Innovation Strategy

2024-2027

Transforming challenges into opportunities

FOR PUBLIC CONSULTATION

Contents

Transforming challenges into opportunities

Global events over the past three years have caused disruptions in our society, including the European gas and electricity markets and led to extreme volatility of energy prices. These events occurred at a time of great transformation for the energy sector. Indeed, the energy transition is entering a new phase: one in which all areas of the energy landscape are changing at phenomenal speed, from the growth in renewables and phase-out of nuclear power through to shifts in the distribution of energy. New futures are being shaped for transmission system operators (TSOs) as a consequence.

To achieve our goal of providing an energy system that is *sustainable*, *secure* and *affordable*, business as usual is not possible. The scale of the challenges we are facing requires us to quickly adapt our ways of working, upgrade the technologies we use, and modify our processes. We must act now to ensure the energy transition is a success.

In addition to working with partners from across the energy sector, innovation will be key for successfully navigating the disruptions, challenges and shifts mentioned above. It is innovation that will allow us to transform these into opportunities for society - opportunities that will ensure that we reach net zero in time. We view innovation as a mindset which must be embedded across the whole organisation, opening doors to more effective processes, products and ideas.

With this in mind, Elia developed this Innovation Strategy. It aims to give stakeholders a holistic view of external trends and their impact on our mandate. This document outlines our strategy for the next regulatory period. It describes each of the innovation areas we are working on in line with the latest developments in the energy sector. Next to setting our priorities for the next years, we are also cultivating a network of internal and external innovators who will help to transform Elia and prepare it for meeting the challenges ahead.

We look forward to receiving feedback from our readers and are keen to hear from organisations who want to partner with us in the future.

We wish you an insightful reading.

Introduction

Being the owner of the transmission system operator in Belgium, Elia provides the Belgian stakeholders with a robust electricity grid, supporting socioeconomic prosperity. We ensure that production and consumption of electricity are balanced around the clock, supplying over 10 million end users.

Since our grid forms the backbone of the Belgian electricity system, we are also a driver of the energy transition in the country - and in Europe more widely. We are helping to meet social, political and economic goals by integrating increasing amounts of renewable energy into the system, supporting the latter as it gradually encompasses smaller, more dispersed and localised energy sources. In doing so, we aim to address the three dimensions of the *'energy trilemma'*: sustainability, security and affordability.

This task is no easy feat. Its difficulty is well expressed in the German word *Energiewende*. Literally translated, the expression means energy turn, or turnaround, making the challenges linked to the transition quite explicit: we must turn away from current methods of producing and consuming energy towards a drastically different way of working. This drastic change is putting a great deal of pressure on the existing system, which must keep evolving if it is to continue serving society's needs. The system and our role within it are becoming increasingly complex, requiring us to consider trends such as the acceleration of electrification, the move away from non-renewable energy sources (RES), the rise in prosumers and the difficulty of obtaining local acceptance for the construction of infrastructure. Building the system of the future is therefore an intricate process that requires us to completely rethink the way we develop and run it, to be flexible, open to learning and collaboration, and to be innovative.

Indeed, as stated by the International Renewable Energy Agency (IRENA), "the energy transition (...) requires systemic innovation, matching and leveraging synergies in innovations across all sectors and components of the system, and involving all actors. (...) Improved processes, research, development and deployment (RD&D) systems and cooperation networks are essential to overcome the barriers to a zero-carbon energy sector."[1]

In fact, we at Elia consider innovation to be crucial for transforming the challenges we are facing into opportunities. It is through the harnessing of these opportunities that we will be able to successfully navigate our way to net zero.

This Innovation Strategy outlines our legal mandate, the trends that are influencing the energy system, and our areas of focus over the next five years. It explains how, with the right policies, technologies and investments in place, we will be able to shape and grasp opportunities and so establish a more sustainable future for all.

[1] **https://www.irena.org/Energy-Transition/Innovation**; last accessed in mid-2022

Our role within the energy system

Our legal mandate as a TSO

Elia is responsible for keeping the lights on around the clock, supplying 10 million end users with electricity. The legal responsibilities we have been conferred - our four core societal tasks - are outlined below.

Grid Management

We plan, build and maintain our transmission grid in accordance with society's long-term needs. We invest heavily in the integration of RES, the development of a meshed offshore grid and the construction of inter-connectors to facilitate the integration of the European energy market. This task comprises the business activities of System Planning, Infrastructure Design and Construction and Grid Operations and Mainte-nance.

System Operations

We monitor the electricity system in real time, maintaining the balance between supply and demand across our control areas on a continuous basis. This requires specialist knowledge, close working with local and national partners, and the use of sophisticated tools and processes.

Market Facilitation

As market facilitators, Elia has ultimate responsibility for ensuring that the balance between demand and supply is maintained across their control areas. We do this by employing flexibility that is provided by bal-ancing service providers (BSPs) and, when the need arises, by procuring ancillary services.

Trusteeship

The Belgian legislator have transferred the responsibility for coordinating and processing legal levy systems that promote environmentally friendly technologies to the TSO. Elia therefore acts as trustee, collecting levies from consumers in Belgium and playing an important organisational role in the remuneration of green energy producers.

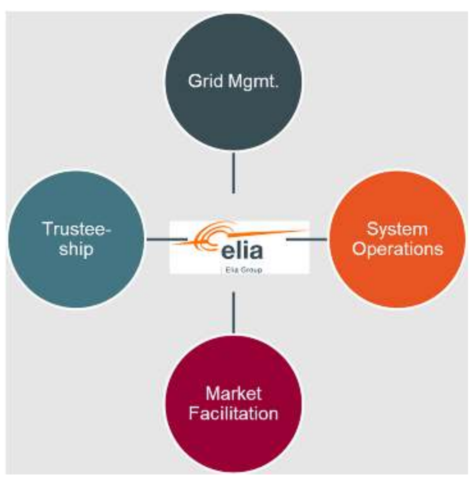

Figure 1: Four mandates of the TSO

The energy trilemma

In carrying out our business activities, our ultimate goal is to effectively facilitate the management of the *energy trilemma*. Coined by the World Energy Council, the term is used to describe the three elements that national energy systems should seek to successfully balance.

Political, social, economic and technological changes (outlined in the following section) are increasing the complexity of the context we are working in and so, alongside this, our activities. In turn, this means we need to adopt increasingly innovative methods in specific areas to ensure that we can indeed balance the energy trilemma as effectively as possible - in the interest of our customers and society as a whole.

As is made clear in the section outlining our domains of innovation, every decision we make is guided by this ultimate goal. As a regulated business, Elia performs its activities with its societal impact firmly in mind: we are a driver of the energy transition and are helping society to establish *affordable*, *secure* and *sustainable* energy systems.

Figure 2: The energy trilemma[2]

Affordability consists of providing inclusive access to affordable energy, so ensuring that basic power needs are met, and that socioeconomic prosperity is supported.
In order to enable energy affordability, the TSO has a crucial role. On one hand, we build and maintain the transmission assets. We have to plan the network in a good way, building all necessary assets to integrate all necessary energy sources, but avoiding the risk of stranded assets. By subsequently maximizing the available transmission capacity to the market, the social welfare can be maximized by optimizing the exchange of energy between different bidding zones.

Sustainability covers avoiding or mitigating environmental harm and the impacts of climate change as energy is generated, transmitted and distributed to consumers.
On one hand, the TSO has the role to integrate renewable energy sources, and cope with the impacts of these new sources on the system management. Next to that, we must minimize the impact of our assets on the environment, by reducing the harm on wildlife, cutting emission of harmful gasses and so forth.

2 EW-Trilemma_Final (energywatch.com.my)

Finally, we have to assess all possibilities to reduce environmental impact of our operations, e.g. sourcing ancillary services or covering grid losses.

Security involves meeting current and future energy needs in a reliable manner, through the availability of energy sources and the dependability of proper infrastructure.
As a TSO, we have no final say over the energy mix in a country. However, we are responsible over the maintenance and hence availability of the transmission grid, using all assets within their operational limits, balancing demand and supply, and limiting market exchanges where necessary. This way, we can avoid unwanted outages or eventual blackouts.

The European green and digital transitions

As outlined in the European Green Deal[3], which was presented at the end of 2019, Europe is aiming to become the world's first climate-neutral continent by 2050. In order to succeed in this, the European Commission published the 'Fit for 55'[4] legislative package in 2021. This covered a wide range of policy areas, including renewables, energy efficiency, energy performance of buildings, the decarbonisation of the gas sector, land use, energy taxation, effort sharing and emissions trading. It also included the aim of reducing the EU's greenhouse gas emissions by at least 55% (compared with 1990 levels) by 2030. Moreover, it proposed the introduction of EU level binding targets regarding reductions in energy consumption and increases in the share occupied by renewable energy.

While the revised and new legislative proposals were being negotiated, Russia invaded Ukraine on 24 February 2022. As consequence, on 18 May 2022, the Commission published its REPowerEU Plan[5], which sets out a series of measures to rapidly reduce the EU's dependence on Russian fossil fuels well in advance of 2030. Its aim is therefore to accelerate the clean energy transition and deliver clean, affordable and secure energy to European businesses and citizens. As part of this Plan, the Commission also proposed amendments to ongoing revisions of the Energy Efficiency Directive and the Renewable Energy Directive, such as:

- an increase in the EU energy efficiency target: from 9% (in 'Fit for 55') to 13%, compared with projections in the 2020 reference scenario, leading to 750 million tonnes and 980 million tonnes of final and primary energy consumption in 2030 respectively;
- an increase in the share occupied by renewable energy in the EU's gross final energy consumption by 2030: from 40% (in 'Fit for 55') to at least 45%.

The measures above are seen as part of the solution to extreme energy prices caused by the COVID-19 pandemic and war in Ukraine. Additionally, the European Commission also set forth a series of emergency measures in the form of Council Regulations which aim to address high energy prices, enhance solidarity in the gas sector, accelerate the permitting process associated with RES (and related grid infrastructure) projects, and establish a gas market correction mechanism.

Furthermore, the Commission has announced it will adopt a legislative proposal for a targeted reform of the electricity market design by end of March 2023. In the meantime, the Commission has launched a public

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[3] **A European Green Deal (europa.eu)**
[4] **Fit for 55 - The EU's plan for a green transition - Consilium (europa.eu)**
[5] **REPowerEU (europa.eu)**; these legislative proposals are still being negotiated by the European Commission, Member States and the European Parliament.

consultation to collect stakeholder input. According to the Commission document accompanying the consultation, this targeted reform aims to address the shortcomings of the current electricity market design and ensure stable and well-integrated energy markets, which continue to attract private investments (in renewables, in low-carbon technologies as well as in grids) at a sufficient scale as an essential enabler for the transition towards a climate neutral economy by 2050, while ensuring energy security and affordability for European industries, SMES and households. The Commission expects that building on and seizing the potential of the digitalisation of the energy system, such as active participation by consumers, will be a key element of our future electricity markets and systems. In particular, the Commission is consulting on options to reduce the impact of gas prices on electricity bills through long-term mechanisms that will support investments in renewables and low-carbon technologies – as well as in grids - whilst enabling consumers to hedge themselves against future high prices. The Commission is looking on options on how to better protect and empower consumers, amongst others by further enabling energy sharing and on how to facilitate demand response from flexible appliances. The Commission is also looking for alternatives to gas to keep the system in balance, amongst others by unlocking the potential of demand-side flexibility and storage, and by using sub-metering data for settlement and observability. Last but not least, the Commission is looking on improvements within the Regulation on wholesale market integrity and transparency (REMIT).

Europe is also undergoing a digital transition. Indeed, the digitalisation of the energy sector is seen as an enabler of the energy transition. Several proposals have been published by the Commission, the most important of which was published on 18 October 2022: ‘Digitalising the Energy System: EU Action Plan’[6]. This outlines key actions for accelerating the digitalisation of the energy sector, and in particular the electricity system, in order to:

- promote connectivity, interoperability and the seamless exchange of data between different actors while respecting privacy and data protection to (amongst other things) start deploying a common EU energy data space no later than 2024;
- boost and coordinate smart and digital investments in the electricity grid, in particular through TSOs and DSOs developing a digital twin of the EU electricity grid (supported by cooperation between ENTSO-E and the EU DSO Entity);
- provide better services based on digital innovation to engage consumers in the digital transition, by (for example) promoting digital tools that support consumers to adapt their consumption patterns and facilitate energy communities to emerge);
- ensure the energy system is secure, in particular by incentivising coordinated risk assessments in critical supply chains such as ICT and cross-border electricity flows, as addressed in the upcoming Network Code on Cybersecurity;
- make sure that the growing needs of the ICT sector are aligned with the EU Green Deal, especially through actions that aim to limit its carbon footprint and increase the sustainability of ICT products and services, telecommunication networks, data centres and cryptocurrencies.

[6] EUR-Lex - 52022DC0552 - EN - EUR-Lex (europa.eu)

The four megatrends shaping the energy transition

The landscape of the energy sector is changing at phenomenal speed, not only accelerated by political factors as outlined in the section above, but also driven by societal expectations and ever-increasing opportunities due to innovation in all sectors.

From the range of social, economic, technological, and political developments that are taking place, we have identified four major interconnected trends that are playing a key role in shaping the future of the energy sector (Figure 3). These trends are increasing the complexity of the power system, triggering a need for increased flexibility and technological breakthroughs.

Figure 3: The four megatrends shaping the energy transition

Accelerated decarbonisation and electrification to fast-forward the green transition

Context

As explained earlier in the document, the Russian invasion of Ukraine in February 2022 returned a sense of urgency to the European energy debate. The geopolitical crisis and record-breaking energy prices have prompted the European Union to take stronger ownership of its energy production and more rapidly fulfil its commitments to renewable energy, decarbonisation and electrification.

Following the start of the Ukrainian war, therefore, the European Commission published its 'RePowerEU Plan' (May 2022), which builds on the 'European Green Deal' (2019) and 'Fit for 55' legislative package (2021). The plan aims to reduce Europe's dependence on Russian fossil fuels. It focuses on the diversification of Europe's energy supplies, energy saving measures and increasing clean power.

Accelerating the energy transition will reduce our dependence on fossil fuels, strengthen Europe's energy sovereignty and ensure more stable and affordable energy prices, helping to mitigate high inflation in gas and electricity markets. Offshore energy, generated in Europe's seas, is set to become a cornerstone of its future energy system.

However, the sharp rise in renewable energy and in electricity demand are triggering important consequences. The building of 'leading' grid infrastructure is critical for matching society's ambition to accelerate the transition. Since areas with high amounts of RES are often remote, the need for long-distance electricity transmission is rising. Moreover, areas with complementary production patterns need to be connected as the availability of RES is not equally distributed across Europe.

To ensure the secure and efficient operation of such a renewable and volatile electricity system, more flexibility should be unlocked from households and industry across all levels of the electricity system and via different electricity markets. The consequences hereof will be discussed in the next megatrend.

Key numbers

RES capacity is due to drastically increase in the run-up to 2030. The European Commission has also published its 'Offshore Renewable Energy' strategy in 2020, which it put forward the goal of increasing offshore wind generation from 12 GW to 60 GW by 2030.[7]

Similarly, in our Adequacy and Flex study 2022-2032[8], we show that we can expect an average yearly increase of solar power in Belgium of 300 MW per year between 2022 and 2032 in the 'Low RES' scenario, and even up to 920 MW capacity increase per year in the 'High RES' case.

Since electrification is an obvious choice for households and heavy industries to decarbonize their activities, industrial processes and the heating and transport sectors are setting the road for significant rises in the demand for power. Driven by the increasing ambitions of the Belgian government, the Adequacy & Flexibility study 2022-2032 predicts a total of 1.4 million EVs in Belgium by the end of 2030, up from about 100.000 in 2022.

Moreover, industry's transition to net zero is accelerating, as demonstrated in our 2022 study 'Powering Industry Towards Net Zero[9]. The study highlights how industry's electricity consumption is due to increase by 50% by 2030 in Belgium respectively. Belgium's total demand (industrial, households and tertiary sectors) for electricity is therefore due to reach 113 TWh in 2030[10] (up from 85.6 TWh in 2020; a 24% increase).

Impact

The steep rise in RES and the anticipated growth in electricity demand are the cause of important repercussions, both on ensuring the grid stability and on the construction of our grid. Since areas with RES are often remote, or located far from consumption centres, this has triggered the need for more long-distance transmission capacity and the connection of areas with different and complementary production patterns. The increased electricity demand needs to be covered, and the balance between demand and supply needs to be ensured every second of the day.

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[7] https://ec.europa.eu/energy/topics/renewable-energy/eu-strategy-offshore-renewable-energy_en

[8] Adequacy and Flex 2022 - 2032

[9] Elia Group, Powering Industry Towards Net Zero (2022): https://issuu.com/eliagroup/docs/powering_industry_towards_net_zero?fr=sNThlMjU0MTU1OTg

[10] Federal Development Plan 2023 and International Energy Agency (IEA)

Flexible electricity consumption to integrate more renewables and lower consumption costs

Context

Our sources of energy are both increasing in number and type. We are moving away from traditional sources like nuclear and fossil fuels to solar and wind power. Renewables are installed in form of large on- and offshore sites and in a decentralized way on the rooftops of our citizens.

Alongside needing to adapt our grid to accommodate these new green energy sources, the growth in intermittent renewables means that production patterns are decreasing in predictability (and new ways of balancing the grid must be adopted). Because the balance of consumption and production needs to be guaranteed at all times, flexible consumption is becoming increasingly important both for supporting the grid as electrification spreads and renewable energy levels rise and for controlling system costs.

Industrial electrification and the rise of electric vehicles, heat pumps and batteries are fundamentally changing the way consumers are interacting with the electricity system. Sector convergence is offering new opportunities for unlocking flexibility, meaning it is becoming important accelerator for an efficient energy transition.

New flexible appliances will allow households to consume more electricity at lowers costs when there is lots of wind and sunshine available and reduce or even shift their consumption in time when renewable generation is limited, and energy use is more expensive. Elia's 'Consumer-Centric Market Design' (2021) aims to facilitate this. Once rolled out, existing and new energy service suppliers will be able to provide their customers with better products and incentives, allowing them to monetise their flexibility and lower electricity costs.

Moreover, industry will become a key provider of flexibility as it electrifies and decarbonises some of its processes. Today, the business case is mostly focused on industry providing ancillary services to the power system. However, much broader opportunities will be offered up in electricity markets provided we further develop these, allowing industry to better align its consumption with renewable generation patterns and optimise it against dynamic electricity prices.

Key numbers

The number of prosumers will therefore continue to grow, empowered by digital technologies that allow them to play a more prominent role in the energy transition (in addition to PV panels, these include heat pumps and electric vehicles). These new technologies, alongside increasing electrification and sector coupling, will also stimulate the emergence of new players, such as service providers that will see consumers being rewarded for providing the grid with the flexibility it needs, whilst benefiting from increased value and comfort.

Demand side response from industry and end users alike will be encouraged through price signals: demand will be reduced by users when prices reach a certain level (known as load shedding), or moved to another moment in the day (known as load shifting). Indeed, in the Adequacy & Flex study 2022-2032 we assume that Belgium will see 2.4 GW of load shedding by 2030 (a 30% increase compared with 2022) and 1.5 GWh/day of load shifting (while it was still at 0 in 2020).

Impact

As households and industries will possess an increasing amount of electrified and flexible devices, and are getting more educated on the opportunities these could offer, they will expect from the TSO to offer them possibilities to use this flexibility in a way that serves the grid and brings economic value. It will be the role of the TSO to link the upcoming challenges linked to electrification and RES increase to market opportunities, in order to accelerate the paradigm shift and increase the overall social welfare.

Increasing international cooperation to harness Europe's full RES potential

Context

As described in Elia Group's 'Road Map to Net Zero' study (November 2021), Europe's direct electricity demand can be met in 2050 - but only if we accelerate RES expansion by a factor of three, boost electrification, increase efficiency and build more on- and offshore interconnectors to balance out the uneven distribution of RES across Europe.

To make optimal use of the continent's RES, Europe needs to set up frameworks for partnerships between countries with different levels of RES potential. Moreover, the full potential of the North and Baltic seas will need to be harnessed through an international approach. The rise of hybrid interconnectors and energy islands will allow electricity to be exchanged between countries whilst also connecting them to offshore wind farms. These interconnectors and energy islands are forming the first building blocks of a European meshed offshore grid.

The increasing integration of the European power system is requiring a supranational approach to be supported by Member States. This can occur across European regions through Regional Coordination Centers (such as Coreso and TSCNET) or via continent-wide cooperation. For example, the Ten-Year Network Development Plan prepared by the European Network of Transmission System Operators (ENTSO-E) is helping to secure fully integrated European grid and energy markets.

Key numbers

Opportunities for improving the power system exist all over Europe. Between 2025 and 2030, the TYNDP[11] finds that 64 GW of additional capacity on over 50 borders would be economically efficient, a 55 % increase over the 2025 grid. In 2040, there is space for 88 GW of cross-border capacity increase after 2025 (a 75 % increase) on over 65 borders, for 41 GW of storage in 19 countries and 3 GW of CO2-free peaking units in 4 countries.

Enhanced TSO coordination has many financial benefits for society. It minimises the need of costly redispatching, costly emergency actions, it reduces balancing costs, and importantly the coordination can reduce the risks of costly brownouts or even blackouts[12]. In June 2022, the PICASSO platform went live in some core European countries (Germany, Czech Republic and Austria). The platform, built for exchanging frequency restoration reserves with automatic activation within Europe, aims to reduce the costs for flexibility in Europe. ENTSO-E states that the additional social welfare gain for PICASSO was 340 million EUR in Q3 2022[13]. This social welfare is set to increase significantly over the months and years to come, as PICASSO will go live in the areas of the 26 TSOs that are member of the consortium.

Impact

[11] ENTSO-E System Needs Study: Opportunities for a more efficient European power system in 2030 and 2040

[12] https://eepublicdownloads.entsoe.eu/clean-documents/SOC%20documents/RSC%20Factsheet.pdf

[13] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/events/2022/221208_PICASSO_IGCC_Stakeholder_Workshop_Telco_final.pdf

Consumers have an interest in enhanced TSO coordination through the RSCs because it increases efficiency in system operation, minimises risks of wide area events such as brownouts, and lower costs through maximised availability of transmission capacity to market participants. It pushes national TSOs to adapt their ways of working and take a pan-European decision-making layer on top of the national one.

Digitalisation and new technologies to deliver system efficiency

Context

The development of new technologies and digitalisation has led to the power sector being increasingly coupled with other sectors, such as heating, transport and industry. The owners of flexible appliances like heat pumps, electric vehicles and small batteries can be encouraged to shift their electricity consumption in time, so contributing to a more efficient operation of the system.

The rise of new technologies that are used for monitoring and maintenance purposes is also contributing to system efficiency. The internet of things and artificial intelligence are leading to the establishment of smart grids (which can be monitored on a continuous basis), automated decision-making and enhanced risk prediction and incident analysis. The use of blockchain and digital identities (decentralized identifiers) will enable the trading of energy between different parties, the tracking of green energy from source to consumer and the creation of trusted asset registries.

Access to the right data and using it as part of real-time decision-making will be necessary for managing this more complex electricity system. In turn, this will lead to data security and consent management becoming key areas of responsibility and concern.

In a European-wide survey among the different TSOs that was issued in 2019, ENTSO-E established that many of these high voltage grid operators see rising opportunities with regards to digitalisation. The main opportunities that were reported in this survey were related to grid and system cost efficiencies (Figure 4). Other opportunities of this digitalization lay in system risk management, security of supply and safety.

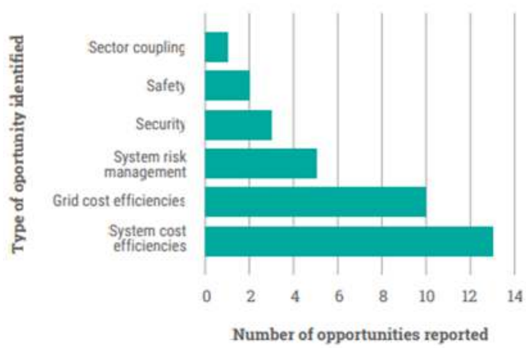

Figure 4: Result of EU-wide survey on digitalisation opportunities[14]

[14] ENTSO-E RDIC - The Cyber Physical System for the Energy Transition

Key numbers

Fluvius, the Flemish Distribution System Operator (DSO), estimates that by 2024, 80% of the households in Flanders will be equipped with a smart meter[15], and for these smart meters, beginning of 2023 more than 50 different applications to deliver energy management services were already available on the market[16]. Consumers can use smart devices to align their consumption patterns with renewable energy availability, so making better consumption management and cost optimisation decisions. Bigger amounts of data and the ability to analyse these is allowing businesses to offer up new products to consumers, providing them with added value and energy services that allow them to valorise their provision of essential flexibility for the grid.

Digitalisation is also allowing us to improve the reliability of our networks through optimised maintenance practices: the use of digital sensors, for example, means that assets can be continuously monitored from a distance, reducing the time, danger and difficulty associated with manual inspections. In Belgium, at the beginning of 2023, a total of 218,000 unique assets from the transmission grid are being monitored on the Asset Condition and Control platform. On this asset fleets, an estimation of 600 million measurements are carried out every year, and about 2.5 million calculations and analytics are performed every week. Thanks to these measurements, we are not only more aware of the state of our assets and their maintenance needs, they also bring opportunities in terms of automatic decision making. Automating decisions in system operations will allow speed to be improved and human errors to be decreased.

Impact

The challenge lies in keeping pace with these digital developments, in order to benefit from them, rather than being overwhelmed by them. As more complex technologies and applications continue to replace traditional operations, questions of interoperability, data storage, computing and management emerge. Issues relating to effective consent management and data security are also surfacing.

[15] Wanneer krijg ik een digitale meter? | Fluvius

[16] Bekijk En Vergelijk - Maakjemeterslim

The domains of innovation

This document outlines our Innovation Strategy for the next regulatory period, which will run from 2024 to 2027. It will ensure that our innovation portfolio remains focused on responding to the challenges outlined above, transforming them into opportunities - so ensuring that the energy trilemma is efficiently balanced and driving forward the energy transition in our home markets.

In order to reach our goal, and to embrace the social, political, economic and technological trends shaping the energy transition, we have identified five core innovation domains that we need to concentrate on to keep creating value for the society. These domains, outlined in Figure 2, are all supported by one transversal domain: "Digital solutions for the energy system". This reflects the fact that digitalisation cannot be treated as a separate domain: it is becoming increasingly ubiquitous and has the potential to shape and accelerate all other initiatives.

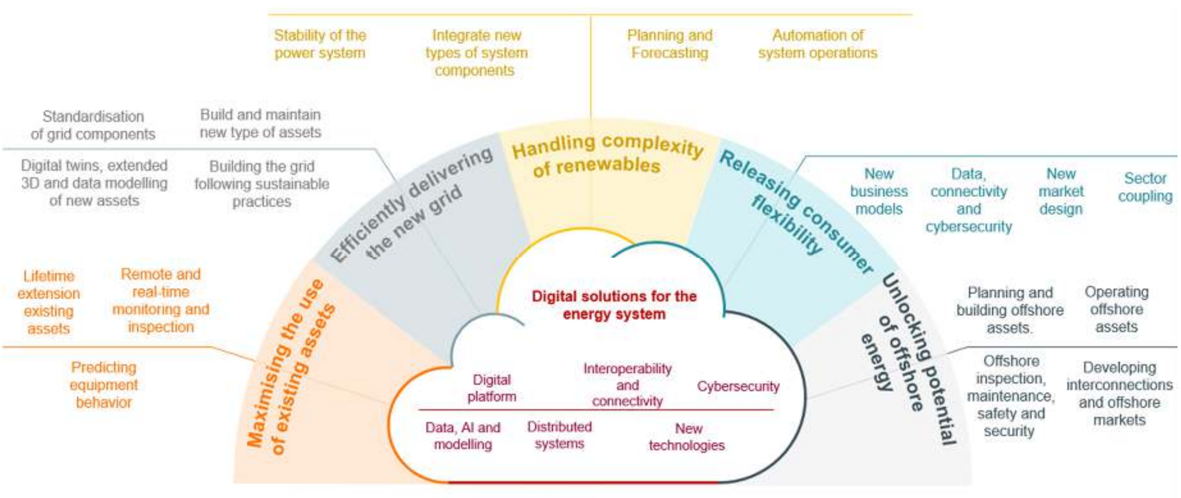

Figure 5: Five innovation domains and transversal digital domain

Figure 5 clearly represents which business activities, energy trilemma elements and megatrends each of the five domains and digital pillar seek to address.

The core strategic innovation domains

Maximising the use of existing assets

Background

Elia seeks to minimise the construction of new infrastructure and so avoid unnecessary impacts on the environment, people and energy bill through optimisation and improvement of existing assets wherever possible. This domain therefore covers the improvement of monitoring and maintenance activities and the enhanced management of an ageing grid.

Belgium's electricity infrastructure is amongst the oldest energy infrastructure in Europe. Figure 4 shows the pylons which are still in use tracked and their installation year, clearly showing installation peaks in the 1930s and 1950s, and from 1960 to 1980. This means that 80% of the installed pylons date from before 1980. Still 20% of our used pylons were installed before 1950, more than 70 years ago.

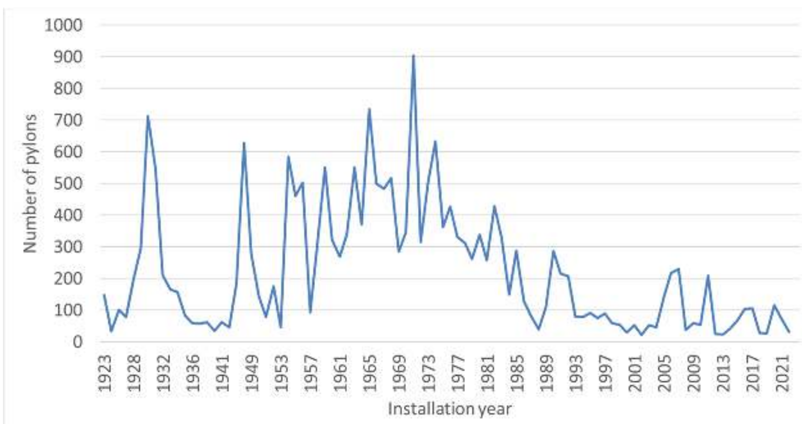

Figure 7: Pylons in use in Belgium and their installation date

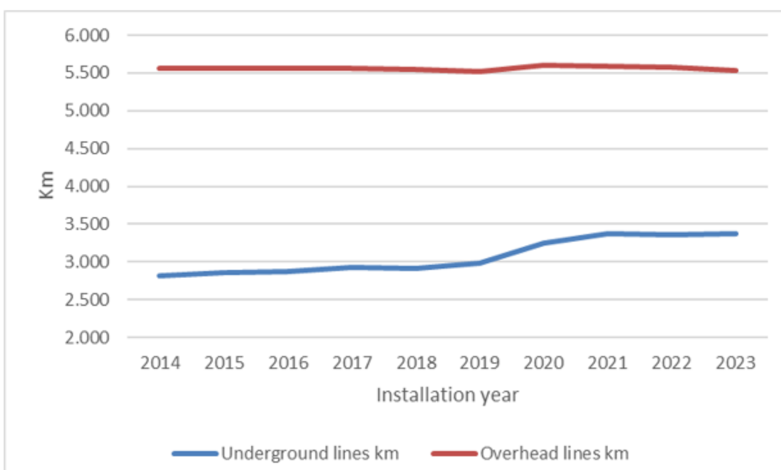

Figure 6: Evolution of the total length of installed lines

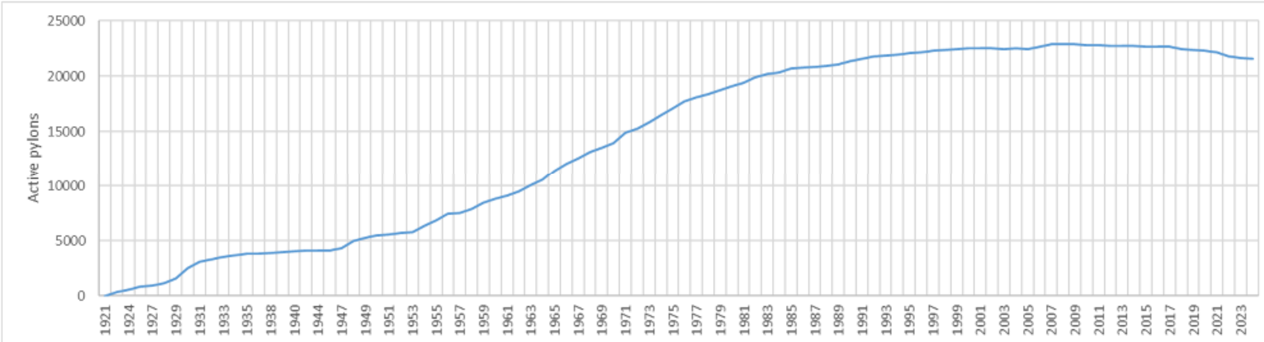

Figure 8: evolution of the total amount of pylons in use

The complexity of this asset maintenance and operation lies in the broad range of assets that we own. Elia owns and operates 5,575 km of overhead lines, 3,292 km of underground and submarine cables and 809 substations and high-voltage direct current (HVDC) converters. The voltage of the Belgian grid ranges from 30 kV to 400 kV, and it includes onshore and offshore infrastructure and both alternating current (AC) and direct current (DC) lines.

Knowing the exact real-time state of our grid and assets will be paramount. Remote monitoring using existing and emerging technologies such as drones or robots, or the capturing of real-time data with sensors will allow us to keep grid availability as high as possible, create cost efficiencies in maintenance, increase safety thanks to unmanned solutions and support sustainability (e.g. by monitoring SF_6 leakages).

Ambition

Successes in this domain will be evidenced by:

- the avoidance of unplanned outages through more condition-based asset maintenance;
- the optimisation of planned outages due to predictive maintenance, AI driven planning and automation of scheduled inspections;
- deferring investments in new grid infrastructure through the lifetime extension and optimization of existing components;
- increasing the transmission capacity of the network without building new lines;
- increases in the transmission capacity of existing assets by addressing opportunities related to ambient temperature, improvements in our situational awareness through sensors;
- Expanding the digital twins from single assets to system view connecting to European electricity grid.

Areas of exploration

Remote and real-time monitoring and inspection	• Installation of sensors to collect new insights and information; Real-time or near real-time communication of IoT devices • Remote inspection via unmanned solutions (unmanned aerial vehicles, unmanned ground vehicles, unmanned underwater vehicles) for substations overhead lines, tunnels, HVDC converter halls, offshore assets etc.

	• Remote monitoring from space (satellite services for the grid) • Automated decision support systems via the above and extended data acquisition and evaluation
Predicting equipment behaviour and leverage optimization	• Data modelling, pattern identification and correlation analysis across all asset types • Training data and making use of analytics to spot anomalies in local domains • Creating standardized database to enable AI in cross-sector domains • Develop tools to optimize the maintenance and outage planning
Extending the lifetime of all ageing assets	• Understanding aging and actual end of life • Focusing on asset type: overhead lines (objective: prioritising replacements) • Identifying factors that impact the ageing of assets and how the combination of different factors impacts systems • Improving modelling capabilities to integrate different ageing models • Test new protective materials used during maintenance (e.g. new type of paint)

Sample projects

ACC 2.0: Inspecting our assets as part of maintenance work takes time and many resources, involving staff members accessing difficult or distant locations.

Over the past few years, we have been working on implementing a new asset condition and control approach (ACC) which makes this process more efficient. It involves calculating and visualising the condition of all assets, and then enabling remote access to them for monitoring and maintenance purposes. We have adopted ACC as part of the automated remote diesel generator testing that we carry out - this testing often needs to occur more than 20 times a day across multiple locations in Belgium. Remote monitoring has therefore greatly improved the efficiency of this testing.

Our ACC 2.0 project will see our database of remote assets grow - we will be installing more sensors along our infrastructure, which will generate more data and analytics for our staff to use. In future, therefore, this will enable use cases such as drone condition assessment, robot inspections, cable burial depth monitoring and SF6 monitoring.

Asset Management moonshot: Being able to identify the cause of an incident as soon as possible after it has occurred is crucial for us: it enables us to minimise its impact.

One of our five moonshots (leading Elia Group innovation projects that were launched in 2021) addresses incident detection: the aim is to understand the cause of incidents that have occurred along our overhead lines within 10 minutes of their occurrence, so reducing the amount of time that a line is down for, and, in the long run, avoiding its reoccurrence. Today, in case an incident is situated at a remote location, it could take up to several hours before the first field worker arrives at the correct location.

We are working on improved cause recognition with existing data, supported by AI and advanced algorithms. Additionally, we are testing new kinds of technologies (such as sensors, drones, etc.) to increase the inflow of relevant data.

Hyperspectral: Corrosion is a major source of damage in terms of our infrastructure. Traditional ways of checking our pylons for such damage have involved staff climbing them; although this is a reliable method for detecting corrosion, it is resource-intensive and involves a high amount of risk for our staff.

We are therefore currently exploring a new way of carrying out this inspection work: using a hyperspectral camera. This technology will allow us to ‘see through’ paint on the pylons (meaning it is a non-invasive method) and, in the long run, we hope to be able to use AI to classify the severity of the damage that is present.

Uncertainties

This domain covers the use of new digital solutions that have not traditionally been used in our sector. Consequently, the main uncertainty lies in the technical, practical and regulatory maturity of these technologies. The useful life and reliability of new devices such as sensors or other unmanned solutions still have to be tested in the field, while European regulation that aims to encourage their use is still being developed. Similarly, with regard to predictive algorithms, we are lacking the historical data that would help to simulate the equipment's behaviour and useful life; this knowledge will have to be built up through application and experience. The data will need to be progressively obtained and processed, in order to build meaningful models and algorithms.

Efficiently delivering the new grid

Background

Given the electrification and decarbonisation of the energy system, we will not be able to operate the future grid by only using the assets that exist today. We will need to build new assets with enhanced capabilities to cope with increasing needs, including avoiding congestion along our lines and the curtailment of renewable energy. We will need to connect new decentralised (solar and wind) capacities that will be built onshore and along the Belgian coast.

In the Belgian Federal Development Plan 2024 –2034[17], we announced an ambitious portfolio of projects in order to develop the 'horizontal system' (380 kV) that is needed to transport energy more efficiently and reliably across Belgium and further our connections with our neighbours. Figure 9 covers the main infrastructure projects that will be carried out over the next decade, including important onshore projects such as the Boucle du Hainaut, Ventilus and the second German-Belgian interconnector[18].

Offshore development will be a priority in the coming decade, leading us to select it as a separate domain in this strategy.

Massive investments will also be made along the lower voltage sections of our grid (110 kV, 150 kV and 220 kV) in order to guarantee security of supply and connect medium-sized and decentralised production units to our network. However, uncertainties remain around the amount, size and speed of the production that will be installed, meaning that the size and planning of investments to our infrastructure can be unclear. To avoid stranded assets (which could emerge if there is a mismatch between our assets and the requirements of the environment they are located in) at all costs, we have to continuously challenge and update our approach to grid development, through risk-based decision making that takes into account expected technological developments and do not lead to over-development of the infrastructure.

[17] Public consultation - Federal Development Plan for the Belgian transmission system (110 kV to 380 kV) over the period 2024-2034 (elia.be)

[18] BE-DE (elia.be)

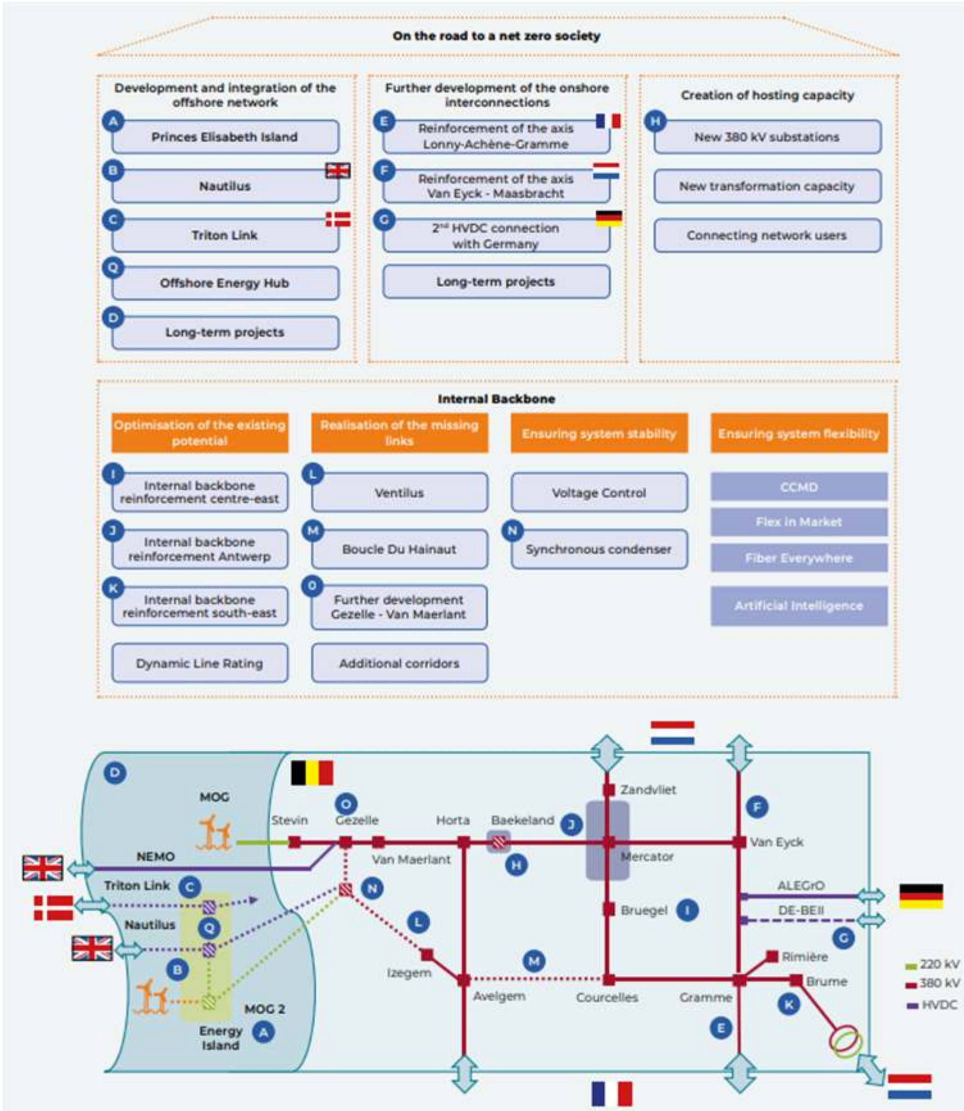

Figure 9: Main upcoming CAPEX projects in Belgium according to latest FDP

Ambitions

Successes in this domain will be evidenced by:

- improved infrastructure through the adoption of new materials, technologies and ways of working;
- optimised approaches to grid planning and the development of future infrastructure;
- keep costs related to newly built assets and an expansion in their capabilities through the use of new materials and technologies under control;
- an acceleration in the speed at which assets are built, through new approaches to permitting;
- an expansion in the capabilities of future built assets;
- the use of multi-state, multi-scenario and probabilistic grid analysis techniques to calculate anticipated costs of redispatching, load shedding, etc. associated with given assets - meaning more optimal solutions will be developed by considering both capital and operational expenditure, rather than only initial asset costs.

Areas of exploration

Standardized and cost-optimized engineering and planning	• Develop & steer technical requirements for standardised components • Embed multi-scenario analysis to optimize total exploitation cost of new assets • The development of a new efficient engineering process to facilitate the engineering, commissioning & maintenance phases of virtual substations
Building and maintaining new types of assets	• Explore and embed maintenance of novel grid components (storage, DC components, HVDC infrastructure, Static Synchronous Compensators, Synchronous Condensers, …) • Understand lifetime and behaviour of new grid components (high-voltage underground cables) • Build on IoT with existing assets and expand understanding of new assets • New assets to increase transport capacity • Explore the opportunities of *virtual lines* to increase the capacity of the grid without building new linear assets • New efficient materials, such as for conductors (e.g. high temperature low sag conductor 2.0) or new steel
Digital twins, improved modelling of new assets	• Develop Building Information Modelling (BIM) as starting point • Expand BIM capabilities in line with digital twin concept
Embedding sustainable practices and accelerate public acceptance	• Eco-design and lifecycle management • Ability to recycle asset components • Resilience in the face of climate change, (condition monitoring adapted to extreme weather conditions, new material, new processes) • Minimise carbon footprint of our value chain

Sample projects

Synapse: In the future, making a stable outage plan for maintenances will become more and more difficult due to volatile external factors. The "SYNergy between Agile Planning and Stable Execution" (Synapse) tool will allow us to carry out outages whilst coping with the uncertainty of renewable generation and highly dynamic load and market behaviour. In turn, this will limit the risk of RES curtailment and the risk of further outages.

New steel: Given that our pylons need to carry increasingly heavy weights - due to higher-performing conductors, higher wind loads and higher cables - S355 steel is no longer best suited to them. We are therefore assessing whether S460 steel could be a good replacement for it, allowing new pylon structures to be designed and speeding up the delivery of new grid projects.

Uncertainties

The main uncertainties linked to this domain are concentrated around the low maturity of the emerging technologies needed to fulfil our ambitions, or otherwise the sector understanding for mature technologies. Whilst some technologies have a readiness level that is so low that research and development is still on-going and/or testing is still needed, others have reached commercial maturity, but the lack of a strong supply chain or of an existing regulatory framework are hindering their application.

Enabling secure integration of renewable energy

Background

As a result of the megatrends explained earlier in the document, and largely driven by policy and public expectations, Europe's RES installed capacity will be doubled (or even tripled for some member states) by 2030. It is our role and purpose to facilitate and enable the integration of these renewable energy sources into the electricity system in an optimal way.

The integration of increasing amounts of renewable energy into the system is triggering changes in system behaviour and causing new grid phenomena to occur, so threatening the stability of our grid - and, ultimately, Belgium's security of supply.

Fossil fuel generators, which comprise large rotating machines, provide inertia, which is a key source of grid stability and reliability. RES are producing energy in a different way than conventional power plants. Instead of big rotating machines such as nuclear or coal turbines, RES produce electricity using so-called power electronics. As RES are integrated into the grid, the inertia decreases, meaning that threats to the stability of rotor angles, voltage and frequency. These risks can tip very quickly into serious issues.

We start seeing phenomena on the grid that are linked to the increasing share of power electronics. Indeed, a number of events linked to the increasing instability of the grid have occurred recently. Most notably in January 2021[19], the synchronous area of continental Europe's electricity system split into two separate regions, leading to outages along transmission networks.[20]

We therefore need to shift from the slow and centralized management of stability to very fast and decentralised digital grid monitoring. However, this will require massive innovation efforts, as it will cover both fully understanding the new phenomena and the development of solutions.

It should be noted that volatility in production will not only have repercussions that can be measured in milliseconds. Indeed, as exemplified by Figure 10 and Figure 11 below, voltage, frequency and congestion management will need to be managed on a closer to real-time basis in future (over much shorter time frames). As we approach 2032 and as renewable energy levels increase, ramps in load are predicted to increase.

During the summer months, a morning downward ramp of up to 3 GW over periods of some hours might occur, while an evening upward ramp of 5 GW between 17:00 and 20:00 can be expected. This will put enormous stress on system engineers, who will need to keep the grid stable and within operational limits during such fast and significant ramping events. At the same time, the use of decentralised flexibility will multiply the number of dispatchable resources that will need to be operated (from dozens today to hundreds of thousands in future), meaning that a decision while considering a significantly higher number of options will be required.

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[19] **Final report on the separation of the Continental Europe power system on 8 January 2021 (entsoe.eu)**

[20] On the day of the incident the system was close to the dynamic stability limit. Usually the stability is not assessed in detail during operational planning and real-time operation. (…) The calculations and measurements (PMUs) of the voltage-phase angle differences can serve as indicators for a potential system stability limit.

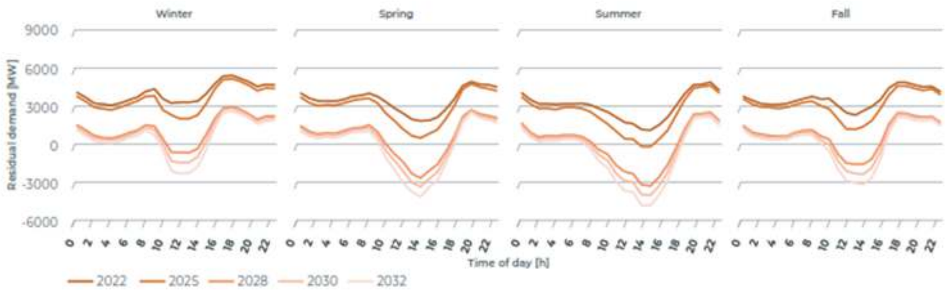

Figure 10: Evolution of the lowest residual load percentiles (1% percentile) per hour between 2022 and 2032[21]

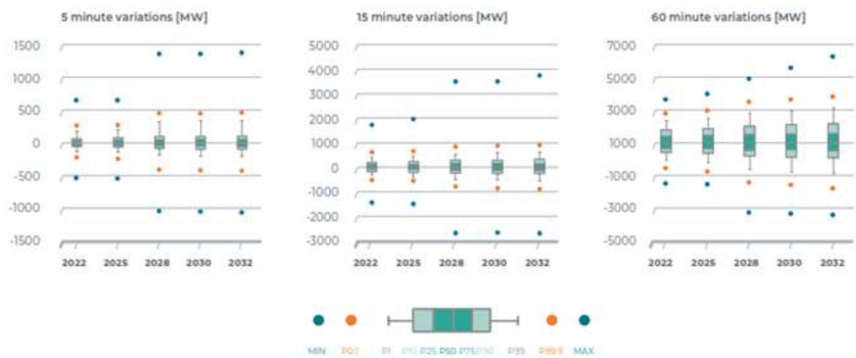

Figure 11: Evolution of the probability distribution of residual load variations over 5, 15 and 60 minutes in 2022 and 2032 (represented by means of percentiles, for example P1 (1%))[22]

Finally, given that offshore wind energy is set to increase, we expect more extreme flexibility needs to arise during stormy weather. Elia's first offshore integration study[23] demonstrated that large variations in flexibility due to changes in wind speed or shutdowns and re-activations of wind turbines during storms may occur. It is of paramount importance that we continuously improve our ability to predict changes in the system during storms. As warned in our Adequacy and Flexibility, increasing offshore wind generation capacity to 4.4 GW will lead to the possibility of up- and downward ramps (amounting up to 2.5 GW over an hour) occurring multiple times per year by 2028.

Ambitions

Success in this domain will be evidenced by:

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[21] Elia Group's Adequacy and Flexibility Study 2021

[22] Elia Group's Adequacy and Flexibility Study 2021

[23] https://www.elia.be/-/media/project/elia/elia-site/electricity-market-and-system---document-library/balance-responsible-party-and-system-imbalance/2018/2018-study-report-on-offshore-integration_en.pdf

- the ongoing guarantee of grid stability, using the large amounts of installed power electronic devices and harvesting their potential as active stability providers (for instance through grid forming control loops, or by providing virtual or emulated grid inertia);
- the automation of decision-making in system operations, so allowing us to cope with fast and complex changes that could not be managed by a human being: the AI system will be capable of taking sound decisions automatically;
- improvements in forecasting, situational awareness, decision-making and execution through the use of new forecasting tools and decision-making support tools.

Areas of exploration

Guaranteeing stability of the power system, manage changing grid dynamics	• Design of the future system and definition of stability requirements • Characterisation of grid strength, Monitoring and control of stability • Black start and restoration plans • Sourcing of power system services
Integrating new system components and assets	• Assess the impact on the power systems of DC connections, HVDC networks, AC/DC hybrid systems, storage systems, power electronics • Technology discovery and feasibility studies of the aforementioned technologies • Statcoms and grid forming equipment
Probabilistic system planning and improved forecasting	• Improvement in forecasting of consumption and renewable energy infeed • Forecasting error management (resilience) Development of probabilistic methods for system planning
Automating system operations to manage increased system complexity	• Human as a supervisor: automated decision support for voltage, congestion, outages and imbalance • Improved quality of the grid models • Increase operational and situational awareness

Inpowel: RES and storage systems operate in 'grid-following' mode: in order to inject power into the grid, they synchronise to the grid, requiring steady frequency and voltage levels to do so effectively. As renewable energy levels rise, and rotating machines used by fossil fuel plants are eliminated from the system, the grid has less inherent stability and strength. Eventually, this will result in a lock-in: renewables will not be able to inject their power into the grid any longer.

The goal of the Inpowel project is to run a demonstrator based on 'grid forming' technologies, which involve RES and storage systems actively controlling the frequency and voltage output of the grid they are connected to. This will enable static devices, which many RES are, to provide system strength, successfully playing the role conventional rotating machines have until now.

VoltControl: Decision-making in the real-time operation of the high-voltage network is becoming increasingly complex due to the decentralisation of the grid, faster changes in the state of the grid because of decarbonisation, and increasing market dynamics.

The VoltControl project aims to provide AI-based decision-making support to system operators. Its end goal is a human-out-of-the-loop type of grid management, where voltage-related actions can be implemented automatically by the system.

Uncertainties

The main uncertainty linked to this domain lies in the need to adapt our grid to the future energy mix, which is due to be dominated by renewables, but will be heavily influenced by political decision-making and geopolitics. Moreover, the technology readiness level of many key technologies such as grid forming is still very low, and they will have to be developed in collaboration with equipment manufacturers and academia to ensure their adoption is as smooth as possible. There is also a lack of skills in this area, meaning that training and recruitment practices will need to focus on finding the right individuals to work in this area.

Supporting consumers to benefit from the energy transition

Background

As part of our societal goal to drive decarbonisation, and in line with European ambitions, we are enabling consumers, from individual households to big organisations, to play a leading role in the energy transition. New opportunities for end users to actively interact with the grid, valorise the flexibility of their assets and contribute to maintaining the balance between demand and supply are emerging as decentralised and flexible assets (such as solar panels, heat pumps, batteries and electric vehicles) grow in popularity. We are aiming to accelerate this shift to a consumer-centric system - one in which consumption follows production - through our market design that will give consumers full freedom of choice and more advantages when participating in the market.

Indeed, this shift will be necessary as increasing amounts of renewable energy are integrated into the system at all levels. Their potentially unpredictable volatility pushes flexibility needs in Belgium upwards between 2022 and 2032[24]. We will need sufficient capacity installed across the system, especially from decentralised assets, to cover 1/ ramping (as explained in the section above), 2/ fast (the ability to deal with unexpected power deviations in real time, or deviations for which information is received between the last intra-day forecast and real-time) and 3/ slow (the ability to deal with expected deviations in demand and generation following the intraday forecast update) flexibility needs.

Uncertainty around generation patterns is becoming an area of concern as well, leading to forecasting errors. For example, between 2020 and end of 2022, the absolute day-ahead forecasting error for solar production increased from 500 MW to 775 MW, due to an increase in installed PV capacity, even if relative error has decreased.

Today, since the grid mainly relies on fossil fuel plants, the probability of making prediction errors which relate to more than 500 MW and forecast an issue that lasts more than 5 hours is lower than 1%. In the run-up to 2032, this probability will at least triple. To cope with such imbalance between real and forecasted generation, the reserve capacity will need to double by 2032[25].

Our Consumer-Centric Market Design (CCMD)[26] will empower consumers to move from simply consuming electricity to valorising their flexibility and contributing to maintaining the grid's balance. Consumers will be able to optimise their own consumption, capitalising on moments when there are high amounts of renewable energy, participate in energy communities, and provide the grid with the flexibility it needs by being rewarded for reinjecting energy back into it at key moments.

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[24] Elia Group's Adequacy and Flexibility Study 2021

[25] Elia Group's Adequacy and Flexibility Study 2021

[26] CCMD (eliagroup.eu)

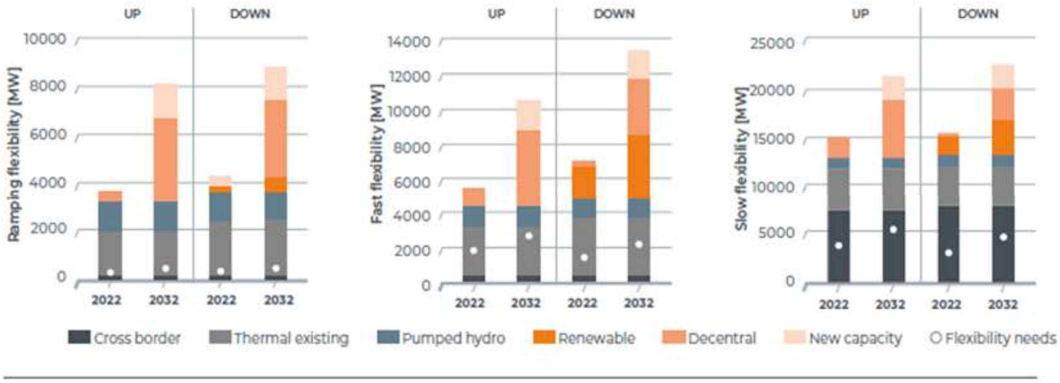


Figure 12: Prediction of installed flexibility means for 2022 and 2032

It is important to be sure that these flexibility means will be operationally available when needed and whether they will be provided in an economically efficient way - or, if they will be costly, whether upfront reserves will be needed. Operational unavailability might occur if units are already fully scheduled in the day-ahead market, if they are not dispatched and their activation time lasts longer than a few hours, and when their available energy levels are depleted or full.

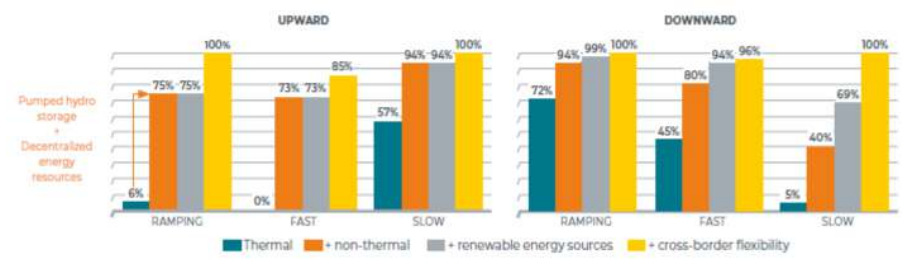


Figure 13: Share of periods where flex needs will be covered without upfront reservations

The results from our study demonstrate that for each type of reserve, and particularly for upward types (reducing consumption or increasing production, vs. increasing consumption or decreasing production which is downward flexibility), non-thermal technologies (including decentralised technologies such a vehicle-to-grid, batteries, consumption shifting and demand response) will contribute substantially to corresponding to flexibility needs without upfront reservation. Of course, this will only be the case if these flexible technologies are effectively installed and participating in intra-day and balancing markets. Facilitating the further development of these flexibility providers and valorising their flexibility will contribute to a cost-efficient integration of renewable energy. This has to be enabled via a balancing market which incentivises market players to balance their position and reserve capacity requirements for residual imbalances.

Ambitions

Success in this domain will be exemplified by:

- Consumers (both households and industries) participating in energy markets and benefiting from this, facilitated by regulatory changes and the development of digital services that steer behaviour,

lower energy bills and allow new business models to emerge;
- close collaboration with new and old energy market players such as distribution system operators, aggregators and energy service providers, prosumers, ecosystems (such as IO.Energy) and equipment manufacturers.

Areas of exploration

New business models	• Support the development of energy communities and a peer-to-peer market • Reward decentralised flexibility • Offer micro-payment solutions • Allow green consumption and granular certification
Data and connectivity of end-users	• Develop IoT and device connectivity solutions for energy applications • Develop data hubs for cross-sector information exchange • Ensure GDPR compliance for consumers, permission management tools to allow data sharing • Develop decentralised data verification processes (asset registries) • Enable scalability to the authentication and activation process for delivering end-user flexibility
Evolving market design	• Testing new solutions on top of the new CCMD, such as: leveraging flexible tariff & real-time price exposure and widening the scope of the capacity remuneration mechanism[27] to cover decentralised assets • Enable supplier splitting
Accelerate sector coupling	• Develop data exchange platforms and data hubs to facilitate sector coupling (mobility, power to heat …)

[27] Capacity mechanisms are temporary support measures that EU countries can introduce to remunerate power plants for medium and long-term security of electricity supply. **https://energy.ec.europa.eu/topics/markets-and-consumers/capacity-mechanisms_en**

Decentralised identifiers and solid pods: As the energy system becomes increasingly decentralised and flexible appliances grow in popularity, so the number of market participants will increase. To ensure they can participate in energy markets in a safe and trusted manner, new requirements related to authentication, proof of identity and consent management will be required. We are planning to tackle this is by using new technologies such as decentralized identifiers (DID) and personal online data storage (Pods). This will allow solutions to be scaled up with limited costs and ensure our processes are GDPR compliant by design, allowing users to be in full control of their data.

Consumer Centric Market Design:

The next decade will be characterised by a fast rise in renewables and the widespread electrification of industrial and residential appliances. Since 2020, Elia Group has been working on its CCMD, which addresses how flexible appliances can be integrated into the system, so helping to balance the grid.

Elia is convinced that the keys to unleash further flexibility lie in:

- giving consumers a leading role in the system at all voltage levels;
- providing energy service providers with easy access to data and digital platforms to support them as they develop new consumer services.

The CCMD comprises two main features:

- the development of an Exchange of Energy Blocks hub, through which consumers could exchange energy with other market parties on a fifteen-minute basis;
- the introduction of a robust price signal, which would reflect system conditions in real time, giving consumers a reference for their consumption and the value of services offered by third parties.

Uncertainties

The uncertainties linked to this domain lay in the regulatory developments that are needed to support the CCMD (in terms of balancing obligations, the exchange of energy blocks and real-time price signals). Whilst innovation work can focus on building the technological foundation for these activities, their legality will lie in the hands of the authorities. Moreover, Elia does not carry sole responsibility when it comes to the rolling out of digital infrastructure such as household meters. Lastly, the direction and speed of development of consortium-driven initiatives, such as data cloud solution Gaia-X[28], depends on all actors and cannot be influenced or accelerated by just one player.

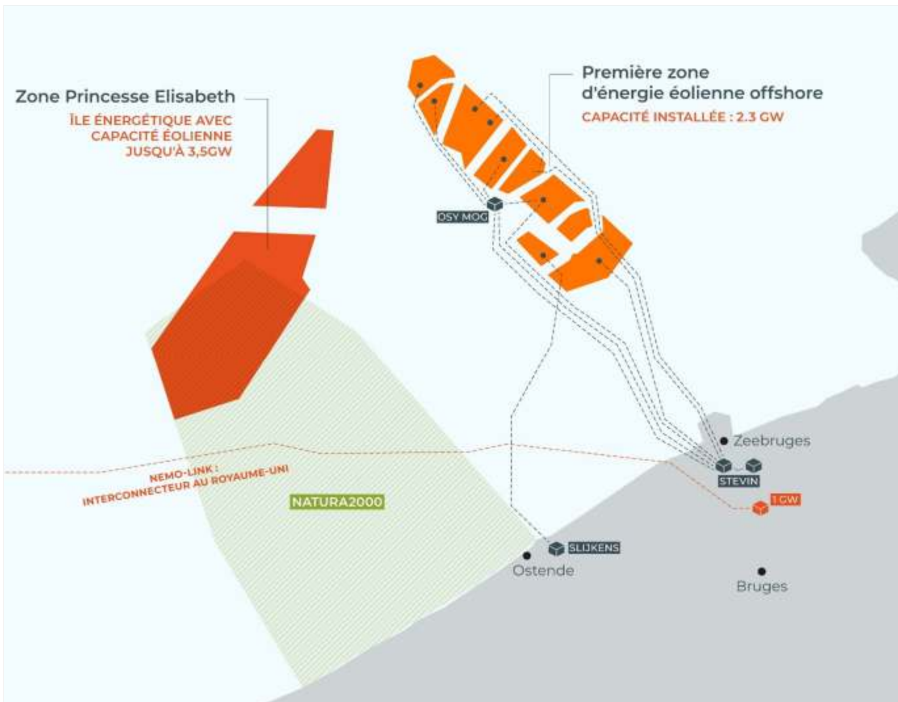
28 Home - Gaia-X: A Federated Secure Data Infrastructure

Unlocking the potential of the offshore energy

Background

Offshore transmission solutions are critical for connecting offshore wind capacity to the onshore grid. As suitable nearshore wind locations are becoming scarce, sites that are located further away from the coastline need to be developed to deliver additional offshore wind capacity. The 2022 Esbjerg Offshore Wind Declaration, which was signed by Denmark, Belgium, Germany and the Netherlands, saw the four parties pledging to expand their collective offshore wind capacity in the North Sea to 65 GW and 150 GW by 2030 and 2050 respectively. In order to use infrastructure in an optimal manner, hybrid projects will be increasingly adopted, leading to the establishment of meshed offshore transmission systems[29].

Elia is establishing itself as a key player in the North Sea. Over the next decade, Elia will connect Belgium to the UK via Nautilus and Denmark via Triton Link. Both hybrid interconnectors will run through the Princess Elisabeth Island, which is being built in Belgium's second offshore wind area. The Belgian island will thus become the first energy hub in the North Sea and will form a crucial element in the development of the European offshore electricity grid.



Ambitions

Success in this domain will be exemplified by:

- the development of sound knowledge and expertise in new concepts and technologies, including offshore hubs and platforms, floating cables, hybrid cables and HVDC technology;
- digital solutions for offshore maintenance that can withstand harsh marine environments and successfully navigate connectivity-related issues;

[29] Elia Group white paper on promoting hybrid offshore interconnectors for reaching Europe's goal of 300 GW of offshore wind capacity by 2050

- operation algorithms for hybrid offshore grids that optimise flows across the offshore meshed network, reduce congestion and improve security of supply.

Areas of exploration

Planning and building offshore assets	• Develop GIS-based tools for planning the offshore grid • Assess new technologies and infrastructure development approaches, including energy islands, hybrid interconnectors, floating offshore substations and HVDC cables • Increase sustainability of offshore assets
Offshore inspection, maintenance, safety and security	• Move from reactive to predictive maintenance • Remote inspection and maintenance using sensors, data analytics, robots, remote autonomous vehicles to increase safety of colleagues and flexibility of inspection • Cybersecurity and hard security of offshore assets
Operating offshore assets	• Optimise integration of renewable offshore wind farms • Software tools to automate operation of offshore assets
Developing interconnectors and offshore markets	• Integration of Belgian energy island and other offshore interconnectors on power exchange and European electricity system • Blueprint of system towards 2050 • Market instruments for integration and cross-country exchange in different bidding zone

Offshore grid optimiser: Whilst the construction and operation of wind farms have already reached a very high level of maturity, their integration into the grid requires innovative approaches to be adopted to facilitate the efficient and flexible transportation of the clean energy they generate to onshore demand centres. The construction of Point-to-point interconnectors therefore needs to be replaced by hybrid, multipurpose offshore interconnectors.

To successfully operate these hybrid offshore interconnectors, master controllers will be required to control active and reactive power flows through the interconnector. The objective of the offshore grid optimiser project is to build such a master controller.

DIRECTIONS: Energy hubs are a new approach that is being explored as part of the development of the offshore HVDC grid. These hubs will bundle together massive amounts of offshore energy and facilitate their cost-effective integration into onshore power systems.

These energy hubs will behave in a fundamentally different way from existing power systems: they are based on the use of meshed HVDC and HVAC systems, which is slightly different to the typology used for point-to-point HVDC. Consequently, they raise several fundamental and conceptual uncertainties. The DIRECTIONS project aims address these by formulating a consistent planning and operational model that takes into account design aspects and the protection of DC grids - ultimately providing a reliable system design for offshore energy hubs.

Smart Offshore Surveying: In June 2022, for the first time, Elia Group successfully tested an unmanned surface vehicle (USV) to survey the subsea cables of the Modular Offshore Grid as well as the Offshore Switchyard Platform. The vehicle was developed by Tide-Wise, the winner of the Group's 2021 Open Innovation Challenge. This Proof of Concept is aligned with the strategy of using increasingly digital tools and unmanned technologies to increase the flexibility, frequency and safety of maintenance activities.

WATCH THE FIRST UNMANNED INSPECTION OF THE MOG'S CABLES BY USING THE QR CODE ABOVE

Uncertainties

Low technology readiness levels and a lack of regulation regarding new solutions are the main uncertainties related to this domain. Moreover, the speed of development of the offshore network is closely bound to the development of offshore capacity, which could take longer than anticipated, particularly if shifts occur at a (geo) political level.

The supporting domain

Driving the digital & data transformation

The transversal digital pillar serves as an enabler for achieving the goals of each of the five core innovation domains. While of course, some of the ambitions within the core domains can be achieved using non-digital techniques, it is clear that many of the goals highlighted above will benefit from the opportunities that the digital transformation offers.

Background

As the complexity of the power system increases, digital technologies are offering new possibilities with regard to building, managing and operating the emerging cyber-physical grid. Embracing these possibilities will allow us to become more scalable, efficient and better serve end consumers.

Sensors collect time data from the grid to support automation and can automate and enhance the system's operations, through real time monitoring or predictive maintenance. This deployment of Internet of Things (IoT) is enabling the so-called convergence of operational technology (OT) and information technology (IT).

The OT/IT convergence will bring along challenges and risks, notably on the field of cybersecurity. The digitalisation of our business increases the exposure to cybercrimes, partially driven by geopolitical factors which can increase the pressure in terms of cyber security. Indeed, the increase in the number of devices connected to the grid means that protecting the virtual grid will become more difficult than protecting the physical one. Figure 14 outlines how cyberattacks on major operational technology systems have become commonplace in recent times. This trend is also expressed in the dramatic increase in cyber-attacks: according to a survey conducted across 1,600 cybersecurity and IT leaders, 98% reported becoming aware of at least one attack in the year before[30]. In this light, European directives on critical infrastructure resilience are being published[31].

[30] **The State of Data Security by Rubrik Zero Labs**

[31] **Critical Infrastructure Resilience: stronger rules (europa.eu)**

Figure 14: Emerge of cyberattacks on operational technology systems (2010 – 2021)

As society continues to digitalize, an abundance of data will become available. This will have repercussions on the coming policies (GDPR, data protection law etc.[32]), which Elia will need to embed and adapt to. Furthermore, this will require a different way of handling data, since it will be impossible in a data-abundant world to capture everything. It will, however, be beneficial for trusted parties to share data in order to enrich the available datasets for model training.

Different EU-wide initiatives, such as the Gaia-X initiative, are already underway to redefine digital and data governance in order to maximize the possibilities while keeping the trust high.

Finally, no matter how hard we try, it is impossible to predict the potential and capabilities of technologies that have not yet emerged. As innovation opportunities arise across all sectors, not only the energy sector, we expect that new tools, technologies or opportunities will arrive that we cannot even imagine today. Therefore, as a crucial part of our strategy, we will always keep an eye open on the world around us, spot and scout new technologies, and be aware of what other industries are successfully incorporating into their operations.

Ambitions

Success in this domain will be exemplified by:

- Embed security by design in our operations, adopt cybersecurity methods and tools that are required to protect our transmission system
- Enable secure access to energy assets and end-users, and enable communication between all assets
- Leverage the possibilities of Digital Twins in all facets of our operations, such as engineering, simulations, training, safety preparation, operations and maintenance
- Create a single data platform that securely collects and links all types of data
- Effectively manage large amounts of data linked to decentralised assets, and use them in the processes

[32] **Data protection in the EU (europa.eu)**

- Facilitate access to data and computing capabilities to achieve our mission.
- Enable the use of various digital solutions across our value chain through data and communication integration
- Successful exploration of innovation opportunities through scouting, spotting and understanding digital skills and technology.

Areas of exploration

Cybersecurity	• Evaluate, understand and adopt cybersecurity methods and tools that are required to protect our energy grid. • Address IT security challenges arising from OT to IT convergence • Implement coming policies and guidelines
Interoperability and connectivity	• Create the tools necessary to communicate between our current assets and the IT infrastructure of tomorrow, and with the decentralized assets of the future • Develop new protection, automation & control systems that are vendor independent and allow for a rapid and seamless replacement of different assets • Ensure secure access for end users (GDPR, verification process, safe payments) • Blackout proof communication using cloud infrastructure • Self-service offerings to sustain growing internal and external demands to avoid scalability by adding new resources
Data management and data platforms	• Increase implementation of sensors to capture relevant data from our assets • Embed “substation configuration language” to describe the dataflow, and understand the automation potential of these machine-readable formats to automate engineering & testing • Usage of computing setups that have potential to outperform classical CPU platforms by faster computing time, better parallelization or algorithmic speed-up on complex calculation problems
Digital twins	• Create digital twins of our assets to test scenarios, tools, methods, firmware ... in a virtual environment (for digital engineering, grid simulation, training, visualization, work and safety preparation) • Create virtual dispatching rooms where operators can control the grid virtually
Sustainability and safety	• Digital solutions making our work force more secure and efficient • Reduce our IT impact on environment • Carbon Accounting for the entire Value Chain of Elia

Uncertainties

The technologies analysed and developed in this domain generally have a low maturity level in terms of TRL and applicability as they are so in their infancy that they have not yet found a concrete application in our operations. From an application point of view, a related uncertainty will be to see whether the service provided by these new technologies, once developed, will be commercially competitive with the existing solution. From a technological perspective, besides the development of the technology itself, a great importance will be the interface between the new solution with the connected hardware and the legacy TSO system. The success of some solutions depends on many factors that are not in Elia's control but that require adaptation at national level or OEM side. On top of that, for some solutions, its regulation or the regulation of its consequences is still not clear (especially for those solutions who work with GDPR, consent...).

How we innovate

The network and partners

In order to accelerate the areas of exploration in our business domains, we need to leverage various external sources of ideas and knowledge. Through a network of trusted partners, be it academics, peers, other industries or startups, we have the ability to accelerate innovation on specific project-level and via project-agnostic exchange. Overall, we aim to have an approach to open innovation that is embedded in the overall innovation process and activities.

We believe in joint responsibility – that is why we aim to engage in joint planning and execution of open innovation projects. These projects can be real-life tests, proof-of-concepts, product or process innovation, whitepapers and other types of collaboration.

We are actively collaborating with the academia, through the Academic Board in Belgium. These collaborative platforms allow Elia and the academic community to discuss the challenges and issues crucial to the future of the energy sector and launch joint studies and research projects. In order to increase our innovation impact, we assess different funding opportunities together with our academic partners.

In parallel, Elia is also involved with other industrial partners through its Cross Industry Innovation Ecosystem, with the goal of joining forces with partners from different industries so to build on the respective areas of expertise and come up with concrete collaborative projects. This type of ecosystem aims to get faster results for solution development on common challenges by bundling different types of actors from different industries, for instance those working on similar tasks related to their vast infrastructure.

Cross-Industry innovators – Asset Management ecosystem

In April 2022, we launched our Cross-Industry Innovators ecosystem that unites companies operating vast life-essential infrastructures across Europe in different sectors, e.g., Energy, Railways, and Telecommunications.

While running business in diverse industries, ecosystem members are united by remarkably similar challenges: we all urge to future-proof and ensure the stability of our infrastructures for millions of its users.

Currently our network fosters collaboration between 7 key market players. Each of us is already making big efforts in investigating new digital solutions (drones, satellites, sensors, etc.) to inspect and manage our assets, resolve incidents quicker and precisely monitor and forecast the assets' condition. Now we have joint efforts to learn from each other and execute innovative pilot projects within our union. It helps to reduce costs and gain insights from our investigations much faster.

Elia utilizes the ecosystem of startups and established scale-ups to leverage cutting-edge technologies as well as access to wealth of innovation through scouting, open challenges based on defined business challenges and ad-hoc collaboration.

The Innovation Hub

The Innovation Hub is where new trends, established innovation, the internal incubator and business innovation experts find each other and create the future energy world.

The core of the Business Innovation domain is driven by the business SPOCs. A SPOC, as the acronym signifies, acts as a single point of contact for an entire business unit. We have a SPOC for the five key domains we identified in our business: Offshore, Asset Management, Infrastructure, Markets & Consumers and System Operations.

A SPOC has a twofold role. On one hand, they are aware of the different business challenges, through a deep understanding of the roles and responsibilities of their respective domain. This way, the SPOC can make the link with insights from other industries from our ecosystem or emerging technologies, and this way trigger innovative solutions by offering an outside-in perspective to the different business responsibles. On the other hand, the SPOC acts as a project manager for the most innovative proof of concepts and demonstrators, and our Moonshots. Together with domain representatives, the SPOC will this way aim to demonstrate the added value of different new technologies or opportunities.

The Moonshots

As a part of our innovation drive, in 2021 we launched a multiyear Moonshot program. The aim of the Moonshot program is to tackle some of the biggest challenges in energy transition and demonstrate the use of concrete solutions to reach this goal. The Moonshots have specific characteristics, of which the most important ones are:

- ***Idealistic**: Solve the biggest challenges of our field*
- ***Hard**: Requires significant breakthroughs or changes*
- ***Demonstrator**: Measurable goals within a compressed timeframe*
- ***Visionary**: Going beyond the business as usual, while strengthening the core*
- ***Together**: Rely on the best capabilities internally and in our ecosystem*

Of course, the SPOCs rely on a broad range of experts and tools within the company to deliver maximum value to the business domains.

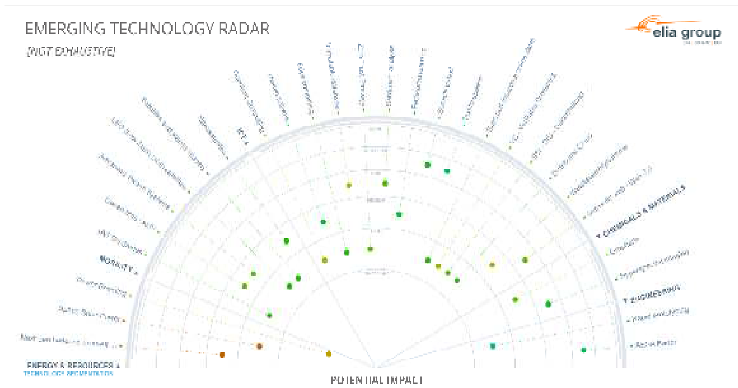
- Emerging technologies are continuously discovered and tested within the Open Technology Lab. The goal of this lab is to spot unexplored technologies and assess their relevancy for Elia through the Technology Radar. Together with the SPOCs, IT and business teams, the lab materializes the value of new technological capabilities for the company. The Tech Lab streamlines innovation roadmap for the supporting domain "Driving the digital & data transformation" and its exploration areas aiming at the discovery of breakthrough or even disruptive technological capabilities and concepts.
- Established technologies that have been proving value to different industries for some years already, such as Artificial Intelligence, Internet of Things, robots and drones, eXtended Reality (XR) and automation, are offered to the company through the different Centres of Excellence.
- Project opportunities that can be tackled by the business representatives, without the need of support from the Innovation SPOC, can enter a trajectory of Citizen Development or Internal Incubation. In the first case, the business expert will work out a simple digitalization idea on their own, supported by experts of different citizen development tools. In the second case, when the idea or opportunity is more complex and more support is needed, we will bring the idea in the productisation fast-track, where within 12 weeks a prototype is built with the experts of the incubator.

Technology Radar

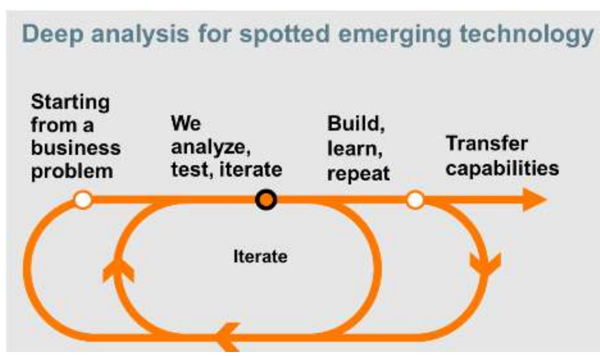
Staying on top of the constantly evolving technical landscape is key. By constantly monitoring emerging technology trends and keeping our radar up, we're able to identify the most impactful technologies that will allow us to tackle current and future business challenges in *the most innovative way possible as well as to mitigate risks. For example, new technologies may expose organizations to new cyber threats.*

With emerging technology monitoring, scouting and analysing our goal is to continuously identify and assess emerging and unexplored technologies and trends that have the potential to disrupt the energy industry and the way we do our business.

We assess technologies based on several factors, such as the potential impact, the potential value of the new technology or the technology readiness level.



If a technology is deemed relevant, we enter into a test and analyse phase to determine the maturity and potential benefit of a technology. Learning in an iterative process, we check how we can apply the new technology – always with the goal in mind to solve challenges of our business operations today and tomorrow.



The phases of innovation

Three stages can be identified in the innovation process: Exploration, Validation and Pre-exploitation. They are outlined in Figure 15 below. Each of these corresponds to a different level of understanding of a particular type of technology and involves a different time frame; for example, pre-exploitation takes the shortest amount of time-to-implement and involves technology which is already well understood by a business.

It is important to understand these different stages, as they are key to the decision-making for the innovation portfolio. A well-established corporate organization should aim to implement the 70-20-10 model, where respectively 70, 20 and 10% of the innovation efforts (time and budget) are invested in respectively the pre-exploitation, validation and exploration stage.[33]

While this rule of thumb is certainly valid for the overall company innovation efforts, we choose to not apply it as such in the framework of the 'Innovation Incentive'. Rather, given that the incentive aims to push Elia beyond its comfortable limits, we will rather implement a 45-40-10 ratio when building the portfolio.

Figure 15: The different stages of innovation

Exploration
In the first stage of innovation, the technology or new process is generally not known by the company. It will be necessary to build an initial understanding via a first proof of concept which is generally limited in terms of time and budget.

- The goal of these first test is generally not to demonstrate a quantified business case, but to show the possibilities and limitations of the technology;
- KPIs will then mainly be hypotheses that need to be validated regarding the advantages and the limitations of the technology or the new process;
- The 'time to business' time is long, we consider a complete implementation time between 5 and 10 years.

Validation
In the validation phase, the technology or process is known. However, there is still a need for validating the use case in order to confirm the added value. As a result, the timing for implementation is shorter than in exploration phase.

- The goal of the validation phase is to verify that the advantages of the solution before starting production;
- As we are getting closer to the production phase, the KPIs are mixing qualitative KPIs (hypothesis to be proven before planning implementation) and quantitative (verification of the business case);

33 What is the 70-20-10 Rule of Innovation and How to Use It (viima.com)

- The implementation time is closer, ranging from 2 to 5 years.

Pre-exploitation
In this phase, the technology or the process is known by the company and the innovation results either in the implementation of the innovation or in incremental improvement. This is the most common type of innovation, and generally run by the business directly.

- In the pre-exploitation the technology and or the process are known, and the business case is validated. As a result, the business is taking over with the goal of putting in place a roll-out plan;
- KPIs can now be more quantitative as the hypothesis about the technology and the business case have already been tested or are already known;
- In this phase, the innovation is very close to implementation (less than 2 years).

The three stages of innovation can roughly be translated into different TRL levels, where the Exploration stage would correspond to a technology with TRL below 4, Validation will be TRL 4-7, and the Pre-exploitation stage will have a TRL beyond 7.

Arbitrage of the innovation portfolio

Unavoidably, throughout the innovation funnel we need to make hard decisions on which projects to prioritize, at the cost of other projects. For this exercise to be as transparent and fair as possible, we have chosen to look at the expected advantages of the project according to the Energy Trilemma (extensively discussed at the beginning of this document), on a mid-long-time scale (5-10 years). The description of the Trilemma impacts from an integral part of the project template. These will be described in more detail in Addendum 1.

In order to prioritize and quantify the expected impact for the Belgian consumer, every one of these trilemma aspects will be assessed before starting the project. We will always aim to make this assessment in both qualitative and quantitative terms. This analysis will result in an overall impact score per project, which is an explicit part of the project template.

Affordability

Affordability is a key variable in this equation, as new solutions need to be financially affordable in order to be viable. Affordability will be the key driver impacting the end-user's energy bill. Innovative projects can automate certain practices or remove the need for physical labour, enabling employees to spend their time more efficiently. In this category we also attach significant importance to future cost avoidance. New technologies can for example help us improve the durability of our assets through predictive maintenance and better awareness. To the extent possible, these indicators will be quantified within every individual project.

Sustainability

In alignment with the European targets, we need to enable a rapid integration of extra renewables in the grid. These can be quantified by the amounts of MW impacted. Another key criterion for sustainability is the safety of the workforce. These are harder to quantify but are often logical and qualitatively understandable. In this category, we will quantify where possible and describe the improved safety in a logical manner.

Security

Hand in hand with an increase in demand for electricity, renewable energy sources are less predictable in comparison to thermal energy sources. This brings significant challenges when it comes to balancing the supply & demand of the grid and guaranteeing security of supply. Additionally, there will be extra pressure to reduce outage time and impact, be it planned or unplanned outages. Criteria which give a clear improvement regarding the security of the supply, forecasting of renewables or the availability of the network will be described in this section.

Each Trilemma aspect will be assigned a score ranging from 1 to 10 by the respective project leader, to assess its impact. This approach will allow for a qualitative evaluation of the project portfolio's balance. In addition, the project portfolio will take into account the number of person hours and euros invested in each project. An inclusive analysis of all these variables will provide a comprehensive view of the innovation project portfolio.

We consider all the categories as crucial to obtain the right prioritization of our project portfolio. Additionally, assessment based on these three criteria will ensure that the portfolio can be explicitly balanced, which is key to the delivery of our strategy.

Valorisation of the results

The business innovation portfolio of Elia is driven by societal needs in terms of the energy trilemma and the external challenges that our business units are facing with a changing environment. Therefore, external valorisation or monetization of the results and products that emerge from the innovation activities we undertake is not part of the initial scope of the projects.

The main goal of the elements of the portfolio is that they will be progressively incorporated in our business-as-usual operations. We therefore see the internal business units and customers as the projects main and only beneficiaries.

In case we manage to develop a truly commercially attractive product – such outcome is not expected to be the norm –, such as a software that can be licensed to other companies, we will inform CREG about this, and decide together how to scale such a product for the benefit of the end consumer within the regulatory framework.

Addendum 1

Project Template