each RS contributed, on average, to peak consumption at the GRS during past winters.

Please note that determining and further analysing peak consumption at the RS level has limited added value. The load of stations within the same GRS behaves dynamically, based on the pressure settings of receiving stations and reducing stations, as well as any switching. When pressure settings are changed or when the grid is switched differently **within a winter period** or **between winter periods**, the forecast at RS level is significantly less reliable.

Note on converting peak consumption to Teq -11°C

Analyses from both Fluvius and Fluxys show that the prediction of peak consumption at Teq -11°C is strongly influenced by temperatures during the winter in question. The extrapolation is less reliable if it was a warm winter because there is less data available at cold temperatures to make a reliable extrapolation. A valid extrapolation can only be made if there were enough days with a Teq < 0°C. The table below lists the number of suitable days for past winters.

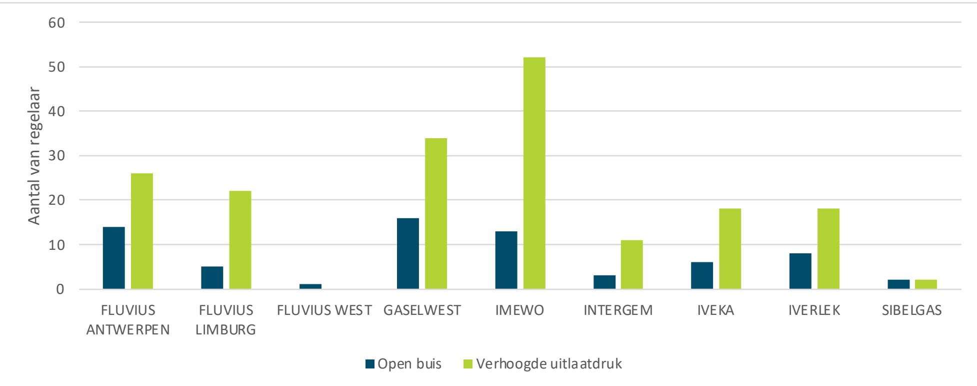
winter	heating degree days	number of days with Teq < 0
2012-2013	1.501	23
2013-2014	1.222	0
2014-2015	1.373	6
2015-2016	1.111	4
2016-2017	1.444	16
2017-2018	1.429	10
2018-2019	1.288	7
2019-2020	1.230	0
2020-2021	1.283	9
2021-2022	1.291	1
2022-2023	1.246	11

Energy-efficiency for gas

In the Gas Reporting Model (VREG, 2022), the regulator asks for further information on the assessment of the energy efficiency potential of its gas infrastructure. In particular, this concerns 'open pipe' cabins and increased pressure deliveries for CNG stations and for CHPs.

Investment measures to reduce energy consumption

By choosing the right customer cabin according to the application, we can ensure optimum energy savings. When connecting CNG filling stations, Fluvius offers an 'open pipe' cabin. By supplying gas at grid pressure, the electrical consumption of the compression facility can be reduced. In doing so, the operator achieves electrical energy savings averaging 16%. We also offer this option to the owners of CHPs so that they can make optimum use of grid pressure.
In addition, by using increased delivery pressure at customer cabins, we provide energy savings of 50% on average.



Potential offered by digital meters

The digital meter also provides a more effective understanding of personal energy consumption. In this way, it creates awareness among grid users, which in turn contributes to the energy efficiency of the distribution system.

Data Tables for Gas

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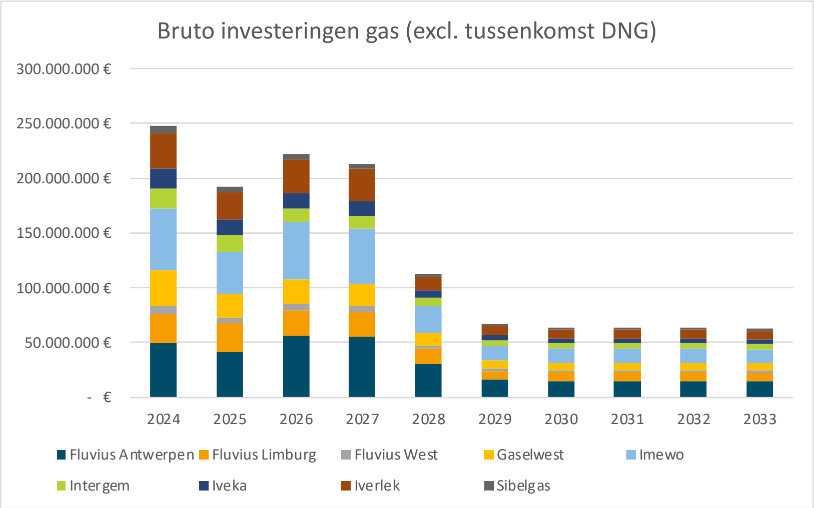

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Appendices for Heat

Different generations of thermal grids

A heat grid is an underground pipe network that transports heat from sources to consumers. The system is perhaps best compared to a large-scale central heating system at the neighbourhood, municipal or even city level. A heat grid forms a coherent whole of production, distribution and consumption.

Heat grids come in different shapes and sizes (see also the illustration). The first generations of thermal networks were operated at very high temperatures, initially using steam and later hot water as the heat transfer medium. They were usually (or still are) powered by large cogeneration units, which simultaneously produce both electricity and heat through the combustion of waste or fossil fuels. Biomass and industrial waste heat are also potential heat sources. Gradually, the supply temperature decreased (from about 200 to typically 90°C) and the energetic efficiency of the system increased.

Recent fourth-generation heat networks use the same unilateral top-down approach as before, distributing collectively generated heat through insulated piping to individual customers. However, they put maximum effort into sustainability and energy efficiency, integrating renewable sources (such as solar thermal or geothermal energy) and further reducing operating temperatures (from 70 to 40°C).

Fifth-generation thermal networks, on the other hand, are fundamentally different from their predecessors. In fact, they do not transport ready-made heat that is directly usable for space heating or domestic hot water production, but very low-temperature source heat (approx. 15°C). Each individual user can use this low-grade heat according to a practical need: as an input for their own heat pump that produces usable heat using electricity, or as a medium for active or passive cooling. This type of network allows for bidirectional exchange between different buildings: the cooling demand for one building (= heat surplus) can serve to accommodate the heat demand in another building, and vice versa. Due to the small temperature difference with the substrate, uninsulated pipes can also be used for this purpose.

In what follows, Fluvius therefore makes a structural distinction between third or fourth-generation heat grids on the one hand and fifth-generation source networks on the other.

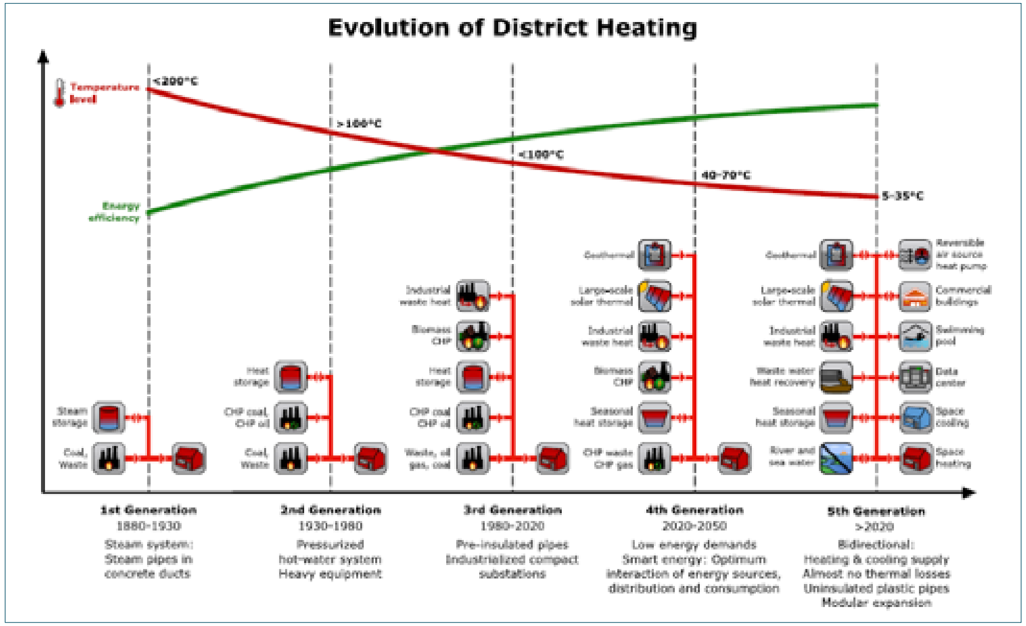


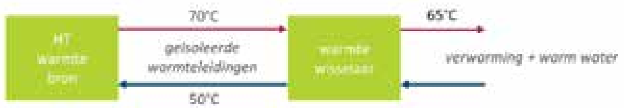
Figure 14: Historical evolution of heat grids[6]

6 Marco Wirtz, "Quantifying demand balancing in bidirectional low temperature networks," Energy and Buildings, Volume 224 (2020)

Practical classification

In classical, unidirectional heat networks, the lower limit for the supply temperature is ultimate determined by the (comfort) requirements on the consumption side, both in terms of space heating and production for domestic hot water. For example, standard guidelines for legionella control in public buildings require that hot water be produced at a temperature of at least 60°C.[6]

Fluvius uniformly qualifies all heat sources that can be used directly for the production of domestic hot water as 'high temperature'. A temperature regime of 70/50°C is envisioned for high-temperature heat networks (see illustration), as a compromise between energy efficiency on the source and network sides on the one hand, and user comfort and technical simplicity at the building level on the other. These grids are an important tool for making the existing building portfolio more sustainable. Because of the significant investment costs for insulated piping systems, the techno-economic potential is mainly to be found in specific geographical clusters where renewable heat production can be coupled with sufficiently concentrated heat demand.

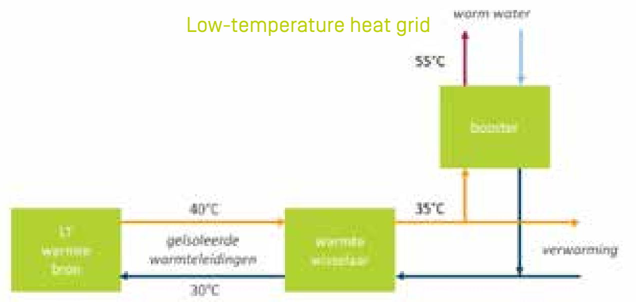


High-temperature heat grid

6 https://www.zorg-en-gezondheid.be/per-domein/preventie/legionella

Heat sources that cannot be used directly for the production of domestic hot water are considered 'low temperature' by Fluvius. If necessary, individual boosters are always needed for targeted post-heating. Ideally, though, the low-temperature heat can be used directly for space heating. From an energy point of view, this is the most efficient solution: on the one hand, economies of scale can be obtained by organising (a large part of) the renewable heat production collectively, and on the other, domestic water is only generated where and when needed. However, **low-temperature heat grids** require high insulation levels and sufficiently large heat exchange surfaces at the building level, which in existing buildings usually requires structural modifications to the building envelope and/or the delivery systems. These grids are therefore primarily suitable for new builds, where increasingly stringent energy performance regulations from 2023 stipulate that the design flow temperature for the heat delivery system must not exceed 45°C.[7]

7 https://www.vlaanderen.be/epb-pedia/epb-plichtig-toepassing-en-eisen/epb-eisentabellen-per-aanvraagjaar/epb-eisen-bij-bouwaanvraag-melding-in-2023-en-2024

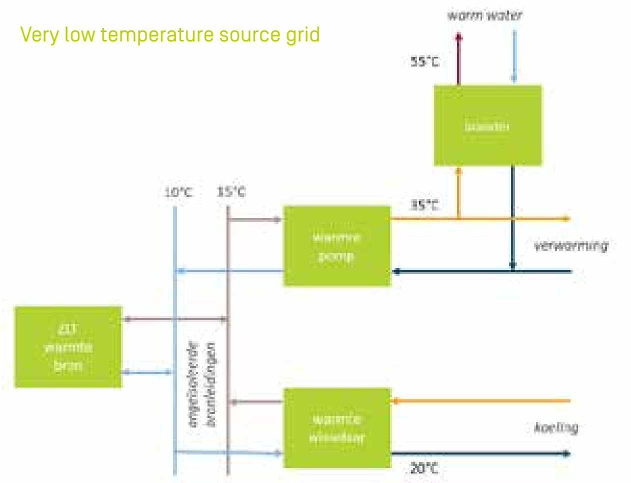


Low-temperature heat grid

Finally, heat sources that cannot be used directly for space heating, nor for the production of domestic hot water are categorised as 'very low temperature'. For heating purposes, these sources can provide input to the evaporator side of a heat pump, but they can also absorb heat as part of active or passive cooling systems. Thus, they allow energy exchange in two directions and therefore the associated grids work fundamentally differently from classical heat grids.

Very low temperature source grids are therefore best compared to shallow geothermal energy at the district level. Notwithstanding that uninsulated piping is inexpensive, source networks also require investment in specific facilities at the building level and associated controlling measures to allow for bidirectional flow. Given the small temperature differences in the system (i.e. a limited ΔT between supply and return pipes), large volumes of water must be circulated to transport the source heat. These grids are therefore best suited to specific building clusters where the distances between them are limited and/or clear synergy benefits can be achieved. For example: multi-purpose buildings where tertiary cooling demand in the immediate vicinity is complemented by residential heat demand, supplemented by seasonal underground storage and/or low-grade sources from the surrounding area (aquathermy or riothermy).

Very low temperature source grid



The table below briefly summarises the main characteristics of the different typologies. The present classification is not exhaustive, as in each category, alternative interpretations or intermediate forms are conceivable with slightly different characteristics. However, this breakdown provides some practical guidance for further analysis in the context of the Investment Plan. The next section explores the main sources and production techniques that can be employed for heat or source grids.

	High-temperature heat grid HT	Low-temperature heat grid LT	Very low temperature source grid VLT
Scope	Existing buildings	New builds	Specific building clusters
Temperature regime	70 / 50°C	40 / 30°C	15 / 10°C
Conduits	Insulated	Insulated	Non-insulated
Sources	Waste-to-energy plantsWaste heatDeep geothermal energyHeat pumps	Waste heatDeep geothermal energyHeat pumps	Shallow geothermal energyAquathermyRiothermy

Classification of heat grids

Heat sources and production

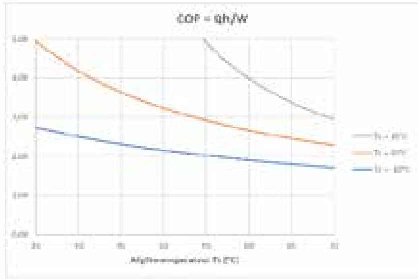
The availability of adequate heat production, both in terms of security of supply and sustainability, is essential for the construction of a future-proof heat grid. Throughout this text, 'sustainable heat' is used as a catch-all term for both 'green heat' (from renewable sources such as heat pumps and geothermal) and 'waste heat' (from industrial applications not necessarily driven by renewable sources).

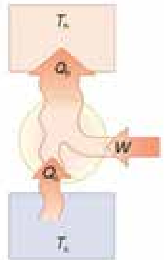
High or low temperature heat networks require sources and/or production technologies that can directly deliver usable temperature levels. Sources for this include those listed below, although of course their actual temperature range may vary.

- **Waste heat** can be released from processes whose purpose is neither to produce heat, electricity or mechanical energy, nor are controllable in line with heat demand.
- **Waste-to-energy plants** process combustible domestic waste that cannot be recycled into electricity and heat.
- **Deep geothermal** uses geothermal energy. In the subsurface, the temperature actually rises by about 30°C per kilometre, which at great depths can provide enough hot water for heating applications.
- **Heat pumps** extract low-grade heat from the surroundings to upgrade it to usable temperature levels through electricity.

Notwithstanding the fact that waste heat and deep geothermal require some electrical power to unlock and circulate the available thermal power, their impact on the electricity grid is negligible overall. Waste-to-energy plants also produce electrical power on balance, but are usually connected directly to the transmission grid.

The electrical power demand of heat pumps is highly dependent upon its area of application, particularly the source and release temperatures. After all, heat pumps thrive best at the highest possible source temperatures and the lowest possible release temperatures. The COP ('Coefficient Of Performance') then represents the ratio of heat supplied to electricity used. The figure below gives an indication of the COP for individual heat pumps according to operational conditions. Economies of scale allow collective heat pumps to achieve higher efficiencies. Air-water heat pumps draw source heat from the outside air and must be able to deliver their peak output at outdoor temperatures as low as -10°C, when the COP is typically unfavourable. Water-water heat pumps can obtain their source heat from elsewhere.





Indicative COP for heat pumps in different temperature regimes.

Very low temperature source grids, as already cited, do not provide directly usable heat to end users. They merely offer an alternative to outside air as a source medium and as such can improve the system efficiency of heat pumps.

- **Shallow geothermal**[6] uses the subsurface to a depth of about 150 metres as a source of thermal energy at a fairly constant temperature (approx. 10°C).
- **Aquathermy**[7] is the general collective term for heat extraction from surface water, waste water or drinking water.
- **Riothermy**[8] specifically recovers heat from waste water streams in the sewage system or from the effluent from waste water treatment plants.

6 https://www.smartgeotherm.be

7 https://www.aquathermie.be

8 https://www.riothermie.be

Shallow geothermal exists in several forms, such as closed vertical heat exchangers (BES fields or 'borehole thermal energy storage') or open systems that use aquifers ('Geothermal energy storage'). Not all forms can be applied everywhere: both the size of the available surface and soil properties play a crucial role. The naming, however, illustrates that shallow geothermal should be considered primarily a form of storage. Indeed, notwithstanding the fact that the subsurface has a certain regenerative capacity, these systems must be periodically balanced to avoid thermal depletion. This means the heat extracted from the soil in the winter must also be injected back in the summer. BES fields or Geothermal systems are therefore ideally suited for seasonal storage and bi-directional use (both heating and cooling demand).

Unlike shallow geothermal, aquathermy in general or riothermy in particular do qualify as a practically infinite resource, similar to outdoor air. Although the capacity is limited by the available water flow rate, these systems are not bound to a thermal equilibrium on an annual basis, and the temperature fluctuations are a lot less pronounced than those for outdoor air. For example, the temperature of the Scheldt water near Kruibeke generally varies between 4°C and 24°C[9]. In principle, aquathermy can also serve both heating and cooling demand, but for passive cooling, temperatures are too high in the summer period.

	Temperature	Points to be taken into consideration
Waste heat	?	Difficult to predict and/or control by-product of industrial processes
Waste-to-energy plant	70 – 120°C	Limited number of facilities in Flanders
Deep geothermal	70 – 120°C	Applicable only in very specific geology (Limburg and Antwerp Campine)
Heat pump	40 – 70°C	Electrical capacity required is highly dependent on source and release temperatures
Aquathermal	5 – 25°C	Not suitable for passive cooling
Shallow geothermal	5 – 15°C	Thermal balancing necessary

Non-exhaustive overview of renewable heat sources and production

9 https://www.scheldemonitor.org/en