ELIA INNOVATION

Innovation incentive 2020-2023
Plan update

Update on the structure and the list of projects for the innovation incentive for the year 2021

01/07/2020

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Content

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1. Introduction: a co-created innovation plan

1.1 Context of the innovation incentive

The present document is an update of **the Elia innovation plan for 2021 presenting to the CREG the portfolio of innovative initiatives Elia proposes for the incentive pursuant to article 26 §2 of the Tariff Methodology for the period 2020-2023.**

This document introduces firstly the key prioritized challenges linked to the main trends of the energy transition and the digitalization of our sector. Indeed, the expected increase of renewable energy in the system to comply with Belgium's ambitious decarbonization targets coupled with the decentralization linked to the electrification of a number of sectors (heating, mobility...) is increasing greatly the complexity of the system and the way to manage it. At the same time the technological breakthrough led by digitalization with technologies such as artificial intelligence, blockchain, IoT or virtual reality are opening many opportunities to support and transform the way we approach the business of the Transmission System Operator. Therefore innovation is more than ever a need to deal with the accelerated pace of changes and guarantee that Elia develops an energy system that is sustainable (allowing the high penetration of renewables), affordable (keeping operations costs low) and secure (guaranteeing adequacy and flexibility).

Secondly, the document describes how the list of prioritized challenges are driving the innovation strategy, resulting in a portfolio of innovative initiatives led by both Elia's different businesses and the specific innovation cell of the company. Open innovation plays a central role in this strategy, which is why Elia works with many different relevant stakeholders linked to the specific challenges, from start-ups to other industrial partners or academics.

However, innovation is a mindset before anything else and such a mindset is key in unlocking the innovative potential at the scale of the company. By instilling a culture of innovation and make a way for creative thinking, Elia has the ambition to design more effective processes, products and ideas. This transformation of Elia towards a more agile and innovative company will touch the complete business including corporate functions that will also face an increase in complexity due to the energy transition and digitalization challenges. That is why Elia is also launching idea incubators and innovative services to embed innovation at the core of the whole company, as we think this will accelerate the transformation of the company and better respond to digitalization and energy transition challenges.

In brief, Elia's innovation strategy is based on 2 main principles: we focus on prioritized challenges to make sure we achieve results, and we rely on strong partnerships and company transformation to accelerate the resolution of these challenges.

1.2 Status after first project selection for 2020

On July 1st, 2019, Elia submitted to CREG a list of projects for its 2020 plan from which a list of 11 projects was selected (see table 1).
As a base for not selecting certain projects, we retain CREG used the following arguments:

- Impact for the Belgian society was not clearly demonstrated;
- Lack of uncertainty/risk that would justify the need for an incentive;
- Timing and budgets were not sufficiently detailed.

	Name	Accepted 2020	Accepted 2021	Accepted 2023	Accepted 2020
1	Spacs 3& 4				
2	Asset Control Center				
3	Optiflex				
4	CMS - Risk based Decision				
5	Use of VLOS drones for pylon inspection				
6	Use of LIDAR for prunning				
7	Internet of energy				
8	Digital backbone				
9	Digital solution				
10	Automation of voltage control				
11	Future grid dynamics				
12	Assessing the role of BVLOS drones for line inspection				
13	Testing robots for inspection				
14	Contributing to the global grid study				
15	Assessing predictive maintenance to improve asset management efficiency				
16	Sensors				
17	Integrating decentralized assets				
18	Automation of dispatcher work				
19	Blockchain				
20	Virtual reality				
21	AMEX follow-up				
22	Smart implicit pricing				

Table 1 - Table of selected projects for 2020 and corresponding amounts for the calculation of the incentive

In subsequent discussions, the CREG also stressed that a lot of information was present in the plan but for some projects, CREG was missing detail on some key elements such as timing, cost and impact. Elia explained that such a level of detail is by definition difficult if not impossible to reach for innovation projects as the main characteristic of innovation activities is the uncertainty of the outcome. Therefore the timing and total cost of a project, as well as its impact are to a great extent discovered as the project goes forward.
Moreover, CREG and Elia agreed also on the fact that no sufficient preliminary discussions occurred before the submission of the report.

Based on last years' experience, Elia initiated in the first days of February this year preliminary discussions with CREG in order review and explain its innovation strategy in the context of the on-going digitalization and the energy transition. To that end, Elia explained why current observations and uncertainties regarding the evolution of its activity as TSO justify the key challenges Elia will focus on via the portfolio of projects proposed.

Also, in order to increase the likelihood that all projects meet CREG's selection criteria this year, Elia has followed the format proposed by CREG. This should improve the structuring and therefore the understanding of the report.

1.3 Improved format

First of all, given the fact that the language most commonly used in innovation-related activities is English, and that even a perfect translation into French or Dutch, instead of making understanding easier would make it more complicated, Elia opted for submitting its improved plan in English (one of the 3 languages prescribed by CREG in its recommendation).

As introduced in point 1.2, Elia has followed CREG's request of April 19th 2020 to include for each project the following information:
- Project specific context;
- Project specific State-of-the-art/Literature study;

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- Expected impact for Belgium;
- Starting point of Elia;
- Uncertainties & risks;
- Project description;
- Partners;
- Summary of project efforts in person months: per work package and per year.

Each project is described following the aforementioned structure and presented in appendix.
In order to better highlight the coherency and above all the objective rationale behind Elia's innovation portfolio, the innovation strategy is described in the first part of the plan, starting from the major trends that trigger consequences for the TSO business (section 2) and the 6 major resulting challenges that Elia needs to address (section 3) through its innovation strategy.

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2. Major trends leading to impactful consequences for the energy system, our business and society

2.1 Major trends & the role of innovation

2.1.1 The 4 Major trends

The landscape of the energy sector is changing at an extraordinary pace. Among the different social, technological or political evolutions, Elia identifies four major trends that will shape the future of the energy sector:

Decarbonization of the energy sector
The biggest game changer in Europe's energy system is of course the rise of renewable energy driven by the need to counter climate change and build a sustainable future, but also by the technological breakthrough in the domain of green generation and storage that pull prices down and increase the energy capacity connected to the grid. Based on the ambitious emission reduction target re-affirmed in the green deal with a proposed rise of the target to 50% emission cut by 2030, this trend is for the long term and will change the old energy paradigm of the centralized thermal generation.
As a result, the distribution of generation across the electricity grid will completely change as the injected energy will come both from small scale decentralized solar and wind installations and from large scale green generation facilities such as offshore windfarms. In consequence, the transmission infrastructure needs to be adapted to a more bottom-up system while at the same time the backbone corridors must be reinforced to transport green energy over long distances. System operations will also be impacted by the increased uncertainty and intermittency of the generation.

Decentralized generation and new players
The increasing fragmentation of the sector, characterized by decentralized energy sources and the increasing number of market players due to electrification makes the system more complex to operate. We will then shift from a system with a few dozens of power plants towards a portfolio of thousands or even millions of small decentralized flexibility means (electric car, heat pumps…). So the management of decentralized means will become more and more crucial to guarantee adequacy and flexibility of the network knowing that TSOs will need more flexibility to keep the system in balance and that the role of classical power plants will decrease.

Supranational coordination
This trend results for a great part from the other two. Increased penetration of renewables and the movement towards decentralized generation means the current grid is struggling to meet region-specific needs. Across Europe we are experiencing more congestion problems and higher redispatching costs, in an increasingly variable and complex power system. Given the interconnectedness of European power markets, responding to these challenges often requires a supranational response.

Digital revolution
These last years, the digitalization wave has strongly affected the whole economy and the energy industry is no exception. Digital technologies like artificial intelligence, automation, drones are now already embedded in part of the value chain and the trend will accelerate in the coming years considering the increase of complexity brought by decarbonization and decentralization. Therefore it is crucial to identify the most impactful use case, to understand the technologies and more importantly to prepare companies for the digital transformation required by a high pace of change.

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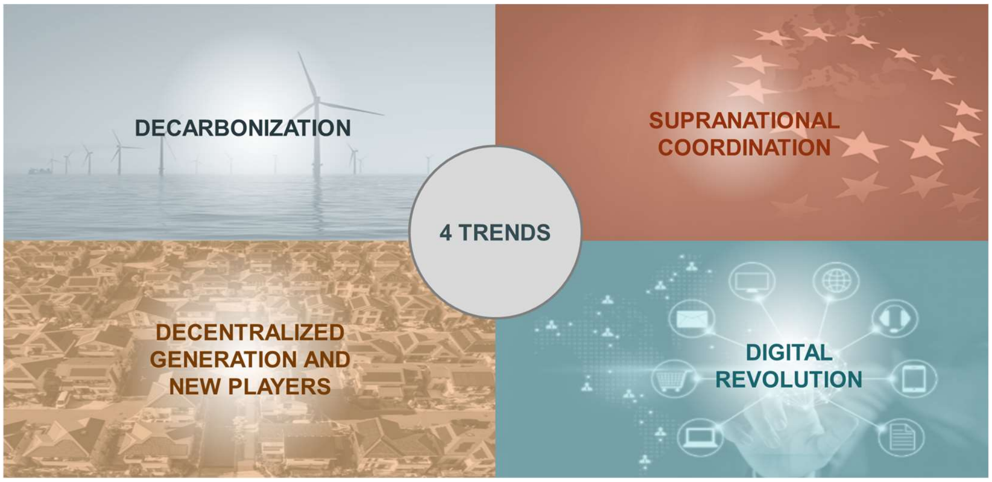


Figure 1 – 4 trends defining the future of the TSO business

2.1.2 The role of innovation

The trends exposed above will increase the complexity of the overall system, taking into account among other factors

- the uncertainty and intermittency of renewables linked to weather conditions
- the increase of flexibility means to be orchestrated, with a shift from a few power plants at hand to balance the grid to thousands or millions of small flexibility means
- the increase of stakeholders to interface with (from the e-mobility sector, from building management…)
- the new regulation needed for voltage or inertia

To tackle the increase of complexity, urgent technological breakthroughs are needed to keep a reliable and affordable energy supply.
Successful innovation should encompass the complete value chain of our sector across the siloes of the core business (market design, system operations and asset management) addressing both technologies themselves and underlying factors such as the organization and the innovative methods used to generate new ideas.

2.2 Consequences of the major trends

These major trends will profoundly change the way the energy system works. The increased penetration of renewables coupled with the integration of decentralized means such as batteries or electric vehicles will drastically increase complexity. At the same time, digitalization will offer the possibility not only to cope with this growing flexibility, but also to improve efficiency (via automation, or better prediction) and workers safety.

CONEQUENCES OF THE 4 TRENDS

Consequence	Today facts and forecast examples
Low marginal price	In 2020: Since the beginning of COVID-19, spark spread (difference between electricity market price and running cost of gas power plants) became highly negative meaning high must-run cost for gas power plant for ancillary services
Uncertainty of generation	In 2018: number of hours with forecast error Day-ahead > 100MW: 780h for solar, 2069 for wind
Intermittency of generation	In 2018, average standard deviation of RES generation: 138 MW solar and 717 MW Wind
New system dynamics	Installation of solar and wind to triple by 2030 while low inertia due to high RES penetration in islanded system has already shown increasing needs of RoCoF to 10Hz/s
New decentralized flexibility means	More than 1mn of EV and 1.5 mn of heat-pumps foreseen by 2030 which could represent more than 1 GW of flexibility
New grid development rules and business models	Development of energy as a service (e.g.e-mobility as a service, heating as a service..) and introduction of new flexible connection contract as G-flex to cope with RES increase
Develop infrastructure to flow important RES infeed	ENTSO-E TYNDP foresees 58 to 156 TWh of less curtailed renewables energy and 24 to 471 GWh of reduction in Energy Not Served
Interface of with new players	New players starting energy activities in mobility sector, heating, building or industrial (e.g. VW launching Elli)
Digital tools & data use	Market for digital technologies in energy to worth 64 bn USD in 2025 according to Bloomberg impacting the full energy value chain (e.g. Smart boxes to optimize consumption as Tesla autobidder)
New market models	Development of local market P2P market (e.g. Elmore House P2P market with EDF in UK, in Norway Adger Energi using local energy marketplace to achieve 4.3 mnEUR of grid deferral)
Sustainability in our business	Many companies aiming to completely decarbonized their operations: Google, Facebook supported
Ageing of the infrastructure	Average age of the infrastructure of xx years in 2020 and a risk of doubling the number of critical outages by 2022

Figure 2 - List of consequences of the energy transition and digitalization

These various consequences, mentioned in point 2.1.2, are discussed in the sections below and introduce the question of the challenges Elia will have to overcome to guarantee a green, safe and affordable energy.

3. Derived challenges to drive the focus of the innovation strategy

These consequences trigger a number of challenges for the future that will effectively drive Elia's innovation strategy, with the same end goal of delivering an energy supply that is secured, sustainable and affordable.
Elia has identified 6 main challenges that will guide its portfolio of innovative initiatives in the years to come. The links between the trends and their consequences with each of the challenges are presented in the figure 3:

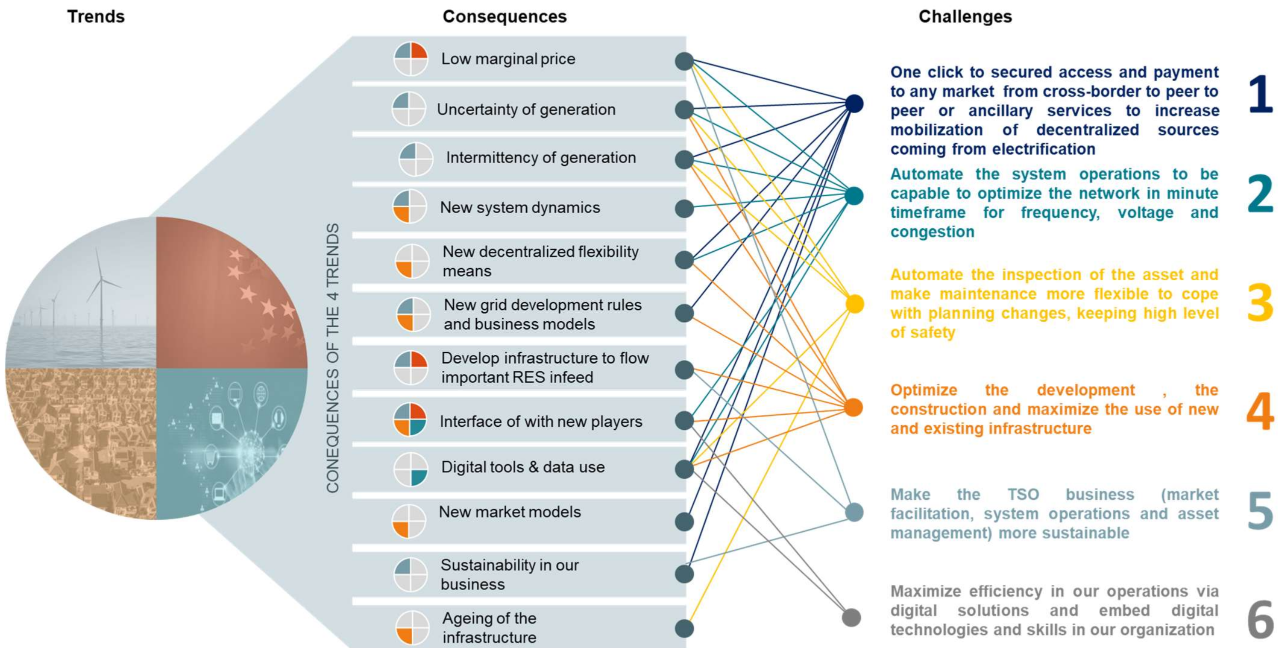


Figure 3 – The 6 challenges driving the innovation portfolio and their links with the consequences

1. **One click to secured access and payment to any market from cross-border to peer to peer or ancillary services to increase mobilization of decentralized sources coming from electrification:**

This results from the increasing flexibility needs due to intermittency and uncertainty of renewables coupled with limited role of centralized generation in the future due to low marginal price. In that condition running the power plants for flexibility (notably fast flexibility) will require to pay some sunk cost for the operations of the power plant which is not remunerated by the market. As a result it becomes crucial to leverage new electrification potential (demand side management from electrical vehicles, battery, heat pumps) benefiting from the digital tools and notably artificial intelligence, that will enable to connect, control and forecast their behavior.

2. **Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion:**

As already mentioned, in a high renewables energy penetration system, the number of running synchronous decrease due to the low marginal cost. This will induce new grid dynamics starting with a lower inertia and a higher volatility. This will not only affect the imbalance and the frequency regulation but also the regulation of the voltage and the congestions that will also be regulated closer to real time. In parallel the use of decentralized flexibility will decoupled the number of dispatch able means to be operated (from dozens to hundreds of thousands…). As a result the complexity of the system will drastically increase and will require new tools to forecast, support the decision and even completely automate some part of the dispatching.

3. **Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety:**

As the ageing of the asset increases, the maintenance needs and therefore cost will increase. At the same time the increase role of the renewable energy sources and the intrinsic uncertainty and intermittency will impact the congestion and the impact an outage could have on these congestions. As a result costly re-scheduling of the maintenance happens more and more to cope with the congestion constraint. Use of technology as artificial intelligence could enable smart planning to take into account new congestion risk while the use of digital technologies as drones and robotics could automate the inspection and give input to smart predictive maintenance algorithm that will optimize the maintenance to minimize the cost and the risk of unplanned outage. Finally the new technologies as sensors, wearables, and connected glasses could improve security and efficiency of the field worker.

4. **Optimize the development , the construction and maximize the use of new and existing infrastructure:**

As the renewables will create a new distribution of the energy flows, new infrastructure will be required to avoid increasing congestion on the network and massive curtailment blocking then the potential of decarbonization from installed renewables capacity. However, as the renewables will rarely produce at their maximum potential, the development of the grid need to be balanced between coping with the installed renewables capacity potential and decrease the total infrastructure cost for the end consumer. In parallel the new technologies have the potential to make the grid construction process more efficient. Firstly by using virtual tools to better visualize their impact and facilitate the discussions with the local communities and other stakeholder involved in the acceptance. Virtual tools can also accelerate the construction phase notably by improving the planning of the different project phases. Finally new material can increase the use of the grid and maximize the energy capacity and the security of a specific infrastructure.

5. **Make the TSO business (market facilitation, system operations and asset management) more sustainable:**

As a leading company in the transformation towards a decarbonized energy system, Elia will also transform its own business to guarantee a CO_2 free operation including the replacement of the SF_6 as insulator for the Gas insulated Substation. In parallel Elia will offer the opportunity to track effectively the green energy production to offer green energy and green services.

6. **Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization**

As the role of digitalization will increase, the pace of innovation will also accelerate and push for more intrapreuneurship and agility to answer in a flexible and efficient way to the new challenges and the technology changes. Therefore it is crucial that Elia transition to the digital TSO and offer the opportunity to its employee to test and implement quickly new digital ideas that could bring efficiency, flexibility or quality. The digitalization should then also benefit to the corporate functions, as the automation of the controlling and accounting operations that will facilitate the financial operations linked to the services market.

Each of the selected challenges can then be split into specific domains that relate to part of the solution and to which each innovative initiatives will rely.

The picture 4 gives the complete overview of the domains for each of the identified challenges.

Figure 4 – Innovation domains

4. Summary of projects

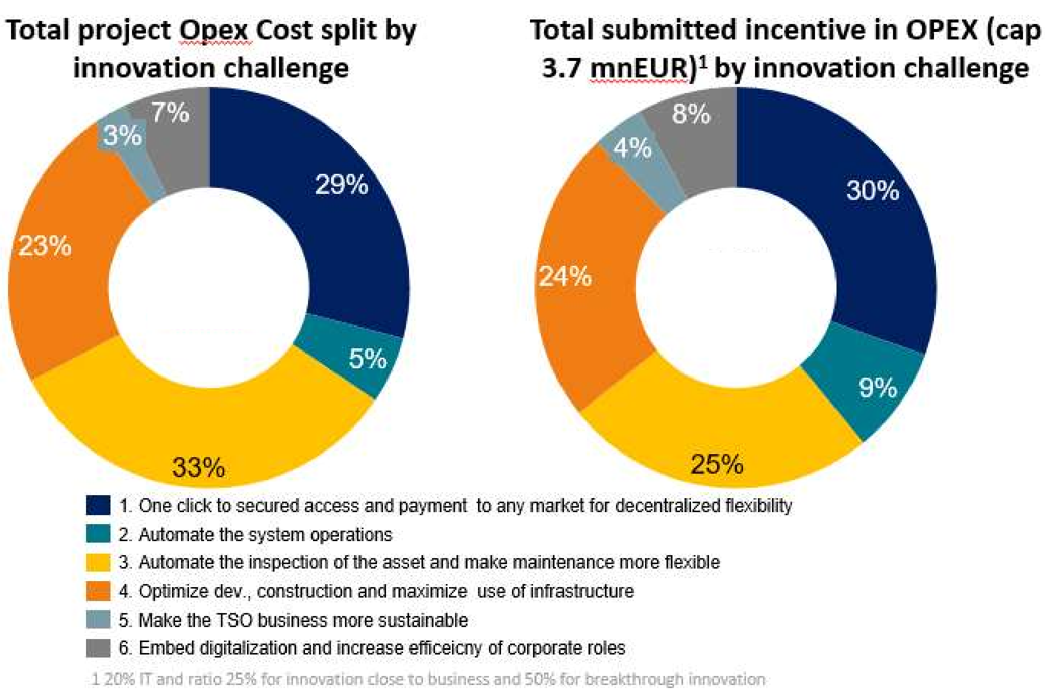
For the period 2021 Elia is currently submitting a list of 26 projects split among the 6 challenges pre-identified:

1. **One click to secured access and payment to any market from cross-border to peer to peer or ancillary services to increase mobilization of decentralized sources coming from electrification**
2. **Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion**
3. **Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety**
4. **Optimize the development , the construction and maximize the use of new and existing infrastructure**
5. **Make the TSO business (market facilitation, system operations and asset management) more sustainable**
6. **Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization**

The total foreseen spending for these project will represent *CONFIDENTIAL* for 2021 with the split presented in the figure 5.

Figure 5 – Budget split between the innovation domains

The table below gives a brief summary of the project list while the complete details are presented in the appendix.



n°	Name Project	2021 Budget	2021 Incentive	Inno-Challenge	Inno-Domain	Description
1	**Digital substation (SPACS 3 & 4 & OSMOSE)**			4. Optimize the development , the construction and maximize the use of new and existing infrastructure	4.3 Advanced material and connected technology to maximize use for infrastructure	In situ test of next generations of protection cubicles that will be deployed on the Elia grid in order to shift from a wired substation towards a digital substation with optic fiber.
2	**Asset Control Center**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.3 Predict and optimize preparation of the maintenance	Implementation of a smart digital platform allowing to change the focus from time based asset management to condition based asset management by the calculation of health index for the relevant assets.
3	**Optiflex (now Synapse)**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.3 Predict and optimize preparation of the maintenance	Improvement of maintenance planning through innovative solutions (e.g. using artificial intelligence) and optimizatin fo the execution to increase productivity and limit unavailability of the grid.
4	**Risk-based approach to develop the system**			4. Optimize the development , the construction and maximize the use of new and existing infrastructure	4.1 Automatic integrated system dev. risk based	Development of a risk based approach to develop the grid depending on the probablility of system evolution (rnewables, decentralized felxibility…) in order to achieve better welfare for the society.
5	**Customer centric system**			1. Increase participation of flexibility sources from decentralized sources coming from electrification	1.1 Manage market related data from and for market parties	Anticipation of future required evolutions of market and system processes in order to unlock the potential of decentralized flexibility from consumer
6	**Digital Backbone**			1. Increase participation of flexibility sources from decentralized sources coming from electrification 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	1.1 Manage market related data from and for market parties 3.1 Connect and cyber secure our asset and substation	Development of innovative digital module including new modular IT infrastructure based on a modernized organizational framework in order to enable new technologies use cases as IoT, open data or artificial intelligence.
7	**Automation of voltage control**			2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion	2.4 Predict and automate voltage decisions	Assess the need in voltage control and set new solution to optimize decentralized voltage control equipment
8	**Undestanding of new grid dynamics**			2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion	2.2 Prepare for low inertia and integrate power electronics	Develop understanding of the impact of new grid element brought by renewables as power electronics on the dynamic on the grid and specifically on the inertia and the opportunity to use virtual inertia.
9	**BVLOS to automate inspection**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.2 Automate inspection onshore and offshore	Validate the feasibility of long distance flight to automate the inspection and effectively detect the default on an overhead line and a pylon and assess the potential to replace foot patrol and helocopters.
10	**Blockchain to facilitate the participation of decentralized felxibility**			1. Increase participation of flexibility sources from decentralized sources coming from electrification	1.2 Apply scalable process for authentication of devices and activation	Test the automatic participation of decentralized energy resources, in this case EVs, to ancillary services market with the help of digital identities to facilitate the onboarding (identification, pre-qualification).
11	**Robotics for inspection in remote, difficult or dangerous locations**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.2 Automate inspection onshore and offshore	Test of robotics for identified dangerous or remote situation: HVDC converter hall, cable tunnel and offshore platform
12	**Test predictive maintenance for critical asset**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.3 Predict and optimize preparation of the maintenance	Test of predictive maintenance for critical asset on the Elia network to reduce the Energy Non Serve and the down-time
13	**Training in virtual reality and mixed reality**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.4 Secure and connected Workforce	Develop and test training for dangerous situations (e.g. climbing pylons or high voltage) to improve safety of the operator and the efficeincy of the training.
14	**Use of artificial intelligence to automate of dispatching**			2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion	2.3 Predict and automate imba-lance dispat-ching decision 2.5 Automate maintenance planning and congestion	Develop new forecast, support to decision and if required complete automation to help dispatcher dealing with complexity increase of the operations for the imballance, voltage and congestion management.

n°	Name Project	2021 Budget	2021 Incentive	Inno-Challenge	Inno-Domain	Description
15	**Analyzing vibration sensors for our infrastructure monitoring**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.3 Predict and optimize preparation of the maintenance	Develop with a university new type of sensors to detect vibration of pylons to increase certitude of the overall pylon structure integrity and therefore increase the safety of the environment.
16	**Mixed and virtual reality to improve public acceptance**			4. Optimize the development , the construction and maximize the use of new and existing infrastructure	4.2 Accelerate the public acceptance	Build mixed and virtual reality models of our infrastructure to increase awareness of improve the understanding of the impact of our assets on the environment in order to accelerate the public acceptance.
17	**Connected Infrastructure to increase maintenance efficiency**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.1 Connect and cyber secure our asset and substation	Connect the infrastructure with new sensors to better monitor the status of the infrastructure and detect/ prevent dangerous situation (e.g. new temperature sensors in substation, specific oil leakage sensors for OF cables) and inrease maintenance efficiency
18	**Use of innovative digital technologies for the automation of finance**			6. Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization	6.3 Automation and analytics for corporate functions	Develop new smart reporting based on artificial intelligence to improve the meaningfulness of the conclusion provided by controlling and improve the support to decisions.
19	**Assessing the impact of local generation and prosumption strategies on the grid infrastructure**			1. Increase participation of flexibility sources from decentralized sources coming from electrification	1.4 Predict and incentivize DER's	The project aims at better understanding the effective availability of decentralized flexibility taking into account the inherent constraints linked to the behavior of the consumer and therefoer their real impact on the grid development.
20	**Carbon neutral operation of the grid**			5. Make the TSO business (market facilitation, system operations and asset management) more sustainable	5.2 Sustainable system operations	Analyze the needs linked tot eh operation of a full carbon neutral grid (and which resources could fulfil those functions). It will be based on a literature study and own study/reflection.
21	**Internal innovative idea incubator**			6. Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization	6.1 Embed digital capabilities and training	The goal of the project will be to set-up the incubator taking into account multiple dimensions
22	**Connect our infrastructure to increase the security & safety**			3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety	3.1 Connect and cyber secure our asset and substation	Connect Elia's infrastructure using new innovative solution as accoustic camera or vibration sensors to increase the security and safety and reduce the theft risk.
23	**Smart pricing**			1. Increase participation of flexibility sources from decentralized sources coming from electrification	1.4 Predict and incentivize DER's	The project aims to develop a range of tools to address the issue of how best to capitalize on flexibility, especially residential flexibility.
24	**Tracking of ancillary services green source**			5. Make the TSO business (market facilitation, system operations and asset management) more sustainable	5.2 Sustainable system operations	Develop a solution to track in near-real time the source of ancillary services provision to ensure decarbonization of the grid operations.
25	**Smart wires**			4. Optimize the development , the construction and maximize the use of new and existing infrastructure	4.3 Advanced / New material and tools to increase use of the infrastructure	Test in Elia grid 'Smart-Valve' technology allowing to dynamically increase or decrease the impedance of connections by injecting a voltage in quadrature with the current.
26	**Universal Cable Junction**			4. Optimize the development , the construction and maximize the use of new and existing infrastructure	4.3 Advanced / New material and tools to increase use of the infrastructure	In order to have more flexibility for projects building further on existing cable links, the idea has risen to qualify transi-tion joints between different qualified cable suppliers in order to connect cable systems from two different suppliers with a qualified universal cable joint.
	Total					

Appendix

Project 1: SPACS 3 &4 and OSMOSE

Domain 4.3

2020 Decision: Accepted

Trends: Decarbonization, decentralized generation and new players, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, interface with new players

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project-specific context

- SPACS 3 and SPACS 4 relate to the next generation of protection cubicles that will be deployed on the Elia grid in order to move from a wired substation to a digital substation using optical fiber
- SPACS 3 is the first step on the path to digital substations. It involves introducing the IEC61850 communication standard at substation level by using Edition 2 of this communication protocol in a multivendor environment, and improving the efficiency of the design and testing of PAC functions through functional integration and standardization. IEC61850 Edition 2 does not represent the majority of installations in the industry at the moment; it was officially released in 2011, but it took several years for the manufacturers to implement this release in their equipment and to obtain the appropriate certificates from the official testing bodies.
- The innovative aspect of SPACS 4 is that it introduces the Digital Substation concept, where process bus technology (exchange of information between the bay and the protection cubicles though the IEC 61850 protocol) plays a key role. The expected capacity of the solution will make it possible to test the installation of the equipment in a container. This container will be fully tested before installation on site in order to minimize the outage time during com
- In parallel with starting the testing of SPACS 3 and 4 and in order to prepare Elia for the implementation of SPACS 3 and 4, Elia has been participating since Q4 2017 in Work Package 7 of the OSMOSE project subsidized by the European Commission in the context of its H2020 tenders. The goal of the project is to test the interoperability framework (IEC 61850) in line with ENTSO-E's dedicated workgroup and by integrating real-life feedback from the demonstrations.

Project-specific state of the art/literature review

- Up to now, there have been only a few pilot projects performed in Europe, and no large-scale deployment has started yet. Such deployment would have also a strong impact on design, commissioning, and maintenance activities.
- The demonstration that will be performed in the context of OSMOSE, including the development of the IST tool, is also the first demonstration at European scale.

Expected impact for Belgium

- OSMOSE will test the feasibility of interoperability in digital substations that are set to have an impact as a result of SPACS 3 and 4.
- SPACS 3 should bring about a *CONFIDENTIAL* reduction of CAPEX in the years ahead by replacing *CONFIDENTIAL*of switching boxes.
- SPACS 4 should result in more flexibility in the replacement and maintenance of switching cabinets, leading to the optimization of the overall cost and increasing availability. The exact gain will be calculated in WP 3.2 described below.

Starting point for Elia

- Nowadays, all substations that are installed are still equipped with copper wires. Tests performed by Elia some years ago demonstrated the lack of interoperability of Edition 1 of the protocol, and so it was decided to wait until Edition 2 before using this technology.

Uncertainties and risks

- Uncertainty surrounding the availability of multi-vendor interoperable solutions in Edition 2 of the standard, both at equipment and at engineering level
- Uncertainty regarding tool availability for the efficient design and testing of IEC 61850-based substations
- Uncertainty surrounding the competencies needed to develop, maintain, and use such digital substations

Project description

- WP 7 of the project H2020, OSMOSE: Elia is leading task 1 from Work Package 7 with a view to improving the interoperability framework (IEC 61850) for plug & play integration and better utilization of flexibility solutions, in line with ENTSO-E's dedicated workgroup, and integrating real-life feedback from the demonstrations with development of an interface tool and a test with two suppliers. The demonstrator is hosted by *CONFIDENTIAL*, the lab branch of the Portuguese TSO *CONFIDENTIAL*, part of the OSMOSE consortium.
- The SPACS 3 and 4 innovation projects should be completed by early 2023. In light of the need to replace existing equipment, the objective is to integrate innovative solutions aimed at:
    1. reducing the cost of the switching cabinets forming part of the grid, thereby accelerating the volumes replaced while limiting the overall impact on the community;
    2. limiting the impact on resources despite the growing inherent complexity of the technology used;
    3. restricting the power cuts required for corrective maintenance and commissioning tests;
    4. maintaining at least the same performance level as the solutions that are currently being used.

- Approach: In OSMOSE, test with two suppliers the interoperability of cabinets in a digital substation (in a demonstrator hosted by *CONFIDENTIAL*) and an interface tool will be developed (IST Tool by *CONFIDENTIAL*); in SPACS 3 & 4, test the implementation of a digital substation in Aarschot as a testbed. First realizations of SPACS 3 (infrastructure project with full commissioning) will take place in Heimolen (*CONFIDENTIAL*) and Trivières (*CONFIDENTIAL*)
- Work packages and timing (M = month)
    1. *WP 1 & WP 4: SPACS 3*
        - Task 1 (WP 1)
            - *CONFIDENTIAL*: Development of applicative standards
            - *CONFIDENTIAL*: Technical description of the solution
        - Task 2 (WP 4)
            - *CONFIDENTIAL*: Training of operational team
            - *CONFIDENTIAL*: Large-scale deployment
    2. *WP 2: SPACS 4*
        - Task 1
            - *CONFIDENTIAL*: Definition of pilot perimeter
            - *CONFIDENTIAL*: Functional specification
            - *CONFIDENTIAL*: Pilot scoping
            - *CONFIDENTIAL*: Engineering/design of pilot
            - *CONFIDENTIAL*: Construction of digital substation pilot
        - Task 2
            - *CONFIDENTIAL*: Feedback
            - *CONFIDENTIAL*: Definition of scenarios and cost-benefit analysis
    3. *WP 3: OSMOSE WP 7*

    - *CONFIDENTIAL*: Specification (definition of criteria, functional test specification, IST format definition, comparison between ISD (IED Specification Description) and SSD (System Specification Description)
    - *CONFIDENTIAL*: Project design (implementation of virtual signal flow, implementation of comparison between ISC and ICD, first pre-test
    - *CONFIDENTIAL*: Creation of the design for the demonstrator and development of the IST tool
    - *CONFIDENTIAL*: Commissioning and testing with the two suppliers
    - *CONFIDENTIAL*: Report and conclusion of the testing
    - *CONFIDENTIAL*: Large-scale deployment
- Deliverables and milestones

WP 1 & WP 4: SPACS 3

1. *CONFIDENTIAL*: Applicative standards
2. *CONFIDENTIAL*: Report on the technical description
3. *CONFIDENTIAL*: Training procedure

WP 2: SPACS 4

1. *CONFIDENTIAL*: Pilot specification
2. *CONFIDENTIAL*: Design of pilot
3. *CONFIDENTIAL*: Completion installation
4. *CONFIDENTIAL*: Completion of cost-benefit analysis

WP 3: OSMOSE

- *CONFIDENTIAL*: Completion of IST specification
- *CONFIDENTIAL*: Provision of SSD and ISD files
- *CONFIDENTIAL*: Provision of SCD file
- *CONFIDENTIAL*: Completion of testing
- *CONFIDENTIAL*: Completion of reporting to the OSMOSE consortium

Partners

WP 1 & 4: SPACS 3

- Manufacturing of the cubicles*CONFIDENTIAL*(35%) and *CONFIDENTIAL*(65%)
- Manufacturing of the control system*CONFIDENTIAL*
- Development of the engineering tool: *CONFIDENTIAL*
- Development of the testing equipment and methodology: *CONFIDENTIAL* (protection devices), *CONFIDENTIAL*(RTUs)
- Experience-based feedback from other users/recommendations from international working groups: CIGRE Study Committee B5
- Benchmarking/exchanges of experiences and visions: other TSOs/DSOs

WP 2: SPACS 4

- Manufacturing of the cubicles: *CONFIDENTIAL*and *CONFIDENTIAL*
- Manufacturing of the control system: *CONFIDENTIAL*
- Development of the engineering tool: *CONFIDENTIAL*S
- Manufacturing of the container and the integrator for the various cubicles in the container: to be determined
- Development of the testing equipment and methodology (including for interoperability tests*CONFIDENTIAL*(protection devices), *CONFIDENTIAL*RTUs)

- Experience-based feedback from other users/recommendations from international working groups: CIGRE Study Committee B5
- Benchmarking/exchanges of experiences and visions: other TSOs/DSOs

WP 3: OSMOSE

- Supply of the technology for testing interoperability: *CONFIDENTIAL*and *CONFIDENTIAL*
- Development of the IST tool: *CONFIDENTIAL*
- Demonstrator and commissioning: *CONFIDENTIAL*(the demonstrator will be set up in *CONFIDENTIAL* facilities)
- Testing and conclusion: *CONFIDENTIAL*are participating in the other task involved in Work Package 7 of the OS-MOSE project

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	SPACS 3 - Task 1	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 2	SPACS 4 Task 1 & 2	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 3	OSMOSE	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	SPACS 3 - Task 2	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

Project 2: Asset Condition & Control (ACC)

Domain 3.3

2020 decision: Accepted

Trends: Decarbonization, decentralized generation, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, uncertainty of generation, intermittency of generation

Challenges: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domains: 3.3 Predict and optimize preparation of the maintenance

Project-specific context

- Currently the asset maintenance strategy within Elia is strongly time-driven, whereas the need for condition-based Asset Management has been identified as a major gain within the AMEX program.
- To be able to shift the focus from time-based to condition-based asset management, dynamic asset data need to be acquired, managed and analyzed in order to estimate/calculate the physical health condition of an asset (Health Index (HI)).
- Dynamic asset data typically change over time during operation of the asset and have an operational application in terms of asset management. Aside from typical measurements like voltage and load, they also cover indicators such as number of operations, switching time, pressure level, expert assessment during visual inspections, and fault recordings.
- Dynamic data can be retrieved as online data (temperature probe, DGA probe, remote reading, EMS, etc.) or as offline data (maintenance checklists, site patrols, historical analysis reports, etc.)
- Storing and using these big data is not possible in an efficient way with the available tools, which have a static referential nature.
- Therefore, Elia needed to develop an innovative data platform that would collect stored data from the various sources in order to build up an HI by asset to closely follow the maintenance requirements.

Project-specific state of the art/literature review

- During a proof of concept (2014-2016) we discovered that there were no HI algorithms available on the market for Elia's fleet of assets. Elia conducted multiple exchanges and benchmarks with various TSOs who are considered to be leaders in asset management (e.g. Fingrid, Terna, National Grid, RTE). None of these have implemented the HI concept, but they are all willing to perform this type of asset management in the future. Typically this type of exchange is sensitive and in general not shared publicly amongst TSO's.
- There are multiple reasons for this:
    1. the lack of such concepts (as yet) at academic level (e.g. at CIGRE consortium level); in the meantime there is a publication for AIS (Air-Insulated Substation) assets, but a large part is based on Elia's experience;
    2. black-box solutions from vendors that cannot be tweaked, cannot be made by other manufacturers or do not have the desired focus;
    3. experimental algorithms from other TSOs are only valid on their fleet with their applied maintenance policy and their asset management strategy.
    4. Experiences from the process industry are rarely relevant as there asset management doesn't share the same goals and has much shorter asset life cycles. Also at other utilities (like gas and water), this type of concepts are mostly to be found on roadmaps or smaller pilots.
- Therefore Elia decided to develop its own HI, based on the experience of its asset manager and field staff (applying FMECA, or a Failure Mode, Effects, and Criticality Analysis) and the expertise from vendors, other TSOs and DSOs, and last but not least the academic community or CIGRE and IEEE.

Expected impact for Belgium

- Some gains can be found in other strategies, but these are high-level assumptions. Similar projects, such as their application to power transformers, have already resulted in more efficient asset management and it is reasonable to expect that benefits can also be achieved from other assets.
- This project will allow Elia to gain a better understanding of the condition of its grid, allowing it to be more efficient in its maintenance and replacement of assets.
- Furthermore the developments will lead to better understanding of equipment failures and will therefore also allow Elia to act before failures happen. This is an important aspect as it will lead to increased safety for the employees and the environment. (Example 2019: identification of current transformers with an increased risk of explosion when operated at summer temperatures of over 35°C.)
- By calculating the health of assets, the project will enable Elia to act before incidents happen. It is however not possible to calculate the number of avoided incidents, or their impact, in a statistical correct way. The calculation of the system risk has not been performed neither. The model to calculate this makes part of the "Project 4: Risk-based approach for grid development decisions".

Starting point for Elia

- In the period 2017-2019, Elia had already successfully implemented a number of asset fleets by adopting this approach: power transformers, switchgear with a rating of ≥70 kV (disconnectors, circuit breakers, CTs, and VTs), underground cables, overhead lines, and gas-insulated Switchgear.

Uncertainties and risks

- The first uncertainty relates to the possibility of integrating the data into the current platform.
- The second uncertainty concerns the relevance of the results of the HI, as for each HI algorithm, it nees to be shown that this makes sense and is applicable.
- The third uncertainty is that the data are insufficient to build up a qualitative HI that will reduce the risk of outage of the asset while lowering the maintenance cost compared to a time-based approach.
- As this methodology will need substantial development and also new capabilities (in data management), a risk for the project is the unavailability of resources.

Project description

- For the period 2020-2023, Elia envisions testing the data platform and the condition-based methodology via the HI for new fleets of assets: Air-Insulated Switchgear (AIS) with a rating of ≤70 kV, substation buildings, 48 and 110-VDC batteries, shunt reactors, capacitor banks, metering cubicles, HVDC, low-voltage equipment (automation, control, protection, measurement). On top of this, the project will aim to optimize previously implemented fleets. This includes gathering data from additional sources (IoT sensors or other databases), and also adapting existing algorithms based on our initial experiences and innovating with a view to achieving a predictive approach in asset management.

- Approach : ACC's implementation is based on the waves of the AMEX program, identifying which asset fleets benefit from condition-based asset management. ACC Wave 1 implemented power transformers, switchgear with a rating of ≥70 kV (disconnectors, circuit breakers, CTs, and VTs). ACC Wave 2 implemented underground cables and overhead lines. Each wave involves tool development (reporting, interfaces with sources, data model, data cleaning, etc.) and the definition and validation of the specific HI and Equivalent Age (EA) for each (sub)fleet. The operational use of the HI/EA falls outside of the project scope and forms part of the ACC team's business as usual.

- Work packages and timing (M = month)
    1. *WP 1 ACC Phase 1 (linked to AMEX waves)*
        - 1.1 *Task 1: Development of the Health Index with gas-insulated switchgear, 48- and 110-VDC batteries, shunt reactors, diesel generators, Point-on-Wave switching IED and Overhead Lines:*
            - *CONFIDENTIAL*:

1. GIS HI: Develop Health Index for GIS in PI system, including reporting, dashboarding, notifications
2. Batteries HI: Develop Health Index for Batteries in PI system, including reporting, dash-boarding, notifications
3. Diesels HI: Develop Health Index for Diesels in PI system, including reporting, dash-boarding, notifications. Interface with Dieselwatch has already been integrated during Wave2
4. Shunt Reactors HI : Develop Health Index for Shunt Reactors in PI system, including re-porting, dashboarding, notifications
5. OHL HI 2,0 : Additional development of OHL HI, which was out of initial wave2 scope (ie/ HI weighted + corrections)
6. PI optimisations: HMI for ACC-IR, ACC-Tran, eForms; Reports to eDoc, PI system moni-toring, PI Dashboard at PUTM of Net element level.
7. PoW (Point On Wave): Dashboard and alarms for the follow up of the new PoW devices RPH3 (number of correct and failed switches) in support of AM APA.

1.2 *Task 2: Optimization of AIS with a rating of ≥70 kV, power transformers, introduction of a new Health Index:*

- *CONFIDENTIAL*:

1. OLAF interface for TI/TP data : replace the current monthly reporting from *CONFIDEN-TIAL* with a real time API connection to *CONFIDENTIAL* cloud: OLAF

2. Optimization AIS & TFO HI: Adapt the current reporting with the new insights of the AM, including the HI formulas.

2. *WP 2 ACC Phase 4 (linked to AMEX waves)*

1.1 *Task 1: Development of the health index with air Insulated Switchgear (AIS) ≤70kV, Substation Build-ings, Capacitor Banks, HVDC equipment*

- *CONFIDENTIAL*:

1. AIS ≥70 kV HI: Develop Health Index for AIS ≥70 kV, including reporting, dashboarding, notifications
2. Buildings HI: Develop Health Index for AIS ≥70 kV, including reporting, dashboarding, notifications
3. Capacitor Banks HI: Develop Health Index for Capacitor Banks, including reporting, dash-boarding, notifications
4. HVDC HI: Develop Health Index for HVDC, including reporting, dashboarding, notifica-tions

1.2 *Task 2: Feasibility assessment and low level development of the health index with Metering Cubicles and Low Voltage equipment*

- *CONFIDENTIAL*:

1. LV of Secondary Systems HI: Feasibility assessment & Develop Health Index, including reporting, dashboarding, notifications
2. Metering Cubicles HI: Feasibility assessment & Develop Health Index, including report-ing, dashboarding, notifications

Partners

- Compilation of a historical database for WP 1 and 2: Elia is working on a partnership with the vendor *CONFIDEN-TIAL* that delivers the PI system, which is the historical database that Elia uses for its HI/EA calculations.

- The Elia Asset management team will be leading the project, working in close coordination with the Asset Department's Transformation Office, while the Asset Committee will be responsible for monitoring progress.
- Sensors for data retrieval: Various suppliers will be involved, including *CONFIDENTIAL* for the testing of SF_6 probes and *CONFIDENTIAL*
- Preliminary conclusions: At CIGRE level a working group has published a technical brochure called *Methodology of Asset Health Index concept* (B3.48). Elia was an active contributor to this brochure, and the content is in line with AC-C's work. Elia hasn't performed any additional publication, nor plans to do this in the future.

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resource - Bodyshopping						
	Material						
	External Services/Licence						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

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WP 1	ACC Phase 1	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP2	ACC Phase 2	2019	2020	2021	2022	2023	Total
ACC Phase 2	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

Project 3: Optiflex (new name : Synapse)

Domain 3.3

2020 decision: Accepted

Preliminary remark : there were neither reassessment nor review of the program since the proposal to the CREG. The name OPTIFLEX has been changed because it was leading to misunderstanding and was not correctly perceived. For this reason, it has been decided to change to Synapse (Synergy between Agile Planning and Stable Execution). Therefore the objectives and scope of the program remain the same as presented to the CREG.

Trends: Decarbonization, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, uncertainty of generation, intermittency of generation

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domains: 3.3 Predict and optimize preparation of the maintenance

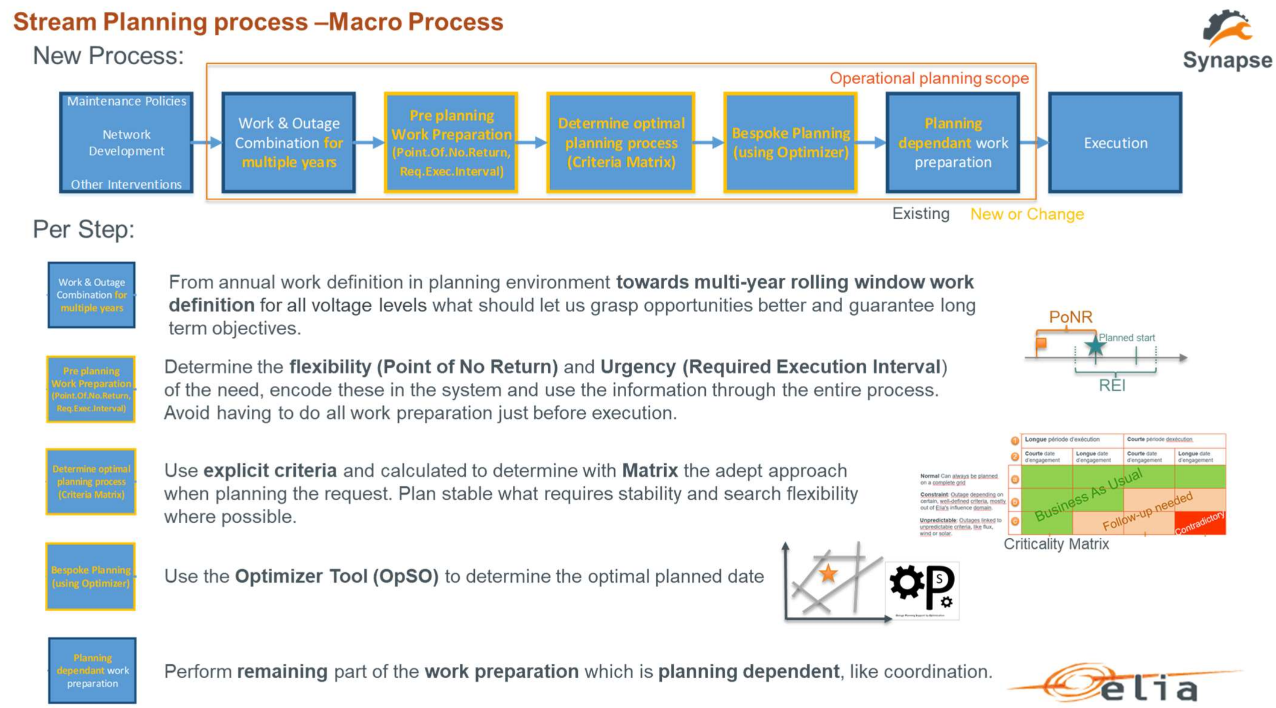
Project-specific context

- We estimate that compared to 2015, the volume of renewables could have doubled by 2022, up to a level where the installed capacity is equal to the peak load.
- Up to 10% of the substations will have a connection with a Gflex (N or N-1) contract.
- The Belgian grid was designed for a top-down flow, with central power generation at 380-kV and 150-kV levels. The future flow will be a mix of top-down and bottom-up and international flows, with substantial installed capacity at DSO level.
- The number of outages and so the MWh@risk is increasing due to the need to perform replacement projects and maintenance and because of the difficulty in finding an optimal planning window due to RES.
- The average time taken to restore power is rising due to the nature of the interventions requiring an outage.
- This challenge will increase in the years to come with the uptake of e-mobility, which will also affect the DSOs' outage planning.
- At the same time, the asset fleet is aging, resulting in an increased need for maintenance in the years to come.
- The number of critical outages is expected to double by 2022. The regions impacted by these outages are usually not densely populated like the region of Gembloux Leuze for instance (which has the advantage that permits can be obtained more easily) but normally do not have the infrastructure required to deal with these increased flows. However, planning is currently managed on a long-term basis and revising it generally involves repeated work. If constant planning revisions could be avoided, this could avoid extra repeated work for Elia.

Project-specific state of the art/literature review

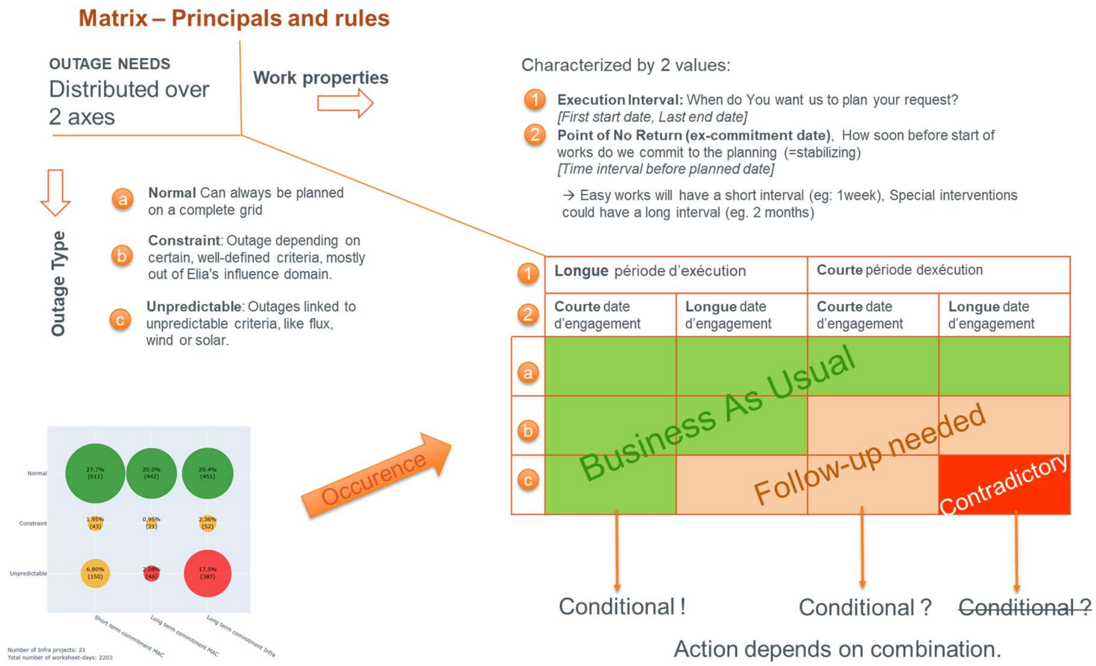
- The new process will apply criteria (specific flexibility and stability planning aspects in a decision-making matrix) that are not applied today by our neighboring TSOs. Elia has so far not performed an official benchmark to compare with all existing references. In the various contacts we have had (Europe and outside Europe) we can say that no TSO are applying those processes and criteria like we are envisioning in this program. These criteria are specifically developed for the TSO environment, e.g. variable commitment dates for the planning depending on the criticality or flexibility of the works and outages.
- The new tool (OPSO) is currently being developed with an innovation partner (N-Side) to allow the integration and optimization of multiple constraints and objectives with a high frequency iteration. The underlying principles, algorithms and methodologies for this optimization are based on the scheduling optimization principles applied in other sectors like the pharmaceuticals supply chain, which are then customized to Elia's situation (outages, real-time availability, etc.). These objectives will be assessed on the basis of scenarios.

Here below the high level description of our Macro process where the basic principles are explained

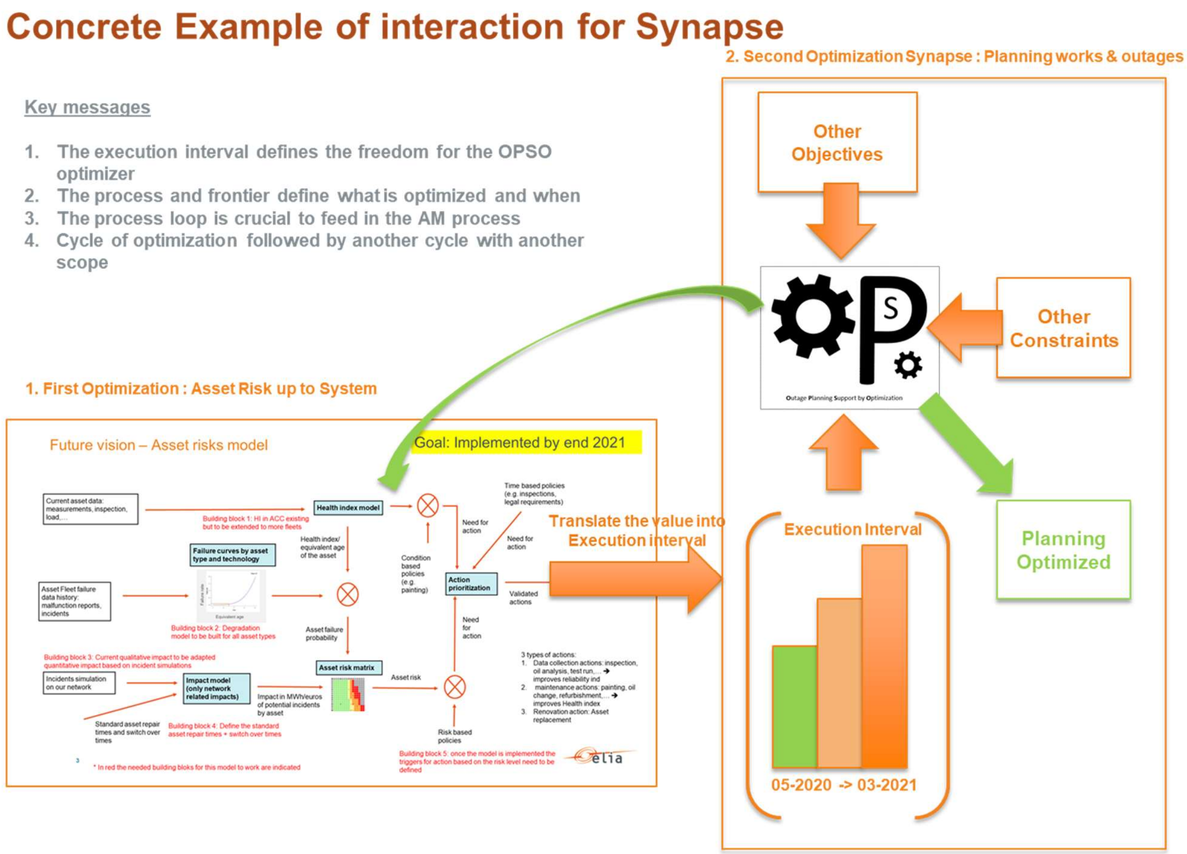


The Matrix implies the use of the tool we are currently developing (namely OPSO) and the criteria's and concepts we would like to apply: Flexibility (Point of no return) and Urgency (Required Execution Interval).

The underlying principles of the matrix are explained in the scheme here below:



In the example here below we illustrate the link between the process of operational planning optimization of thousands of works and outages and the Asset Life Cycle (including also ACC and health index).



Expected impact for Belgium

- The implementation of flexible optimized planning to cope with the uncertainty of renewables and other components of the energy system such as e-mobility will result in the following improvements from the non-optimized situation:
  1. a 10% decrease in the outage risk, or the MWh risk;
  2. a 10% decrease in the number of outages and a 10% increase in works/outages;
  3. in the future, limitation of the impact on the number of RES by increasing planning agility;
  4. an increase in planning agility and stability for critical works and outages, allowing the maintenance and CAPEX plans to be implemented in the required execution time frame (70% stability).
- The improvements here above are related to the optimization related to Synapse. In the example in the previous section (interaction with Synapse) we explain the link between the Asset Risk (Asset Health Index/ACC & probability) and Synapse (the Execution Interval).
- The improvements detailed here above are compared to the non-optimized situation. Those figures have been calculated based on concrete proof of concepts realized in 2019.
- Absolute figures related to outages and works will strongly vary from one year to another and depend from the environment (RES evolution…). In other words, even with an hypothetical case with less works considering the additional

upcoming constraints, the situation could be more difficult to optimize. We are currently considering the various constraints and objective that could be optimized including amongst other market capacity, RES impact. The integration of those criteria will allow us to further assess the impact of our program.

- Finally, we can say that those improvements are concrete objectives for the program Synapse and therefore will be internally closely monitored.

Starting point for Elia

- Today at Elia, operational planning is mainly managed using several planning cycles from yearly planning to weekly meetings, with operational printed documents based on various non-integrated output (operational team capacity, network availability, etc.). In the future, the increasing complexity of such planning and the higher frequency of the updates will require new integrated tools and processes.

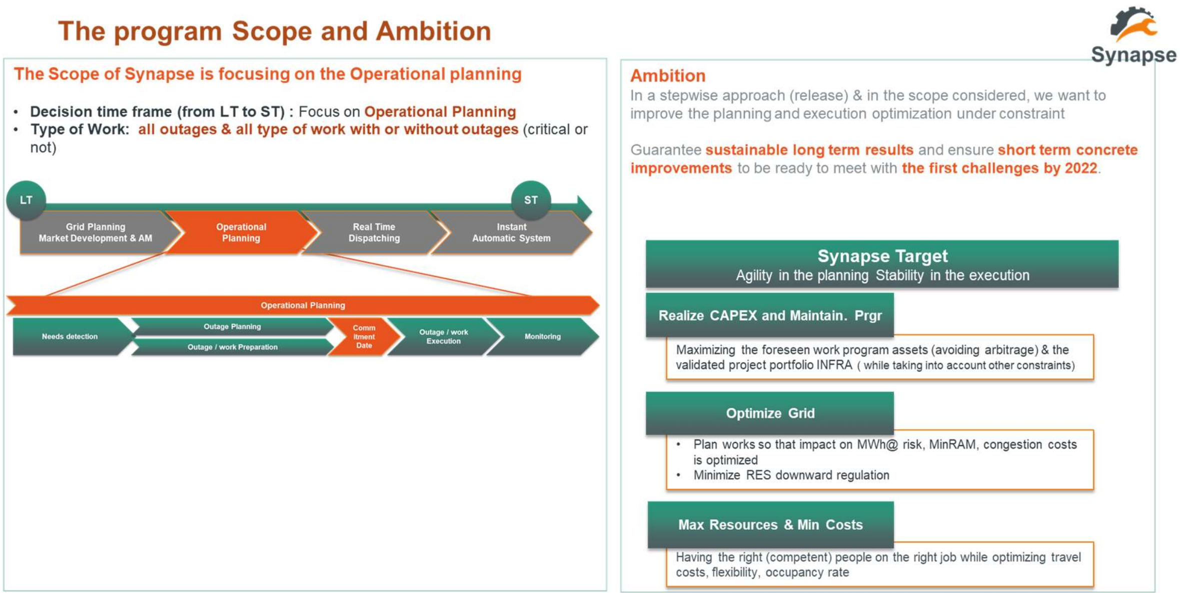
Uncertainties and risks

- The environment changing speed is a major uncertainty for which the project implementation should adapt accordingly.
- E.g, we have foreseen progressive implementation of various constraints (RES, impact on network, MWh@Risk...) in our model. If the external factors lead to new constraints we could have to change our releases and priorities.
- The program is including the development as well as the implementation of the solution to achieve the results foreseen. The releases will drive those implementations.
- The risks related to the program are the following

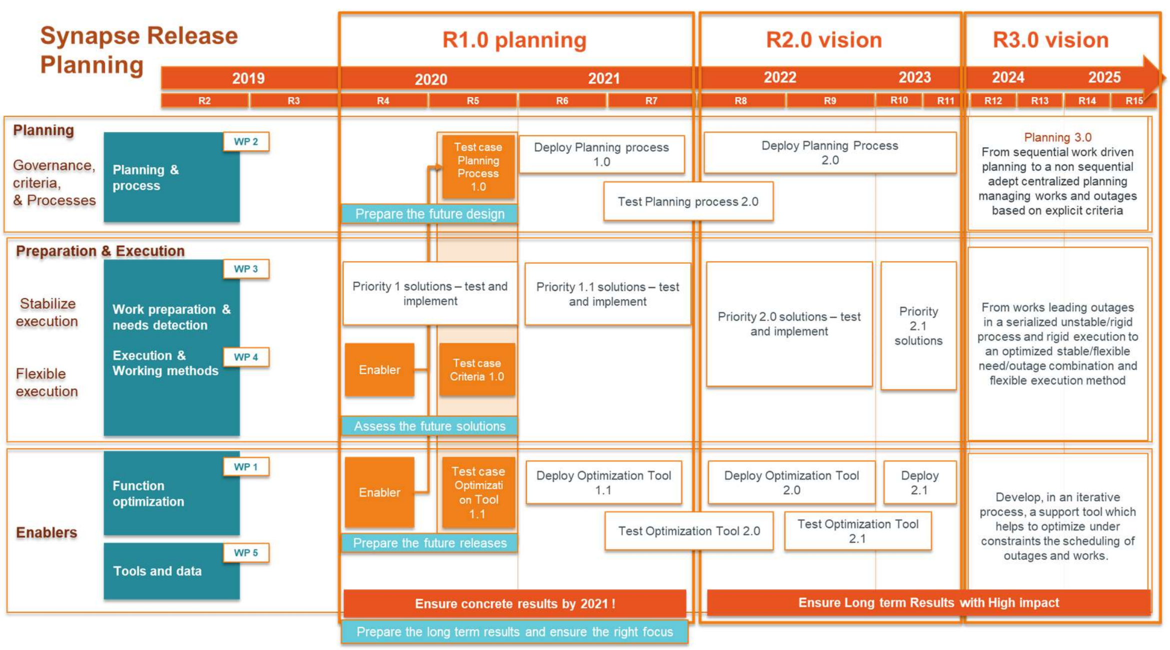
- Being able to transform large operational process with new state of the art processes and tools impacting large population through all departments
- Software development :
  - Being able to model and integrate the various constraints and objectives
  - being able to integrate various type of data (large quantity, quality, reliability, availability and various protocols) and sources into a single tool to ensure the perfect integration and optimization
- Be ready to progressively switch to the future release of the tool including AI.
- Having the right resources at the right time for this specific innovative tasks and ensure adequate business continuity and development.

Project description

- The primary objective of the Synapse project is to develop and improve, through innovative solutions (e.g. using artificial intelligence), planning and the optimization of execution in order to increase productivity (works under constraints) and decrease unavailability risk for Elia and stakeholders (clients, generators, etc.). More specifically, the program will aim to maximize results under various constraints:
  1. safety, which remains the top priority, which must not be jeopardized when carrying out our works;
  2. maximizing the planned Elia maintenance-work program and implementing the validated grid project infrastructure development program;
  3. optimizing the grid by planning works to minimize the impact on MWh risk;
  4. minimizing downward adjustments of RES;
  5. having the right (skilled) personnel doing the right job, and optimizing travel costs and flexibility.



The high level long term planning



- Approach: For Synapse, Elia has decided to develop a tailored analytical model to assess the scale and urgency of critical power cuts. For this purpose, Elia is working with experienced external partners (*CONFIDENTIAL*). The goal is in particular to learn about the technology while at the same time avoiding blackboxing. An Agile approach is being adopted with frequent keynotes assessing the evolution of the solution.

The workpackages are organized to provide specific results (tool, processes, governance) that will allow to achieve the global objective of the program.

- Work packages and timing (M = month) and deliverables: *Three releases are envisioned: R1 (2020-2021), R2 (2022-2023), and R3 (2024-2025).*

1. *WP 1: Tool functional optimization*

The tool should allow to increase operational (planning) **efficiency** (operators and planners) and optimization of the **prioritized works** under increasing constraints. The tool (OPSO) allows to optimize multiple constraints (Resources, Grid) taking into account **multiple objectives** (incentives, works…) on a multi year rolling window horizon. WP1 aims to develop a tool with several releases. Each release is a concrete intensive IT and data development to ensure that reliable, available and qualitative thousands of data are processed in time to provide the adequate usable results. 2020 will also ensure the support of adequate field test (real life test after POC 2019).

- R1 – OPSO 1.0 (industrialized optimization tool taking resources into account: year-ahead planning with frequent intra-year updates (monthly and weekly); all voltage levels and entire Elia grid)
- R2 – OPSO 2.0 (planning three years ahead + new constraints)
- R3 – OPSO 3.0 (integration of AI/machine learning – AATO link)

a. *WP 2: Planning and process*

Prioritize works (decision criteria, see matrix here above, and governance) and improve agility when required by the grid. Centralization allows for better integration and cross-departmental coordination of works and resources and avoids sub-optimization. The new process and criteria will also follow the principle of releases. Those releases aim to incrementally increase the impact of the changes throughout the organization with the principles of centralization and automation.

R1 – Advance maintenance planning (advanced maintenance planning – maintenance planning is steered in a centralized way, based on the results of the industrialized optimization tool and planned, including new working methods – new R&R for planners and foremen – application of new criteria)

R2 – Advance centralization of CAPEX and maintenance planning (to be confirmed, based on the outcome of the previous release – incremental approach)

R3 – Integrated centralized planning (to be confirmed, based on the outcome of the previous release – incremental approach)

2. *WP 3 and WP 4: Work preparation and work execution*
Increase the efficiency of the process and reallocate those resources to centralized planning -> better coordination and synergies. Enable the agility to implement the works under constraints -> focus on priority works under increasing constraints

- R1 – Work preparation improvements and process streamlining (agile and efficient work preparation, remote switching, reduction in lead times, several field tests to test the new process)
- R2 – Work preparation 2.0 and work execution improvements
- R3 – Work execution 2.0

3. *WP 5: Tools and data*

This WP will follow the implementation plan of other packages and ensure appropriate development of IT and tools (IT specification, data, tools, protocols)

In order to further explain the work packages and the program we believe that a presentation could be organize for the CREG where our experts could directly answer to CREG's questions.

- Deliverables and milestones
    - See above

Partners

- Development of the optimization tool by the *CONFIDENTIAL* based on the input of the various Elia experts involved
- Peer review with other TSOs
- Transversally at Elia level: national and regional dispatching, Maintenance Department, project (CAPEX) and portfolio management, asset expertise management, IT and Business Analysis Departments.

Summary of project efforts in person months (by work package and by year)

Total Project	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Function & optimization	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 2	Planning & Process	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 3	Work preparation and needs detection	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 4	Execution & working method	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 5	Tools & data	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

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Project 4: Risk-based approach for grid development decisions

Domain 4.1

2020 decision: Rejected

Trends: Decarbonization, decentralized generation and new players, supranational coordination and digitalization

Consequences: New decentralized flexibility resources, increase in maximum usage as well as variability of the usage of grid infrastructure, need to update grid security rules and resilience rules in the interest of society

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.1 Automatic integrated system dev. risk based

Project-specific context

- Changes in the energy landscape, the energy transition, and the integration of market players at lower voltage levels are expected to result in a growing number of uncertainties for the development of the grid, mainly due to:
  1. the substantial market share of variable renewable generation;
  2. a high level of decentralization;
  3. a change in consumption profiles related to sectors' electrification;
  4. the growing frequency and magnitude of bidirectional flows between transmission and distribution systems;
  5. an increased level of imports and transit flows arising from European integration.
- These trends will drastically accelerate in the years to come due to the decarbonization target (three times more renewables by 2025) and electrification (of mobility, heating, etc.), while at the same time Elia is generally investing in assets with a long lifetime (30-40 years). Therefore, it is important to accurately assess whether an investment that is needed now will still be used in 10 years from now and not become a stranded asset due to the existence of alternatives like decentralized flexibility.
- We believe that to cope with these challenges in an effective and exemplary way, there will need to be a change in decision-making processes from implicit/qualitative risk management (based for example on N-1 deterministic criteria for grid development and operation) to explicit/quantitative risk management.
- This means that in this new context, the decisions put forward by Elia can continue to be in the interest of society and be assessed from consumers' perspective.
- Elia is therefore continuing the work launched in 2013 with the GARPUR and GRASP projects.

Project-specific state of the art/literature review (Elia and external)

- J. M. Arroyo, N. Alguacil and M. Carrión, *A Risk-Based Approach for Transmission Network Expansion Planning Under Deliberate Outages*, in IEEE Transactions on Power Systems, vol. 25(3), pp. 1759-1766, Aug. 2010, doi: 10.1109/TPWRS.2010.2042310.
- E. Karangelos and L. Wehenkel, *Probabilistic reliability management approach and criteria for power system short-term operational planning*, Bulk Power Systems Dynamics and Control X – The Power System of the Future: Global Dynamics arising from Distributed Actions (IREP), 2017 IREP Symposium, Sep. 2017.
- G. J. Correa-Henao, J. M. Yusta and R. Lacal-Arántegui, *Using interconnected risk maps to assess the threats faced by electricity infrastructures*, International Journal of Critical Infrastructure Protection, vol. 6(3-4), 2013, pp. 197-216, ISSN 1874-5482, https://doi.org/10.1016/j.ijcip.2013.10.002.
- S. Willems, P.-E. Labeau, J.-C. Maun, **A. Vergnol (Elia)** and **J. Sprooten (Elia)**, Probabilistic Power System Planning: Outcome variability and decision making, in *21st Power Systems Computation Conference (PSCC)*, June 2020.
- S. Willems, P.-E. Labeau, J.-C. Maun**, A. Vergnol (Elia)** and **J. Sprooten (Elia)**, Deterministic and Probabilistic Transmission System Expansion Evaluation Methods: Insights in the Requirements of a Probabilistic Method, in *Congrès Lambda Mu 21 « Maîtrise des risques et transformation numérique: opportunités et menaces »*, Oct. 2018.

- W. Bukhsh, K. Bell, A. Vergnol, **A. Weynants (Elia)** and **J. Sprooten (Elia)**. Enhanced, risk-based system development process: a case study from the Belgian transmission network, in *20th Power Systems Computation Conference (PSCC)*, June 2018.
- G. Dogan, P.-E. Labeau, J.-C. Maun, **J. Sprooten (Elia)**, **M. Galvez (Elia)** and **K. Sleurs (Elia)**. Discrete forecast error scenarios methodology for grid reliability assessment in short-term planning, in *Probabilistic Methods Applied to Power Systems (PMAPS*), Oct. 2016.
- G. Dogan, P.-E. Labeau, J.-C. Maun, **J. Sprooten (Elia)**, **M. Galvez (Elia)** and **K. Sleurs (Elia)**. Monte Carlo sampling and discrete forecast error scenarios in grid reliability assessment for short-term operational planning, in *IEEE International Energy Conference (ENERGYCON)*, April 2016.
- G. Dogan, P.-E. Labeau, J.-C. Maun, **J. Sprooten (Elia)**, **M. Galvez (Elia)** and **K. Sleurs (Elia)**. Grid reliability assessment for short-term planning, in *European, Safety and RELiability Conference* (ESREL), Zurich, Sep. 2015.

Expected impact for Belgium

- The idea behind developing an advanced risk model for grid development and asset management and the interaction between these two processes is to ensure that all decisions consistently meet explicitly defined reliability criteria at minimal cost for society. This will become critical for the company in the future as the uncertainty surrounding how renewables and decentralized flexibility will evolvemight lead to sub-optimal development of the grid if they are not taken into account (oversized if we underestimate the development of decentralized flexibility as an alternative; or undersized if we incorrectly assess the development of renewables).
- First, development criteria are set out in terms of their impact on customers and society, and quantified using impacted MW, ENS, ENI, etc. In a second stage, the value of loss load is included in the objectivized risk levels to assess the impact for society.
- A methodology is developed to assess the impact of an asset (fleet) failure and backlog on the whole system. Such indicators are used to optimize asset maintenance and replacement. In a second phase, the impact on society of each asset decision will be quantified.
- A new consistent risk-based approach is developed and applied to prioritize infrastructure projects.
- Long-term studies are performed, not only to drive investment decisions but also to motivate the need to update operational tools, processes, and contracting. In a first step, the maintainability of grid components in the future and future usage of flexibility are quantified.
- Judgments on investment decisions are made explicitly based on TOTEX (CAPEX + OPEX for society) thanks to the development of a probabilistic analysis in the context of grid development.

Starting point for Elia

- This project is the follow-up to two previous research projects in which Elia participated in the past: GRASP (a PhD project aiming to develop grid operational planning taking into account uncertainty of renewable generation) and the GARPUR project which designed, developed, assessed, and evaluated new reliability criteria to be gradually implemented in the decades ahead at pan-European level, while maximizing social welfare.
- These two projects mainly focused on operational planning and asset management where the levels of uncertainty to be managed are lower. Limited work was performed in the context of grid development and at the interface between these fields. The main challenges identified in the projects for industrial application in grid development and asset management were the need to develop an asset failure model, the need to take into account the complexity of a real system and the need to develop a pragmatic approach for probabilistic assessment to deal with inaccuracies in industrial data, the complexities of a real system, and the large size of a real system impacting the computation time.

Uncertainties and risks

- A first set of uncertainties and risk is associated with the ability to find a structural representation of each decision which is simple enough to be implemented which is accurate enough to convince decision makers and experts looking at each decision. Indeed, this is a completely new way of developing the grid that will need to take into account a

large number of parameters, including some highly probabilistic dimensions such as the evolution of installed capacity (in term of renewables, of decentralized flexibility, etc.).
- A second set of uncertainties is associated with the timing of project implementation, which will depend on the complexity of the task.

Project description

- The project aims to align the risk appetite defined at company level with the risk appetite considered in operational grid-development and asset-management decisions. The main objectives will then be the identification of grid-development criteria and asset management. The project will also help Elia to develop an explicit risk mentality through ensuring consistency between planning practices and operational practices. The following results are expected:
    1. new parameters reflecting the risk taking into account the system-operations and grid-development constraints;
    2. a new approach to long-term studies and shorter-term grid planning.

  To achieve these goals, the project will start by defining the anticipated interruption time based on statistical data and will set out clearly the policies for the years ahead (e.g. what is considered to be an acceptable incident). Based on this the model, the study will adapt the risk appetite of the company and therefore also the criteria for grid development. Finally, the study will analyze the impact of the new risk-based grid-development decision on asset maintenance and grid operation.
- Approach: Following the European GARPUR project organized by SINTEF with a consortium of TSOs, Elia is now developing and re-evaluating its own risk-based criteria drawing on internal resources, in particular a PhD student hired from Université Libre de Bruxelles (ULB)/Vrije Universiteit (-VUB), who stopped work in late 2019.

- Work packages and timing (M = month)
    1. *WP 1: Alignment of the company-level risk appetite with risk management at operational levels and decision-making based on the identification of risk*
        - *CONFIDENTIAL*: Task 1.1: Set the level of the operational risk acceptable for asset maintenance, grid development and operation, in particular defining the acceptable frequency and impact in terms of ENS, ENI, and MW interrupted for industrial and non-industrial areas and based on comparisons with other TSOs' risk appetite.
        - *CONFIDENTIAL*: Task 1.2: Improve the risk culture by disseminating initial results and establishing an understanding of the basic concepts involving asset management and system operation.
        - *CONFIDENTIAL*: Task 1.3: Set a roadmap for long-term decision-making improvements, including putting forward a plan to create a risk-matrix model, including the establishment of indicators of asset components' importance.
        - *CONFIDENTIAL*: Task 1.4: Set up methodologies for the integration of assets (collecting and generating data/statistics) to enhance the risk matrix.
        - *CONFIDENTIAL*: Task 1.5: Improve the portfolio management rules based on the risk-based matrix.
        - *CONFIDENTIAL*: Task 1.6: Define criteria for critical grid situations requiring resilience testing and benchmarking them with other TSOs.

    2. *WP 2: Development of consistent and risk-based grid planning and operation*
        - *CONFIDENTIAL*: Task 2.1: Improve the consistency between planning and operational criteria. This includes coordination regarding the use of flexibility margins on the grid (for phase-shifting transformers, HVDC, thermal capacity, etc.). Moreover, enhance the feedback loop between planning and operations about the operational risks observed in the long/medium term and in real time.
        - *CONFIDENTIAL*: Task 2.2: Develop a specific approach for long-term (>Y+3) planning based on explicit and transparent formulation of the risk and including the assessment of future OPEX for operations and maintenance and a long-term model for flow-based prices.

- *CONFIDENTIAL*: Task 2.3: Develop a specific approach for medium-term planning (Y+1 to Y+3) based on explicit and transparent formulation of the risk and including the assessment of future OPEX for operations and maintenance.
- *CONFIDENTIAL*: Task 2.2: Develop a specific approach for short-term planning based on risk evaluation and ensuring consistency between the various time frames (Y-1, M-1, D-2, D-1).

3. *WP 3: Overall project coordination and administration of the project*
    - *CONFIDENTIAL*: Coordinate and guide the project in terms of its strategic decisions and ensure project quality.

- Deliverables and milestones

    - *CONFIDENTIAL*: Updating grid-development and grid-operation **criteria**, ensuring **consistency**
    - *CONFIDENTIAL*: Defining and **quantifying parameters (MW interrupted, ENS, ENI, etc.) to include** in the objective assessment of the risk appetite
    - *CONFIDENTIAL*: Assessing the **maintainability of grid components in the future**
    - *CONFIDENTIAL***:** Conducting **multi-state grid studies** allowing enhanced justification of CAPEX
    - *CONFIDENTIAL*: Ensuring a consistent **flow-based** approach in LT/MT studies
    - *CONFIDENTIAL*: Developing a high-level (and manual) **methodology to assess the impact of an asset failure** on the continuity of supply
    - *CONFIDENTIAL*: **Developing a consistent risk-based approach** and applying it to prioritize infrastructure projects, and noting lessons learned
    - *CONFIDENTIAL***:** Developing an **objectivized understanding** for System & AM of **acceptable and unacceptable risk levels**
    - *CONFIDENTIAL*: Developing a methodology to assess the impact of an **asset (fleet) failure and backlog** on the whole system -> optimizing asset maintenance and replacement
    - *CONFIDENTIAL*: Devising a method and process for MT planning enabling a **smooth LT-ST-RT handover**
    - *CONFIDENTIAL*: Assessing **use of flexibility**
    - *CONFIDENTIAL*: **Highlighting expected operational consequences** by grid-development studies
    - *CONFIDENTIAL***: Conducting multi-climate annual and multi-scenario** grid studies allowing for robust decision making
    - *CONFIDENTIAL*: **Making improvements based on lessons learned** to ensure consistent application by all those with needs
    - *CONFIDENTIAL*: Including **value of loss** load in objectivized risk levels to **assess the impact for society**
    - *CONFIDENTIAL*: Establishing best practices for operational excellence thanks to a **clear view of the necessary tools**
    - *CONFIDENTIAL*: Performing a **probabilistic analysis** allowing decisions to be made, explicitly based on TOTEX (CAPEX + OPEX for society)
    - *CONFIDENTIAL***: Quantifying the impact on society** of an asset decision

Partners

- Alignment of system planning and operational risk: Elia internal department for system operation (National Control Center), grid planning and asset maintenance
- Review and challenge of progress: Grid Development (acting as a sounding board) and Asset Management team
- Development of a probabilistic grid application: Ongoing discussions with software companies to ensure that tools are available on the market to meet Elia's needs (discussion with *CONFIDENTIAL*)

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Alignment of company risk appetite with operational requirement	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Costs: Achats + Intramuros (€)						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incitant (=Total cost - 80%IT)* (25% or 50%)						

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WP 2	Develop a consistent and risk-based grid planning and operation	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Overall project coordination and administration of the project	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 5: Consumer-Centricity Program (Formerly known as the Internet of Energy project)

Domain 1.1

2020 Decision: Rejected

Trends: Decarbonization, decentralized generation and new players, digital revolution

Consequences: New decentralized flexibility, Interface with new players, new market models, consumer centric offerings

Challenges: 1. Increase participation of flexibility sources from decentralized sources coming from electrification
Domain: 1.1 Manage market related data from and for market parties

Project-specific Context

- One of the key drivers for change in the sector is the societal ambition to put "the consumer at the center" of the energy system. As stressed by the European Commission in its communication Clean Energy for all Europeans, the EU sees consumers as active and central players on the energy markets of the future, who will be instrumental in ensuring that they themselves can fully benefit from the energy transition.
- Consumers' current energy experience involves a lot of pinch points: complexity and non-transparency in the offering and billing, uncertainty about the final bill, limited means to align consumption with renewable production and/or energy prices, etc. The challenge for the sector is to overcome these difficulties and develop energy services addressing the needs of consumers, while at the same time seizing the opportunity to better integrate renewable energy into its offerings and take advantage of available consumer flexibility to help to meet the requirements of the grid.
- So far, consumers have been left out of the energy debate, yet they finance the sector. Technological development and the emergence of innovations such as EVs mean that consumers are gradually becoming more active players, but they still have only moderate levels of involvement, and the same goes for their contribution to system requirements.
- Enabling a substantial offering of energy services and facilitating access to them as well as creating an ecosystem of service providers are key to involving consumers in the energy debate. However, for a business, especially new entrants, to provide innovative services to end consumers, it will be necessary to get an easy access to regulated data and applications.
- The lack of access to consumers' regulated data and of the ability to exchange data in real time has been identified as a major gap in this ecosystem, and as a result, as a barrier to developing such innovative energy services. That is why Elia and all the DSOs joined forces in early 2019 to launch the Internet of Energy (IO.Energy) project, developing a real-time communication layer.
- Additionally, the IO.E initiative built an ecosystem around it as a testbed for new innovative services that has triggered significant market interest and has so far led to various inspiring use cases (e.g. Sensa, Flexcity, Enleash…).
- Following the launch of IO.E in 2019, Elia has upgraded the project to include large-scale consumers and is also looking to go beyond the elements described in the Clean Energy Package, with an increased focus on issues related to data access management and consumer-centric market design. For that purpose, Elia has made changes to its organizational arrangements to give greater prominence to consumer-centric initiatives and move things a step forward. Therefore, alongside the development of an innovative real-time communication platform, Elia aims to study the design and operation of a consumer-centric system: one of the central principle that will be analyzed is that the end consumers have to delegate their responsibilities to their BRP(s)/suppliers as a precondition for injection or offtake of electricity and so on, resulting in passive end prosumers: consumers are not allowed to exchange electricity with other parties without the consent of their BRP(s)/suppliers.
- In the future, in line with its ambition to put consumers center stage, Elia advocates a system based on empowered end prosumers free to exchange electricity with other parties. This will require a new market design based on the principle of robust and flexible energy services offering between parties.
- This new market model will look at the new roles in a consumer-centric system and facilitate the development and adoption of a new Energy as a Service business model for any sector (mobility, heating…).

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Project-specific State-of-the-art/Literature study

Various initiatives have now started in Europe, notably led by other TSOs that face the same challenges (see above) as Elia, and drove the move to consumer-centric program:

- **Equigy (Crowd Balancing Platform):** a platform established by TenneT, Swissgrid, and Terna to automate the involvement of small flexible assets in the balancing markets; more information can be found at equigy.com;
- **Energy Data Exchange Platform:** an interoperability platform set up by Elering (along with TenneT and Energinet) to provide retailers, energy service providers and other eligible market players with a single, standard access point for consumers' metering data; more information can be found at elering.ee/en/data-exchange;
- **APG (Austrian Power Grid):** a flex hub project to test and implement new elements in retail market design;
- **Energy Web Foundation:** initiative accelerating low-carbon, consumer-centric electricity systems by leveraging blockchain and decentralized flexibilities; more information can be found at energyweb.org. In parallel Grid Singularity has developed a market model and a solution called D3A.

Elia is working closely with these initiatives and participating in some of them. While the challenges tackled are similar, the basic approach differs from Elia's Consumer-Centricity program. These initiatives focus on available data (15-minute smart-meter data) and existing balancing products, while Consumer-Centricity is looking in particular at the system and market value of real-time metering data and base its reasoning on market design components can be built on top of this data layer, as well as innovative consumer capabilities and assets.

Existing research and the most recent experiences in Europe have shown that energy savings of more than 5% can be made by consumers when they have access to near real-time data. A European Commission report, produced by Expert Group 1 of the Smart Grid Task Force in 2015, showed that the majority of EU Member States already require a local real-time data interface on the meter, but no measures have been taken to make them available on the market. The recent revised Electricity Directive requires the provision of near real-time data (covering "a short time period, usually down to seconds or up to the imbalance settlement period in the national market") by the smart-metering Infrastructure, but again without specifying the access framework for market players.

However, currently, to access near real-time data, smart meters use a separate, specific hardware interface that can be drawn on by consumers, or by third parties designated by them, to connect a display or other devices that can present these data in a consumer-friendly way and/or utilize it to provide energy-related services. Making these data largely available with the consent of the consumer would greatly increase and entrench service providers' ability to set up a new offering for consumers. Testing the means to provide access to these real-time data and fostering and understanding which energy services could emerge from that and contribute to system needs are key aspects of the work performed in the Consumer-Centricity program.

As a conclusion, the Consumer-Centric program goes beyond the state of the art and explores unknown quantities in the organization of the power system of tomorrow.

Expected impact for Belgium

The Consumer-Centric program is expected to have an impact on Belgian end consumers, service providers, and Belgian system operators:

- **For end consumers:** The main ambition of the Consumer-Centric program is to initiate and facilitate energy services that have a positive impact on end consumers from a financial perspective and in terms of quality. Benefits include the ability to calculate end users' flexibility, to define a customized energy purchasing strategy, to view energy-consumption and cost data transparently in real time, to join an energy community with a single click of a mouse, and select preferred sources of energy. These services should meet consumers' need for sustainability, cheap energy, comfort, and transparency. While such offerings involve a limited number and range of players, it is expected that an initiative like Consumer-Centricity will accelerate the emergence of an ecosystem of new service providers for Belgian consumers.

- **For service providers:** The new consumer-centric model is an important enabler for enterprises to develop their business and to offer innovation to their consumers.

  The ecosystem brings together complementary players with different areas of expertise and backgrounds to test new ideas. This includes providing contractual support and helping to find an appropriate external partner or supplier. Notably, legal experts helping enterprises to ensure compliance with the EU's General Data Protection Regulation (GDPR) in their interactions with end consumers, while academic experts provide comments on and suggest improvements to their use cases, and business experts offer support when it comes to developing use cases. Then the use cases bring expertise and insights for the development of new business models.

  1. The technology platform aims to take away one of the main barriers facing enterprises, namely the access to real-time data, and provides a communication platform that can be used to build up services. Moreover, the ambition is to extend the communication layer with additional regulated/enabling services to make it even easier for market players to develop services.
  2. The new market design will offer more flexible and robust rules for the development of new energy-related services for the ecosystem.
- **For system operators:**
  1. New energy services (as forecast, data access and processing…) can provide new sources of flexibility for both residential consumers and others and could even unlock a potential 2.4 GW by 2030 (through load shedding and load shifting). Decentralized flexibility has a vital role to play in ensuring the adequacy of Belgium's power supply (as described in the *Adequacy and flexibility study for Belgium 2020-2030*).
  2. Better collaboration between TSOs and DSOs: The initiative is supported by all of Belgium's system operators, providing a unique opportunity not only to facilitate such collaboration but also to discuss and harmonize their activities based on technological resources and operational processes.
  3. The test environment provides a significant learning opportunity, testing hypotheses and analyzing trends in use cases and pinch points in an energy environment that is new to all. That is why the IO.Energy initiative at Elia has led to the creation of a consumer-centricity department that will cover the design, development, and testing of consumer-oriented initiatives and the relevant shift in the market design.

Starting point for Elia

IO.E, the journey so far

- In late 2018, Elia launched its Consumer-Centric vision paper and subsequently launched the IO.Energy initiative in early 2019 with a general 'call to participation.
- More than 90 enterprises and organizations joined the initiatives and started to help to create consumer-centric use cases during the ideation phase, of which eight were selected for the sandboxing phase. In this phase, the concepts set out in the use cases are put into practice and assumptions are put to the test.
- At the time of writing, the end of the sandboxing phase is approaching, representing a milestone in the IO.Energy program and an opportunity to scale up.

IO.E as the trigger for a Consumer-Centricity program at Elia

- Fleshing out the various use cases and the obstacles that became apparent in this context have, first, revealed various pinch points/areas to make improvements in the current operational processes, the available tools, and the energy value chain in general and have, second, reinforced the consumer-centric dynamic/mindset at Elia.
- The IO.E initiative has so far shown itself to be a useful starting point and will be further expanded into a Consumer-Centric program:
  - **Design:** Several existing design elements, related to data and flexibility, will need to be analyzed and shaped to be future-proof. Therefore, this stream will focus on defining retail market design and data access management.

- **Technological framework:** The real-time communication layer will be upgraded to cope with an increasing data exchange volume and will also be extended to include several enabling services, such as a consent management tool and a module for historical data access to tackle and overcome pinch points that have already been identified.
  The end consumers of the consumer centric program will not be limited to those connected to the distribution grid but will include major industrial players for example.
- **'Factory' use cases:** Existing use cases will be examined and then upgraded and integrated into (or removed from) a second sandbox starting in October 2020. Also, new use cases will be developed and tested, for example relating to e-mobility and large-scale consumers, to increase the impact by iteratively dropping unsuccessful use cases and launching new ones, thereby developing insights and gradually increasing value. The 'Factory' is an Elia-internal stream to analyze the use cases in detail, gain insights, and identify lessons learned and pain points. This knowledge is shared within the enterprise but is also contributing to the identification of new use cases and ways in which the real-time communication platform could evolve.
- **Ecosystem**: Interactions with business service providers and co-founding DSOs take place via the IO.E Ecosystem. This defines the timetable, milestones, and next practical steps of the external program to maintain the initiative's momentum, while organizing contractual, business, and organizational support for the various IO.Energy use cases.

Uncertainties and risks

- The first uncertainty is related to the many questions and assumptions Elia and the DSOs have about future energy services, consumer interest, and market design (format, role evolution, data needs, rules…). The goal of the Consumer-Centric program is to verify these assumptions directly with the market players and with consumers.
- The second uncertainty surrounds the interest from market players in real-time data and in open innovation in general. One of the goals is to generate interoperability between players, although these players might try to create a lock-in effect for end consumers and create their own unique, direct connection with them.
- The third uncertainty is related to the technical feasibility of the technological framework behind the Consumer-Centric program. This includes the issue of connectivity to avoid the platform being inflexible or being too complex for service providers to connect to and interface with.
- Another uncertainty revolves around the viability and (consumer) traction for the business model and tools developed for the IO. Energy platform.

Project description

- The project's objective is to anticipate future required shifts in market and system processes to unlock the potential of decentralized flexibility for the consumer. In this process, account must be taken of consumers' scant interest for and awareness of system-related issues, resulting in a seamless experience for them.
- To achieve this objective, the IO.Energy project has been created. This consists of three streams: platform, ecosystem, and Factory (for Elia-internal use-case analysis). In 2020, these three streams have been scaled up into four main work packages: whereas the ecosystem (1) and Factory (2) streams are still similar to before, the platform stream has been transformed into a 'technological framework' (3) as enabling services have also been integrated. A fourth work package consists of the design aspects of retail market design and data access management (4).
- The aim is to launch use cases that become widespread in Belgium and beyond, based on the real-time data exchange and the related services offered on top. Therefore, each use case needs to go through four consecutive phases: ideation, sandboxing, demonstration, and, finally, industrialization. As all the use cases were launched together, they are all more or less at the same stage, namely approaching the end of the sandboxing phase. In the future, it is expected – and indeed the objective is – that in the years to come, the ecosystem will include various use cases that come and go, in order to ensure that one or more really break through.
- The IO.E real-time communication platform is based on the Microsoft Azure IoT platform that is developed internally using the Agile approach and by internal Elia IT and business analyst resources. Currently, over 300,000 production messages are already exchanged over the IO.E platform each day.

As well as the IO.E Ecosystem, the establishment of the consumer-centric system has been shaped by the development of an Elia Energy Hub (EEH) to interact with customers with a view to receiving direct feedback and enabling co-development (open innovation). EEH should be regarded as a central portal serving as a one-stop shop for Elia customers to facilitate and simplify access to the various services and tools provided by Elia. In parallel, a consumer market design study will be launched so that it can be tested based on the technological resources in place (real-time communication platform/Elia Energy Hub) and the existing ecosystem.

- To better apply Agile and fast learning/testing, Elia has created a consumer-centric department that consists of six teams, representing the work packages (while Design is split into retail market design and data access management, and Technological Framework is split into platform and enabling services). This will enable fast development and learning within the teams, which bring together Elia employees with different backgrounds.

- Work packages and timing (M = month)
    1. *WP 1: Design: Data access management*
        - *CONFIDENTIAL*: Initial consideration before the launch of the IO.E Ecosystem about the consumer-centric system
        - *CONFIDENTIAL*: Based on lessons learned from initial sandboxing for IO.E, study looking into a new consumer-centric market design
        - *CONFIDENTIAL*: Development of the innovative customer portal Elia Energy Hub
        - *CONFIDENTIAL*: Compilation of a study looking into a new consumer centric-market design
        - *CONFIDENTIAL*: Testing of the new design and data access through another sandboxing phase
        - *CONFIDENTIAL*: Drafting of conclusions (TBD)

    2. *WP 2: Technological framework: Development of enabling services and platform capabilities*
        - *CONFIDENTIAL*: Selection of the provider for the real-time communication platform
        - *CONFIDENTIAL*: First MVP of the real-time communication platform
        - *CONFIDENTIAL*: Establishment of platform requirements
    3. *WP 3: Factory: Development of use cases*
        - *CONFIDENTIAL*: Development of three use cases involving Elia team members (*CONFIDENTIAL*, *CONFIDENTIAL* etc.)
        - *CONFIDENTIAL*: Dissemination of the lessons learned and support for the development of use cases via knowledge-sharing sessions, expert sessions, etc.
    4. *WP 4: Ecosystem*
        - *CONFIDENTIAL*: Presentation and mobilization of the ecosystem
        - *CONFIDENTIAL*: Workshops and identification of use cases
        - *CONFIDENTIAL*: Pitch and selection
        - *CONFIDENTIAL*: Sandboxing phase

- Deliverables and milestones
    - Until now:
        - *CONFIDENTIAL*: **Consumer-centric vision paper**, including the first conclusions of the initial use case
        - *CONFIDENTIAL*: **Call for registrations**: System operators issued a call for registrations to all those interested in working together on creating new energy services for consumers.
        - *CONFIDENTIAL*: **Kick-off session**: On February 21, the interested parties came together to learn more about the next steps and their potential partners.

    - *CONFIDENTIAL*: **Ecosystem workshops**: During our workshops, complementary teams of participants were formed and innovative consumer-centric ideas were fleshed out, with the support and coaching of experts.
    - *CONFIDENTIAL*: **Closed pitching session**: A total of 14 groups individually pitched their use-case ideas to a special panel consisting of experts with different perspectives: system operators, regulators, academics, and entrepreneurs.
    - *CONFIDENTIAL*: Assessment: Eight use cases were given the green light to continue to the sandboxing phase based on their innovative aspects and the value they give consumers.
    - *CONFIDENTIAL*: **Open pitching session**: The eight selected use cases were presented to a broad audience followed by an exchange of ideas among the partners regarding what they had learned so far and their expectations for the next steps.
    - *CONFIDENTIAL* : **Sandboxing phase**
- From now on:
    - *CONFIDENTIAL*: **Continuation of sandboxing**
    - *CONFIDENTIAL*: **Sandboxing closing event**: Presentation of outcomes, lessons learned, introduction to Sandboxing v2
    - *CONFIDENTIAL*: **Development/fine-tuning of pre-defined and/or existing use cases**
    - *CONFIDENTIAL*: **Sandboxing v2 contractual phase**
    - *CONFIDENTIAL*: **Sandboxing v2**
    - *CONFIDENTIAL*: **Demonstration and continuous sandboxing**

Partners

- Orchestration of the consortium, and decision-making bodies: DSOs (Sibelga, Fluvius, ORES, RESA); facilitated by Co-Station
- Technology provider for the IoT platform: Microsoft
- Expert support:
    - Academics: *CONFIDENTIAL*
    - Regulators
- Legal support and IP requirements: *CONFIDENTIAL*
- Support for development and validation of use cases: *CONFIDENTIAL*
- Market-related regulatory issues: *CONFIDENTIAL*
- Participants: More than 60 participants, including enterprises from the relevant industries (Proximus, BESIX, NRB, etc.), technology firms (Voltalis, Haulogy, etc.), start-ups, and leading energy players (ENGIE, Next Kraftwerke, etc.). The full list can be found here: **https://www.ioenergy.eu/**

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR	2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Design	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Costs: Achats + Intramuros (€)						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incitant (=Total cost - 80%IT)* (25% or 50%)						

WP 2	Technology Framework	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 3	Use cases - IO.E Factory	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 4	IO.E Eco-system	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

Project 6: Digital backbone

Domain 1.1 Domain 3.1

2020 decision: Accepted

Trends: Decentralization of generation and new players, digital revolution

Consequences: New decentralized flexibility, interface with new players, new market models

Challenges: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety
Domains: 1.1 Manage market related data from and for market parties
3.1 Connect and cyber secure our asset and substation

Project-specific context

- As TSO activities become more digitalized, Elia needs to prioritize data over processes. On many occasions, innovative proofs of concept (POCs) have blocked the way to creating an initial product (e.g. imbalance forecasting), as new technologies like artificial intelligence and the Internet of Things (IoT) require new innovative solutions to manage data.
- As a consequence, data management now needs to be taken forward with the introduction of a new ecosystem that complements the existing frameworks, in which data are cleaned up, enriched, connected, and tracked.
- The innovation and the associated challenges mainly have to do with interactions, platforms, connectivity, and automation.
- Elia plans to implement new features where it must innovate because no solution on the market offers this type of integration and automation, which can then also be incorporated into our IT infrastructure. This includes: using metadata (integrated into a first component) and interlinking them with a glossary (defined in a second component) to automatically create data quality rules (executed in a third component) governing the conflict resolution process in reference data management (in a fourth component):
- Building these components requires some tangible, cross-cutting applications that rely on them to allow our partners and stakeholders (internal and external) to get involved. Therefore, Elia is developing new innovative applications such as an Open Data platform and an IoT platform enabling implementation of various use cases:
    1. Open Data: e.g. asset localization for contractors, updated grid publication data for stakeholders, data stories for events (e.g. the impact of COVID-19);
    2. IoT: e.g. cable-oil leakage monitoring, detection of copper thefts, market-price incentive notification.

Project-specific state of the art/literature review

- As indicated, we identified two key elements Belgium is lacking that will play a vital role in unlocking decentralized flexibility via new innovative solutions:
    1. an IoT platform to provide access to decision support tools, automation along with the ability to exchange information and services in near real time to match the needs of consumers themselves, the market players and the power system at all voltage levels;
    2. an Open Data platform facilitating the co-development process with all relevant stakeholders from consumers themselves to market players (not only from the energy sector), system operators, and – last but not least – regulators.
- These two elements have to be created from scratch, and apart from some scientific papers and various POCs, there are currently no concrete existing POCs or even detailed designs that could be made available to all consumers.
- To that regards, a good example is Fingrid with the Elvis project aiming to revamp completely the information system based on 8 modules.

Expected impact for Belgium

- The main impact of the data architecture provided by the Digital Backbone program is easy access to internal and external data with a flexible interface to innovative applications like IoT…. The main benefit of this is that it will improve efficiency and flexibility levels when using data at Elia. By doing so, it will ensure that we can develop the innovative applications to respond to the increase in complexity of grid management (development of smart algorithms for forecasting, support for decision-making, automation, connection of infrastructure, etc.) and therefore promote the integration of renewable energy. The five main anticipated benefits are as follows:
    1. the ability to integrate and pass on to our partners more quickly more accurate, consistent, reliable data;
    2. the ability to sustainably support the increase in data volume and agility of processes resulting from the energy transition combined with the digital transformation;
    3. the ability to activate the consumer-centric energy system;
    4. the ability to mitigate the digital and technological shortcomings of our internal resources;
    5. the ability to identify among internal resources in the business side of activities use cases or better use of internal resources and the creation of added value through improved internal and external stakeholder engagement.

- Defining KPIs at such an early stage in this program is quite problematic and complex, but we might expect the following benefits:
    1. a 20% reduction in time to market for new datasets;
    2. a 50% improvement in the user experience;
    3. a 30% increase in the number of connected applications;
    4. a 15% reduction in the number of data incidents;
    5. a 10% reduction in response time to data incidents;
    6. a 5% boost to our reputation.

Starting point for Elia

- Our data infrastructure at Elia is still strongly dependent on our organization, but data using it need to be enriched during their life cycle.
- Data are often the poor relation in IT systems and usually come from the various applications supporting business processes, which evolve over time. The result is a multitude of disparate, inconsistent, corrupted, irrelevant, and duplicated data defined in an ad hoc way, meaning that there is no guarantee of their homogeneity or reliability.
- Elia is planning to attempt a paradigm shift where we prioritize data over processes. This alternative strategy has led to the implementation of a data office focusing primarily on data governance and their intrinsic quality in their respective reference framework. However, this now needs to be taken forward with the introduction of a new ecosystem that complements the existing frameworks, in which data are cleaned up, enriched, connected, and tracked: this is the new data backbone.

Uncertainties and risks

- The first risk is that the components developed as part of the Digital Backbone program cannot interface with the legacy infrastructure.
- The cybersecurity of the new innovative data lakes is of course a major risk as well.
- The first work package, namely data preparation for data scientists and the Integration Hub, must be available before the other innovative modules can be developed as open data.
- For the shared data lake component, the underlying technology should be supported by some providers (not the case at the moment but it should be within two years). The main risks are as follows:

- the continuing uncertainty surrounding the infrastructure's ability to scale up the wide range of data needed;
- data sovereignty and the EU's General Data Protection Regulation (GDPR) (risks that must be mitigated);
- partners not being sufficiently involved in terms of data and features potentially leading the data infrastructure being underused;
- the tendering process slowing down the adoption of commercial off-the-shelf packages.

Project description

- Digital Backbone is a cross-cutting transformation program that aims to introduce a new IT infrastructure based on a modernized organizational framework that tackles the data-related challenges posed by the transformation program of the company's operational departments. It revolves around the following key aspects:
    - coordinating the data needs of the various activities to converge on an architecture that will be used by computer scientists, data scientists, the various operators, and external partners to create applications specifically relating to the respective activities;
    - implementing the data strategy: a set of Elia-wide processes and frameworks for managing and integrating data into new technologies and solutions;
    - creating a set of architectural components based on new technological aspects enabling integration and access to cross-cutting data flows;
    - working with human resources and external partners to co-develop the digital skills and data-driven organization of the future.
- To address these four priorities, Elia will develop eight modules, each representing a work package of the Digital Backbone project:
    1. ***Integration Hub***: The operational data integration process consists of merging and enriching two or more data items sourced from distinct systems to use them in another system. Today, this process takes many hours of development for each release. To solve this, Elia will create a pilot project to put in place the foundations and initial iterations of an Integration Hub, where we will deploy the various technical components needed for an Integration Hub and developing best practices and policies about this Integration Hub.
    2. ***Data Preparation for Data Scientists*:** Each data science project consumes large volumes of data. It takes a lot of time to extract these data from the source system. Unavailability of the data is leading to a delay in the data science projects. Due to the size of the volumes, source systems are permanently deleting data that are never stored anywhere else. To overcome this challenge, we will set up a data lake to maintain structured and unstructured data (LIDAR, IoT, documents) data and also create pipelines to enrich these data. This data lake should be sourced from existing IT landscapes as smoothly and automatically as possible by leveraging the notion of business events generated by applications.
    3. ***Lambda Architecture*:** Currently, historical data for publications are sourced by a single source, but data from the most recent few days are not integrated into this data store. When a publication needs both recently created and historical data, those responsible for this are on their own carrying out this complex consolidation. Lambda Architecture integrates various solutions to fill this gap. The first step is to create a 'hot track' (ideally coupled with the establishment of the Integration Hub) and then a service layer consolidating the hot track and a 'cold track' (storing historical, so pre-existing data). The hot track represents the channel for real-time data, whereas the cold track represents the channel for archived data. Both tracks are abstracted from users' point of view but must be there to support end-to-end scenarios.
    4. ***Metadata-Driven Integration*:** Manually building and maintaining the whole set of artefacts (error management) for data integration is a daunting task. At the start, it is not necessarily a huge issue but the more artifacts one has to maintain, the less time one has to construct new artifacts. Soon, it will take so much time to maintain existing artifacts that it will be impossible to construct new artefacts. To solve this question, we will use metadata (a business glossary, technical lineage and data-quality artifacts), it is possible to partially automate the development and maintenance of data-integration artifacts. Metadata-driven solutions reduce the cost of maintenance and development of new artifacts but also increase the quality of the development.
    5. ***Open-Data APIs*:** The integration of Elia-owned real-time data with our external partners and customers is managed on a case-by-case basis and not in a uniform way. This creates gaps in our monitoring and testing systems, resulting in data-quality issues. Elia will then provide a uniform, modern layer to present the real-time data to the external providers based on an open-data API.
    6. ***Data Lake Shared with External Parties***: Nowadays, when two companies want to use each other's data (speaking in terms of large historical volumes), they transfer the data to their own environment, creating a lot of data traffic that consumes a lot of resources in terms of manpower, financial resources, and energy and creating many data-quality issues and some regulatory matters (GDPR, etc.). It will be possible to share

data in a data lake (filled by Elia and other parties) and optionally to do their invoicing based on consumption calculations.

7. ***Master Data Management (MDM) for Grid Components***: Many businesses within Elia across Customer and Market Services, Assets, and Infrastructure are relying on a list of grid components (assets or functions), but all of them have valid unique requirements leading to different lists of such components. To overcome this problem, we will launch an MDM project where we will have multiple source systems, each of them driven by an individual business but needing to be bundled together again so that after warning businesses in case of misalignment, data can be presented to the relevant applications. Each issue must be dealt with by the various impacted businesses with a formal process. The more you can automate the process, the easier it will be to manage it.
8. **IoT Platform**: This project aims to put in place an IoT platform considered to be the final access point to an IoT ecosystem. An IoT ecosystem is a set of integrated tools to support the huge numbers of IoT initiatives (see for example project 17)at Elia. The development of such a platform will avoid silos, facilitate the adoption of IoT solutions, and explore/understand all the IoT-related technologies, a concept that is new to Elia. This group of new technologies will help to innovate based on relevant use cases.
   This will help the business side to achieve its digital transformation through a connected infrastructure. The focus is on user experience in order to make sure everyone at Elia can benefit from and manage IoT initiatives.

- Work packages and timing (M = month)
  1. *WP 1: Integration Hub*
     - *CONFIDENTIAL*: Initial establishment
     - *CONFIDENTIAL*: Assistance with streaming data
  2. *WP 2: Data Preparation for Data Scientists*
     - *CONFIDENTIAL*: Initial establishment
  3. *WP 3: Lambda Architecture*
     - *CONFIDENTIAL*: Initial establishment
  4. *WP 4: Metadata-Driven Integration*
     - *CONFIDENTIAL*:
  5. *WP 5: Open-Data APIs*
     - *CONFIDENTIAL*: Eye opener and early enablers
  6. *WP 6: Data Lake Shared with External Parties*
     - *CONFIDENTIAL*:
  7. *WP 7: Master Data Management (MDM) for Grid Components*
     - *CONFIDENTIAL*: Initial establishment to aid comparisons
     - *CONFIDENTIAL*: Second merging phase
  8. *WP 8: IoT Platform*
     - *CONFIDENTIAL*:Eye opener and early enablers
- Deliverables and milestones
  - *CONFIDENTIAL*: Program kick-off
  - *CONFIDENTIAL*: First release of the Integration Hub
  - *CONFIDENTIAL*: Kick-off of Open Data and IoT enablers
  - *CONFIDENTIAL*: First release of Master Data Management (MDM) for Grid Components
  - *CONFIDENTIAL*: Conclusions of Open Data and IoT enablers
  - *CONFIDENTIAL*: First release of Data preparation for Data Scientists
  - *CONFIDENTIAL*: Second release of Master Data Management (MDM) for Grid Components

Partners

- Thanks to the open-data APIs and the shared data lake, including the Data Usage and Privacy Agreement features, the Digital Backbone will be able to handle the use of Elia data by partners such as DSOs, BRPs, BSPs, start-ups, and universities and also to collect new types of external data as part of items jointly created with these partners.
- Technology partners will be: *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL* *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, etc.
- Digital and Data Department

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

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WP 1	Integration Hub	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 2	Data preparation for data scientists	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 3	Lambda architecture applied to external publications	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 4	Metadata-driven integration	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 5	Open-data APIs	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 6	Data Lake shared with external parties	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 7	Master data management for grid components	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 8	IoT platform	2019	2020	2021	2022	2023	Total
IoT platform	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

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Project 7: Automation of voltage control

Domain 2.4

Decision 2020: Accepted

Trends: Decarbonization, supranational coordination, digital revolution

Consequences: Uncertainty and intermittency of generation, new system dynamics, new decentralized resources

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.4 Predict and automate voltage decisions

Project-specific context

- Voltage control in the high-voltage grid is becoming more and more complex as a result of multiple factors.
  - First of all, small and intermittent distributed energy sources are emerging, which means that conventional power plants are being decommissioned. Up to now, these conventional units have been the main ways to manage voltage control dynamically. For instance, the nuclear power plants of Doel and Tihange have a total band of [-1180;2675] Mvar (~650 Mvar band for 1 GW).
  - Secondly, more and more overhead lines are being replaced by underground cables that generate much more reactive power. These cables are then offset by switchable and variable shunts distributed throughout the grid.
  - A third development is the increase in active power exchange capacities through upgrading interconnections, causing the Belgian power system, driven by the European market, to become highly flexible. A highly flexible active power distribution will result in a highly flexible reactive power distribution, because of higher Mvar losses with higher load / power flows. This results in grid voltages that change continuously and need close attention from the system engineer.
- These trends together have an impact in two ways:
  - First, due to decommissioning, decisions will need to be taken for multiple small units instead of one big unit. This will mean the messages sent in connection with each decision will increase.
  - In parallel, due to the increased dynamics, more decisions will be necessary in each time step. Therefore, the complexity of voltage management will increase significantly.
- The integration of renewables and associated power electronics equipment will also change the dynamics of the system, leading to voltage issues and therefore also a risk of blackout. Voltage support is a system control task mainly performed with synchronous generators today, which will be joined by non-synchronous devices in the future.
- We see an increasing number of HTLS and PSTs in the Belgian and European grid, which are responsible for high Mvar losses at high load, in turn again changing dynamics related to grid voltage. The trends mentioned above are not fully compensated by new Mvar sources. On top, the Mvar sources are not so well placed in the network, for instance on antenna instead of firmly meshed into the grid.
  - Offshore wind voltage control is not yet fully implemented, and the fact that they will provide Mvar services at zero active power is to be confirmed
  - Potential new thermal power plants on Elia grid will not be running all year long, and their availability for Mvar services will be volatile
- Simulation sessions with experienced System Engineers have shown that up to 13 voltage related actions per hour would be necessary in the future if we do not change the current approach. Given the fact that an action comes with multiple actions (aligning with stakeholders, checking N-1 security etc.) this would mean that voltage control becomes a full time job for the SE.

- A general approach by TSOs to solving voltage problems is to revert to the installation of power electronics assets such as STATCOMs, devices that can cost millions of euros. At Elia, we want to look into trying to avoid such investments, by optimizing the usage of the voltage-regulating assets we have today (e.g. shunt or capacitor bank) and making their control more dynamic, for instance by making modulation possible instead of switching on and off.
- The COVID-19 crisis has had a negative impact on the situation. Due to load reduction, voltages have increased in many parts of the European grid. Several European TSOs have triggered emergency alerts via the European emergency alert system (EAS) due to extremely high voltages. Mass dispatcher interactions and coordination with neighboring TSOs and impacted DSOs have been necessary to keep the European system up and running.

Project-specific state of the art/literature review

- RTE and Swissgrid have already developed some initial solutions. Specifically, RTE is looking into improving voltage control using artificial intelligence as part of its APOGEE project. In this project, the idea is to develop an assistant for short-term operations. RTE is working on achieving this goal with various PhD students. They take four parallel approaches, namely (i) using machine learning to mimic humans; (ii) using optimization algorithms or optimizers; (iii) using expert systems, such as a remedial actions database; and (iv) capturing what operators intend to do in near real time. Experiments with dispatchers are ongoing. Swissgrid is working in a slightly different context than Elia, in the sense that they do not have proper voltage-regulating assets and instead depend on services contracted from Swiss DSOs. They have developed a day-ahead market optimizer that works out voltage schemes for a 15-minute time scale.
- We had a call with Energinet DK, who have attempted at implementing a similar scheme some years ago. Their feedback was that their OPF proposed too many actions that had a limited validity (e.g. activation of a shunt that will be deactivated in the next hour). This is a clear attention point for our project, and we will stay in contact with the relevant persons. Subsequently, via our links to the R&D committee of Entso-E (RDIC) we try to identify other relevant stakeholders in the TSO business.
- Based on calls with both project teams, none of them has for the moment reached a level of automation that might be required in the future after the nuclear phase out in Belgium. Therefore, we will stay in contact with RTE to assess where some lessons learned or synergies could be identified.
- We have contacted several startups (*CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL**CONFIDENTIAL*, etc.) and multinationals (*CONFIDENTIAL*, *CONFIDENTIAL*, etc.) to assess the possibility of launching a partnership. Assessments regarding these discussions are ongoing.
- The complete state of the art for automatic voltage control is currently under review and will be finalized by the end of summer 2020.
- Regarding automatic, decentralized switching, we are aware of the 'SMACC' system deployed by *CONFIDENTIAL*. This system is used in the *CONFIDENTIAL* grid to cope with critical situations, in case a voltage threshold is reached, the asset will switch. The downside of the system is the fact that it concerns a static voltage setpoint, in our project we want to take this one step further and change the setpoint based on system requirements.

Expected impact for Belgium

- Significant voltage deviations can lead to decoupling of many devices and ultimately to a local blackout. One of the best examples of this is the blackout in New York, Ohio, Michigan, and Ontario on August 14, 2003 mainly caused by a voltage control and stability issue and costing between USD 4 and 10 billion.
- Given that in Belgium, nuclear power plants account for around 50% of the voltage control and considering the increase in the share of renewables in the energy mix, an automated voltage control solution needs to be developed to increase the dynamic voltage capabilities of our grid. This way we can ensure the security of the grid in case of voltage instability caused for example by an abrupt change in the generation of renewables. So far, no exact quantitative impact calculation has been made available. This will be evaluated in the first part of the study.
- Due to the current trend of replacing conventional conductors with HVDC lines (reactive power depends on the square of flux) combined with higher market volatility and the fact that plants regulating voltage automatically will be replaced by solar and wind energy infrastructure, an increase in voltage-related actions in the future is expected.

Starting point for Elia

- Up to now, at Elia we have not used an optimizer or a decision support tool to control voltages. Voltage management is a specialist task performed by system engineers. Today, the system engineer has two different, complementary tools, depending on which task he needs to perform. Firstly there is the EMS, which via our SCADA system directly controls assets we own, such as shunts or condenser batteries. By sending (de)activation signals, the voltage is managed. Secondly, if the system engineer wants to change the Mvar absorption or production of a specific power plant, he needs to use the ReVolt tool, which sends requested signals to the operators of these plants.
- In the processes, voltage management is started in at 11:00 the day before the voltage is needed. Through coordination between the National control center (system engineer) and the Regional control center, all voltages in the system are normalized. That day at 18:00, the procedure should be finished, and the actions that are still necessary are decided on and coordinated in (near) real time by the system engineer or the near real-time engineer.
- Today, this is a manual process that requires a lot of expertise, knowledge, experience, and manual interventions from the responsible parties.
- Because of the shift from big, centralized assets connected to the extra-high voltage level to small, decentralized units, coordination between different control centers will be crucial.

Uncertainties and risks

- The first uncertainty relates to the availability of tools for such voltage-management automation, as previous research has shown that there are no existing solutions on the market. Voltage management is a highly complex issue because we need to take into account interactions between loads, electrical zones, neighboring TSOs, impacted DSOs, and voltage-regulating assets, such as capacitor banks and shunts.
- The second uncertainty surrounds whether the decentralized voltage control resources will be sufficient to cope with the uptake of renewables and the nuclear phase out, and whether a human can control these resources.
- For the autoswitch project, a big uncertainty lays in the potential ping ponging between different assets. If a change in voltage causes a condenser bank to automatically switch, and the subsequent change causes a nearby shunt to change position, this would lead to unwanted grid dynamics.

Project description

- The goal of the project is to support dispatchers in managing the voltage schedule and Mvar distribution on the grid to prepare for an energy system with a high share of renewables. The first step is to improve the forecasting of voltage control needs, before gradually increasing the support provided to the dispatcher until there is full automation of some voltage control processes (still to be determined). This support to the dispatcher will become vital in the years to come, given that today around 50-60% of dynamic voltage control is managed via nuclear power and that in an energy system with a high level of penetration of renewables, dispatchers will need to activate voltage control more frequently and with a much wider pool of decentralized control resources.

  The project is currently divided into two independent parts:

  1. The first part aims to develop a decentralized control mechanism or algorithm, which will autonomously make decisions regarding connecting or disconnecting a voltage-regulating asset (shunt or capacitor bank) following an incident. The components will react within very short time frames; meaning that the system will be more responsive than if it were to depend on humans alone. One of the project's key considerations is to make sure that no harmful interactions can take place, i.e. two decentralized controllers cannot make conflicting decisions at the same time.
  2. The second part involves introducing an optimization algorithm in Dispatching, which will help the dispatcher to always achieve the optimal voltage spread over the grid over a 15-minutes time span. This tool will need to take into account existing predictions for load and production and consequences in terms of the N-1 security of its decisions. On top of this, the tool will need to be able to cope with the complex reality of voltage regulations, in which many actors and influencing factors play a role, such as local load fluctuations, neighboring TSOs' voltage management, voltage-regulating assets, and transformer tap changers. In that sense, the tool will be usable as a means of communication and alignment between all stakeholders.

  Eventually, the experience gathered in those projects will be used to pave the way for automated voltage regulation.

- Approach: For the first part, we need to understand how the local controller for such devices should be configured. Since the main idea is to use a decentralized control blueprint, we need to be sure that such a controller cannot cause grid instabilities, for instance by influencing the controller of nearby devices. Therefore, we will first develop and simulate the implementation of multiple controllers in the grid. The next step will be to develop the device and test it in real-life conditions.
  For the second project, we need to gain a clear view of the business needs of our Dispatching team. This is the most important part of the work. By aligning with these business requirements concerning what the tool should be capable of (which assets to control, which constraints to respect, which objective function to use, etc.), we will be able to describe in detail what we need to develop (potentially in a partnership) or buy. This means that currently only this first study phase of the project is being planned. This will enable us to learn from other TSOs and contact startups and multinationals to understand what is possible and what is not. Based on the identified needs, by the end of the year we would like to further flesh out the business requirements and develop potential ways of implementing the tool in Dispatching. This will give us a clear view of the road beyond 2020, when we want to start implementing voltage-management support and coordination at Elia.
- Work packages and timing (M = month)

  Project 1
  - WP 1.1: 'Means of Voltage Control' study
  - *CONFIDENTIAL*: WP 1.2: Development of the controller:
  - *CONFIDENTIAL*: WP 1.3: Simulations and impact on grid stability:
  - *CONFIDENTIAL*: WP 1.4: Development and implementation on the grid
  - *CONFIDENTIAL*: WP 1.5: Real-life testing:

  Project 2
  - *CONFIDENTIAL*: WP2.1: Alignment and description of vision Elia / 50Hertz: 03/2020
  - *CONFIDENTIAL*: WP2.2: Contact with other TSOs, market parties: 06/2020
  - *CONFIDENTIAL*: P2.3: Business needs description, use cases; 09/2020
  - *CONFIDENTIAL*: WP2.4: Business case, CBA: 12/2020

- Deliverables and milestones
  - Completed study on needs and resources
  - Description of the controller that can be implemented
  - Documentation of the robustness of such an auto-switch controller
  - Description of business needs regarding optimal voltage-management support (interfaced with people and processes)
  - Translation into business requirements (interfaced with IT tools)
  - Development of the business case/CBA
  - Internal knowledge spreading and valorization

Partners

- Analysis of the needs, criteria/the design: experts from the Elia Group's control centers and relevant experts from EGI.
- Exchange of expertise with other TSOs, DSOs, startups, multinationals, etc. and assessment of the best partnership for the project.
- Development of the algorithm: This will be analyzed in close liaison with Elia's Artificial Intelligence team, set up in close liaison with the analytics consultancy N-SIDE, or with another partner if the previous step of the project shows us that this is a good idea.
- Alignment and potential involvement with academic experts, e.g. via EnergyVille .
- Search for potential innovative partners: Danish research startup Accelerace.

- Running of certain simulations and OPF calculations: Digsilent.
- Contact with other TSO's to exchange on the voltage solution development, mainly RTE and Swiss grid.

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP1	Auto-switch: Study + test	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP2	Optivolt: Study to refine the business needs	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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HVDC
Domain 2.2

Project 8: Understanding of new grid dynamics

2020 decision: Accepted

Trends: Decarbonization, decentralized generation and new players

Consequences: New decentralized flexibility, interface with new players, new market models, low marginal price

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.2 Prepare for low inertia and integrate power electronics

Project-specific context

- Future power systems will face new challenges, with traditional thermal generation units being replaced by renewable energy sources with power electronics grid interfaces. In Central Europe, an increasing share of wind and PV generation in the energy mix is leading to periods when few synchronous generators are operating. Due to the physical characteristics of these resources, this leads to a grid with low rotating inertia.
- Inertia represents the capacity of units connected to the grid to store kinetic energy and inject it back into this grid during a certain period, even after an increase in the load. This inertia is necessary to ensure that the network can overcome an imbalance between generation and consumption and stabilize again. The lower the inertia level, the faster the frequency changes when there is an imbalance between generation and consumption, and if the frequency deviates from its stability range (from 48.5 to 51.5 Hz), there is a significant risk of a grid blackout. A noteworthy example of this occurred in the UK on August 9, 2019, a day with a high level of renewables in the energy mix, when two generators disconnected leading to a partial blackout[1].
- The RoCoF (rate of change of frequency) was a parameter of minor relevance in the past, but it is now becoming relevant because of low levels of system inertia. Inverter-based generation can result in synthetic inertia through control algorithms, but these need to be implemented carefully.
- We distinguish between the risk of low *overall* inertia (on the interconnected grid) and the risk of low *local* inertia (in a limited synchronous system).
- On top of the inertia risk, which will affect frequency, the integration of renewables and linked power electronics equipment will also change the voltage level of the system, leading to voltage issues and therefore also the risk of a blackout. Voltage support is a system control task that is currently mainly performed with synchronous generators. These will be joined by non-synchronous devices in the future.
- For both new dynamics (frequency and voltage), Elia must understand the future risk linked to the change in dynamics so that we can continue to operate our grid reliably and without any impact on our users. Therefore, Elia is teaming up with various universities in the context of PhD research and subsidized programs to work out how to prepare for these new dynamics, resulting in three main projects (Local Inertia, HVDC Inertia, and InnoDC).

Project-specific state of the art/literature review

- Studies have shown the need for synthetic inertia in the future (see the ENTSO-E study from November 2017 about the "need for synthetic inertia (SI) for frequency regulation", which recommended that TSOs conduct collaborative studies.
- As for the RoCoF, ENTSO-E has requested that TSOs collaborate on determining the RoCoF withstand capability criteria.

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[1] https://theenergyst.com/national-grid-blackouts-lcp-analysis/

- National Grid has already performed in-depth analysis, as the UK's geographic separation from continental Europe exacerbated the risk of inertia there already.
- Central Europe[2]: A task force comprised of European system operators studied the frequency behavior of the European system for decreasing system inertia. The main conclusion is that in interconnected mode the system still exhibits its acceptable frequency behavior even with significantly reduced inertia. However, in the case of split operation after a disturbance, the resulting imbalance combined with low inertia could result in unstable system behavior.
- Nordic grid[3]: Given a combination of increasing renewable generation penetration and the shutdown of nuclear power plants, the operators of the Nordic grid list low inertia as one of the three main future challenges faced by their system. Proposed solutions include technical measures and also imposing operational requirements, such as a minimum available kinetic energy.
- However, none of these studies has had a closer look at Belgium, while Elia needs to prepare for the new dynamics.
- Many of the challenges related to low-inertia power systems have been highlighted in recent reviews and magazine articles.[4] While many of these issues are now widely recognized, there is still no scientific basis for the modeling, analysis, and control of low-inertia systems.

Expected impact for Belgium

- With the implementation of Stevin and Ventilus, and the de facto increase in renewable energies, we need to be cautious about the behavior of HVDC and wind farms, and have a clear definition on which ratio of power electronics to synchronous generators is manageable.
- In Belgium, the level of overall inertia is higher than the UK due to the higher level of interconnection; however, the uptake of renewables and the nuclear phase out could in the future bring about a similar situation to the blackout on August 19 in the UK, which cost millions of GBP (to give a rough quantification of this, RWE and Orsted agreed to pay GBP 4.5 million to close the investigation).
- The exact impact of the risk of a local inertia issue will be quantified during the local inertia study. In parallel, the role of HVDC converters in supporting the low-inertia Belgian power system will also be quantified in the HVDC inertia study.
- The studies will then quantify the needs of local inertia (the Local Inertia project) and work out how HVDC connectors can participate in solving this issue (HVDC inertia provision). Finally, the last study (InnoDC) will give a better idea of system stability modeling in the context of high-voltage power electronics.

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[2] RG-CE System Protection & Dynamics Sub Group, *Frequency stability evaluation criteria for the synchronous zone of continental Europe*, ENTSO-E, Tech. Rep., 2016.
[3] Svenska Kraftnät, Statnett, Fingrid and Energinet.dk, *Challenges and Opportunities for the Nordic Power System*, Tech. Rep., 2016.
[4] EirGrid and Soni, *DS3: System Services Review TSO Recommendations*, EirGrid, Tech. Rep., 2012.
M.-S. Debry, G. Denis, T. Prevost, F. Xavier and A. Menze, *Maximizing the penetration of inverter-based generation on large transmission systems: the migrate project*, 6th Solar Integration Workshop, 2017.
RESERVE, 2016 [online]. Available at https://www.re-serve.eu.
CSIRO, *Change and Choice – The Future Grid Forum's analysis of Australia's potential electrical pathways to 2050: Final Report*, Tech. Rep., December 2013.
P. Tielens and D. Van Hertem, *The relevance of inertia in power systems*, Renewable and Sustainable Energy Reviews, vol. 55, pp. 999-1009, 2016.
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B. Kroposki, B. Johnson, Y. Zhang, V. Gevorgian, P. Denholm, B.-M. Hodge and B. Hannegan, *Achieving a 100% renewable grid: Operating electric power systems with extremely high levels of variable renewable energy*, IEEE Power and Energy Magazine, vol. 5(2), pp. 61-73, 2017.

Starting point for Elia

- As ENTSO-E's RG-CE System Protection & Dynamics Sub Group stated, "decreased system inertia will have a significant impact if the Continental European power system faces a system split similar to the November 4th 2006 event" (referring to the blackout of 15 million people on November 4, 2006).
- It has been said that new equipment, and in particular, HVDC converters, could provide an opportunity to solve inertia issues. Since we have more and more of this equipment at our disposal, this is an interesting avenue of investigation that needs to be explored further.
- We have created a special Dynamics and Harmonics advisory group, bringing together key experts from the company and keeping its finger on the pulse when it comes to problems concerning dynamics and harmonics in operations, grid planning, incident analysis, and other domains.

Uncertainties and risks

- The first uncertainty relates to the effective risk of blackout that Belgium as an interconnected power system will face in a system with high levels of renewables and a much-decreased role of centralized power plants in the energy mix. As a result, we need to consider the efficiency of our BAU processes, specifically those concerning dynamic and harmonic grid behavior.
- The second uncertainty the study is aiming to tackle surrounds the fact that the HVDC converter can effectively solve issues linked to low-inertia systems.
- The final uncertainty relates to establishing that power converter increase will not cause major stability (voltage) issues in the future.

Project description

- The project takes the form of three separate studies (PhD projects):
    1. *Local Inertia*: PhD research project started with Brunel University in London and pursued with KU Leuven in order to better understand the local inertia distribution on the Belgian grid and the associated blackout risk and also potential mitigation measures;
    2. *HVDC Inertia Provision*: research, orchestrated by SINTEF in which KU Leuven is also participating, which is aiming to assess the role HVDC converters can play in the supply of virtual inertia;
    3. *InnoDC*: on this project, a PhD student working for Elia and in close liaison with KU Leuven is trying to develop a converter model in MATLAB to better assess the risk for the stability of the grid.

- Approach:
    1. For each of these projects, the approach is to team up with universities (KU Leuven, Brunel) or research consortiums to perform the analysis in close liaison with the relevant Elia departments (mainly the National Control Center).

- Work packages and timing (M = month)
    1. *WP 1: Local Inertia study – phase 1*
        - *CONFIDENTIAL*: Part 1: Examination of the RoCoF algorithm on the Elia grid
        - *CONFIDENTIAL*: Part 2: Development of criteria to quantify and measure the risk of transient stability issues as has already happened for local RoCoF
        - *CONFIDENTIAL*: Part 3: Analysis of the impact of small power oscillations
    2. *WP 2: HVDC Inertia Provision*

    2.1 Quantification of the potential technical and economic benefits and implications of operating HVDC interconnectors for inertia support from a transmission system perspective
        - *CONFIDENTIAL*: Task 1.1: Data collection and literature review relating to the quantified needs for inertia response support and possible implementations
        - *CONFIDENTIAL*: Task 1.2: Preparation of user-defined case studies and establishment of a model for inertia provision from an HVDC supply

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- *CONFIDENTIAL**CONFIDENTIAL*: Task 1.3: Analysis of the potential benefits and implications of operating HVDC
- *CONFIDENTIAL*: Task 1.4: PhD study at KU Leuven (Prof. *CONFIDENTIAL*) to quantify the technical limitations and potential economic benefits of inertia exchange via HVDC interconnectors

2.2 *Quantification of the potential technical and economic benefits and implications of operating HVDC interconnectors for inertia support from a transmission system perspective*
- *CONFIDENTIAL*: Task 2.1: Assessment of the level of access for controlling various HVDC converters
- *CONFIDENTIAL*: Task 2.2: Depict possible implementations depending on the level of access to the HVDC converter control system
- *CONFIDENTIAL*: Task 2.3: PhD research study on implementation and control system integration of inertia support arrangements at Ecole Centrale de Lille (L2EP) (Prof. *CONFIDENTIAL*)

2.3 Development of new techniques and tools for accurately assessing small- and large-signal stability in large-scale power systems with inertia support from HVDC transmission
- *CONFIDENTIAL*: Task 3.1: System modelling and time-domain simulation of various implementation arrangements in a large-scale power system
- *CONFIDENTIAL*: Task 3.2: Small-signal modelling and evaluation of dynamic characteristics and system stability with various implementation arrangements
- *CONFIDENTIAL*: Task 3.3: Postdoctoral research at the Norwegian University of Science and Technology (NTNU) (Prof. *CONFIDENTIAL*)

2.4 Demonstration of virtual inertia control in a laboratory environment, targeting TRL 4/5.
- *CONFIDENTIAL*: Task 4.1: Demonstration of the most relevant inertia support implementations in a relevant laboratory-scale grid configuration
- *CONFIDENTIAL*: Task 4.2: Laboratory demonstration of inertia support implementations connected to a grid emulator running a power-system model in real time

3. WP 3: InnoDC
- *CONFIDENTIAL*: Literature review relating to phasor-based models of electrical components used in transient stability programs
- *CONFIDENTIAL*: Implementation of VSC models on MATLAB/Simulink with and without quasi-stationary phasor simplifications
- *CONFIDENTIAL*: Analysis of the accuracy of the VSC models to represent stability issues in weak grids considering the small-signal behavior of the system
- *CONFIDENTIAL*: Literature review relating to control interactions between large converters embedded in the AC system
- *CONFIDENTIAL*: Test-case implementation of two large converters and analysis of the impact of phasor-based representations
- *CONFIDENTIAL*: Development of an aggregated (reduced-order) system model for several converters in large offshore wind farms
- *CONFIDENTIAL*: Compilation of benchmark results
- *CONFIDENTIAL*: Development of a screening methodology to assess the risk of a converter and development of guidelines on how to model a power system considering the limitations of phasor-based models
- *CONFIDENTIAL*: Writing-up of the PhD dissertation

4. Local Inertia study – Phase 2:

  - RoCoF screening methodology
  - RoCoF BE system impact assessment
  - Performance assessment of protection devices
  - Outlook and other challenges
- Deliverables and milestones

  HVDC inertia:

  - Task 1.1: Data collection and literature study relating to the quantified needs for inertia response support and the possible implementations
  - Task 1.2: Preparation of user-defined case studies
  - Task 1.3: Analysis of the potential benefits and implications of operating HVDC interconnectors for inertia support from a transmission system perspective

  InnoDC:

  - Addition of deliverables of InnoDC

  Local Inertia – Phase 2

  - June 2021: Report on the system impact assessment of high RoCoF values, including guidance on RoCoF settings/specifications/limits to consider in grid codes or analytical tools
  - June 2021: Report with the results of the impact assessment specific to the Belgian (and Central-European) power system
  - August 2021 Report on the RoCoF screening methodology and the proposed procedure that might be used in the Belgian context
  - August 2021: Report with the results of the application of the methodology to the Belgian (and the Continental European) power system
  - August 2021: Report on the performance assessment of protection devices – evaluation and test procedures, including guidance on RoCoF limits and analytical tools
  - August 2021: Report with the results of the application of protection devices' performance to the Belgian (& Central-European) power system
  - October 2021: Report on the qualitative assessment of other challenges related to low levels of local system inertia, including a proposal for additional phases/an extension of the project

Partners

- First part of WP 1 (Local Inertia): Study led by Brunel University in London in 2018 and 2019
- Second part of WP 1 (Local Inertia): Study by a postdoctoral researcher from KU Leuven (yet to be hired)
- HVDC provision: Consortium led by SINTEF, including *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, and *CONFIDENTIAL*
- InnoDC: Elia is taking care of a PhD project as part of a broader consortium with Cardiff University, *CONFIDENTIAL*), *CONFIDENTIAL*), *CONFIDENTIAL*), *CONFIDENTIAL*), *CONFIDENTIAL*), *CONFIDENTIAL*, and *CONFIDENTIAL*)
- InnoDC subsidy: The European Commission is subsidizing the project in the context of the H2020 program.
- InnoDC supervision: KU Leuven is providing the academic supervision while the expert's team from the National Control Center is providing business support
- The experts from the NCC and the Grid Dynamics workgroup will support the follow-up of each project.

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Local Inertia	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	HVDC Inertia Provision	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Inno-DC	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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Project 9: BVLOS drones for automate inspection

Domain 3.2

2020 decision: Accepted

Trends: Decarbonization, decentralized generation and new players

Consequences: New decentralized flexibility, interface with new players, new market models, low marginal price

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.2 Automate inspection onshore and offshore

Project-specific context

- Today, the need of maintenance activities is generally identified by technicians and engineers who inspect the lines at source once or twice a year. The overhead lines are mostly inspected by observation by food patrol using binoculars or by climbing.
- In parallel the grid is inspected via helicopter covering the complete Belgian grid every 1-3 years. These helicopter flight are covering complete picture representation of the grid to detect default and use also LIDAR technologies to identify the areas where vegetation is reaching the safety limit and require pruning activities. These helicopter flights represent an important cost considering they cover the complete high-voltage grid every 3 years and have a cost of +/- *CONFIDENTIAL*/km, which is *CONFIDENTIAL*/hour and a fuel consumption above the 250l/hour.
- The general inspection covered notably the default identification as well as the inspection of vegetation and founding, of painting work, the micro-view, the air inspection, the thermography.
- Finally the inspection in case of incident is generally performed via car patrol or by feet which can take long time and lead to delay in recovery in assessment of the incident and extend the potential outage.
- For all these 3 use cases the use of autonomous drones has the potential to reduce the cost of inspection (lower cost than paying recurrent helicopter flight), increase safety (less climbing on towers) as well as reduce environmental impact (less usage of helicopter for regular inspection flights) if it is coupled to advanced technologies as:
    1. Artificial intelligence for pattern recognition in combination with high definition picture;
    2. Ultra-lidar for 3D scan of the overhead line as well as the vegetation refined detection (until 400 points/m²) for 3D modelling;
    3. Hyperspectral camera;
    4. Photogrammetry camera;
    5. Thermovision camera;

- It can increase also the quality of the detection (higher detection rate than the patrol) while finally improving the safety of our operators by avoiding dangerous climbing.
- Currently Elia has already tested and start implementing the remote control drones for micro view, work preparation, air inspection, and diagnosis of line incident or painting inspection.
- But these drones require to fly the drones via an pilot in visual line of sight (VLOS), decreasing the potential of automation and therefore the potential gain. The goal of the project is then to use autonomous drones to automate the inspection for a long distance (up to 100-200 km) using embarked technologies (lidar, HD camera) for data collection used then for automatic analysis (incident analysis, default detection, painting analysis…).
- In order to automate the inspection a software the retrieve of pictures and grid model needs to be coupled to a high-performing algorithm to detect defects and analyze the assessed situation. To perform this analysis the collection of data from drones needs also to be coupled with an efficient data management.

Project-specific state of the art/literature review

- Today, the legal framework for unmanned aerospace systems (drones) is described in Regulation (EU) 2018/1139 which regulates unmanned aerial systems below a take-off mass of 150 kilograms at EU level. From 01.01.2021 for every member state it is binding that you will get the permission for your drones project based on a risk assessment. For 2019 drones may only be flown on visual line of sight without permission and flying drones at altitudes above 100 m is generally prohibited. BVLOS operation is only allowed due to specific derogations.

- From technical point of view drones with 100 km coverage incl. multi-Camera/sensor systems and portable data storages can be seen as state of art but due to the legal framework described above it is not allowed for any industry/branche to operate drones BVLOS. In many industries/branches different applications and services are currently developed but until now no commercial services are available. In addition to the energy infrastructural industry the following industries are marked by certain development effort to
    - Agriculture (including targeted use of plant protection products and fertilisers),
    - Medical care (e.g. transport of medicines, blood, tissues),
    - Distribution logistics (including delivery UAS),

- Many European TSO are testing whether drones can support the monitoring of overhead lines but mostly in kind of flown by drone pilots and in visual line of sight. A few TSO made some first pilot projects such as
    - *CONFIDENTIAL*have tested drones for the inspection of power lines on BVLOS mode
    - *CONFIDENTIAL*developed their own drowns and tested it
    - *CONFIDENTIAL* is testing drones applications fir incident inspections in mountainous terrain.
- However, none already address the full automation via image recognition or test of onboarding at the same time multiple technologies as HD lidar and thermography, HD camera.

Expected impact for Belgium

- There will be an impact expected that the cost reduction due to substitution of helicopter inspection will be between *CONFIDENTIAL* which has to be approved during the PoC.
- Furthermore an increase of safety due to less need to climb on towers is also expected for the Elia employees as well as for third parties.
- A decreased environmental impact will also expected by substitution of helicopter inspection by reduced pollution and noise.
- The 3D models resulting in the Lidar modelling can be seen as additional added value for future innovation activities.

Starting point die Elia

- Currently VLOS (Visual line of Sight) drones are implemented
- BVLOS first flight has been performed in the context of the SAFIR consortium (including Proximus, Amazon…) aiming to demonstrate the feasibility of a flight in the European sky

Uncertainties and risks

- The first uncertainty is the feasibility to grant agreement to fly in the Belgian sky to perform drone autonomous flight (according to the European directive “Sora”).
- Another uncertainty is that the Bvlos drone will manage to fly close enough to guarantee a quality of picture / scan in order to reach a better rate of detection of default.
- Moreover, the increase of embarked equipment could lead to an important consumption of energy that will decrease the autonomy of the drone and therefore the decrease the business case.

Project description

- The first goal of the project is to develop and train an algorithm that can effectively detect the default on an overhead line and a pylon.
- The project aims to validate the feasibility of a 100-200km flight performing the following actions:
    - High definition picture
    - Lidar and photogrammetry
    - Thermography camera

This data should then be sufficient (quality) to detect default through the pre-developped algorithm

Different methodology will be used to detect default (starting from image recognition to lidar)

Finally we will assess the quality of 3D model obtain via advanced photogrammetry to support our infrastructure management and complete the plan we already have.

- Approach: the algorithm will be developed jointly with *CONFIDENTIAL* and *CONFIDENTIAL*. Then the test of the BVLOS drones flight will be performed via partnership with drones operation company (selected via tender process). In parallel, the in-house algorithm will be compared to vendor solutions Elia is currently testing with Vlos drones.

- Work packages & Timing(M=month)
    1. *WP1 Initial BVLOS drone flight in the context of SAFIR consortium*
        - *CONFIDENTIAL* : Consortium set-up
        - *CONFIDENTIAL* : test in the port of Antwerp
        - *CONFIDENTIAL* : report writing
    2. *WP 2 Development of an AI solution for image recognition for overhead lines and pylon defect detection.*
        - *CONFIDENTIAL* : capture of pictures via VLOS (View Line Off Sight) drones
        - *CONFIDENTIAL* : development of the first version of the algorithm
        - *CONFIDENTIAL* : Labelling of the picture
        - *CONFIDENTIAL* : Training of the model
        - *CONFIDENTIAL* : Back-testing of trained model and report
    3. *WP 3 Application for permission of corridors to fly with BVLOS drones*
        - *CONFIDENTIAL* : Selection of partner
        - *CONFIDENTIAL* : Application for the Sora
    4. *WP 4 Train the AI solution for image recognition with specific images obtain via preliminary drone flight*
        - *CONFIDENTIAL* : Selection of drone company
        - *CONFIDENTIAL* : Selection of zone to be inspected
        - *CONFIDENTIAL* : 20: New pictures taken from VLOS flight on pre-define sight
        - *CONFIDENTIAL* : training refining based on BVLOS drones pictures
    5. *WP 5 First long distance flight including a 3D scan (Lidar and photogrammetry)*
        - *CONFIDENTIAL* : preparation of the flight
        - *CONFIDENTIAL* Test flight
        - *CONFIDENTIAL* : Analysis of the picture and back-testing of the model
    6. *WP 6 Detailed inspection of minimum 10 towers*
        - *CONFIDENTIAL* : preparation of the flight : preparation of key assumptions, identifications of on boarded technologies
        - *CONFIDENTIAL* : potential additional contracting with new partners
        - *CONFIDENTIAL* : Test flight in the identified areas including benchmark (e.g. foot patrol or heli-copter images)
        - *CONFIDENTIAL* : Analysis of the results
        - *CONFIDENTIAL* : Conclusion, identification of complementary tests

- Deliverables & milestones
    - *CONFIDENTIAL* : SAFIR project finalized
    - *CONFIDENTIAL* : AI solution for image recognition developed
    - *CONFIDENTIAL* : BVLOS permission for 3 different corridors received (if not possible in BE due to delay in the change of regulation, use of German testbed where regulation is more flexible for delivering corridor authorization)

- *CONFIDENTIAL* : First technical tests are finalized
- *CONFIDENTIAL* : Conclusions of operational tests for drones flight
- *CONFIDENTIAL* : Test case definition for detailed inspection (e.g. thermography, hyperspectral camera…)
- *CONFIDENTIAL* : Results of inspection and business case
- *CONFIDENTIAL* Recommendations for the business and communication

Partners

- Flight demonstration: In the context of SAFIR, Elia has partnered with 13 organization public and private (*CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* *CONFIDENTIAL* r, *CONFIDENTIAL*).
- Neural network development: For the development of the algorithm Elia has partnered with *CONFIDENTIAL* and *CONFIDENTIAL* while we plan to exchange also data with other TSO's (*CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL*).
- BVLOS test: The BVLOS flight will be managed with partners that will be selected in the context of a tendering process to be launched in the summer of 2020.
- Internally, the transformation team from the asset management department will partner with innovation to follow the test of BVLOS drones including the comparison with the currently VLOS drones solutions (as *CONFIDENTIAL*).

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

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WP 1	Initial BVLOS drone flight in the context of SAFIR consortium	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Development of an AI solution for image recognition for overhead lines and pylon defect detection.	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Application for permission of corridors to fly with BVLOS drones	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Train the AI solution for image recognition with specific images obtain via preliminary drone flight	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 5	Long distance flight including a 3D scan (Lidar and photogrammetry)	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP6		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

Project 10: Blockchain to facilitate investment in decentralized flexibility

Domain 1.2

2020 decision: Accepted

Trends: Digital revolution, decentralized generation and new players, supranational coordination

Consequences: New decentralized flexibility resources, interface with new players

Challenge: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

Domain: 1.2 Apply scalable process for authentication of devices and activation

Project-specific context

- The coming decades will see a huge increase in behind-the-meter installed capacities connected to the internet and investments in decentralized energy resources. With the battery prices decreasing, not only home storage installations are expected to increase, but also electric vehicles (EVs). By 2030, it is anticipated that there will be 33 millions of EVs on Europe's roads. In parallel, as energy system is starting to digitalize. Various services for customers using artificial intelligence and mass data analytics will be developed, meaning that easy access to such data will be required.
- As presented in section 3.1, over the next 10 years, it will be vital for Elia to draw on the potential provided by decentralized flexibility (heat-pumps, batteries, EVs, etc.) to balance the grid and ensure its security, given that such resources will need to account for at least 5 GW of balancing power by 2030. This will be largely because of the absolute increase in errors in intraday/day-ahead generation forecasts due to renewables.
- However, if we continue running the system as we do today, this would mean that asset and customer information would be fragmented across multiple siloed systems, often remaining invisible to grid operators and therefore unable to reveal its full potential. Above all, the separated management of the data will make transparency and trust very difficult to verify.
- In parallel, the process of introducing new flexibility to the ancillary services market is not currently scalable because of the many bilateral interactions it involves (verification of the status, installation of a meter, pre-qualification tests, etc.) which will results in a highly costly process if the decentralized flexibility is managed the same way than today.
- As we will be shifting from a portfolio of dozens of flexibility resources to one of hundreds of thousands of such resources (albeit small), Elia must provide a scalable secure way to qualify decentralized assets and to ensure/verify the activation of these assets delivery monitoring), given that introducing flexibility in a conventional way would drastically increase OPEX costs and kill any business case for decentralized flexibility.
- The aggregation will of course happen at market level but as adequacy and the grid balance are a TSO responsibility, Elia needs to guarantee that at any time the required flexibility (whether aggregated or not) will actually be available and if not, Elia needs to quantify the lack of availability so that penalties can be applied accordingly.
- Therefore, Elia is looking into how to create trusted decentralized digital identities on the basis of self-sovereign identifiers for the decentralized assets that could then be used to authenticate any resources and validate the relevant activation (delivery monitoring) and potentially even payment. The status of each identity could be shared with other system operators to optimize the use of decentralized flexibility and provide access to the devices to multiple services (if the user agrees): balancing, market arbitrage, DSO congestion, P2P trading, proof of origin and use, etc.
- The technology comes with another promising benefit, in that it gives full control of the device to its owner who can easily give any service provider his or her consent without losing control of his/her data.
- As the blockchain is, by design, decentralized and trusted/ secured, Elia is looking into how this technology could facilitate the creation of a digital identity for the ancillary services market that could interface with the TSO system and could also be used for other market purposes.

- The project will also assess the feasibility of implementation, interfacing with legacy systems and the level of trust in blockchain technology for the primary and secondary reserve market (to be confirmed).
- As, in the future, electric vehicles could become a major source of flexibility, accounting for several GW if we consider the whole fleet of connected cars (in one-way charging 2 ways, charging-discharging, i.e. V2G), Elia decided to apply its first test to e-mobility.
- In an initial phase the goal of the project will be to test (including hardware components), if possible, the introduction of EVs onto the ancillary services market. After that, we could also consider the rest of the value chain of flexibility management: activation, validation, settlement, and payment.

Project-specific state of the art/literature review

- Elia contacted the Energy Web Foundation (EWF) as a strategical partner and had discussions with various players active in the blockchain ecosystem having experience of running proofs of concept on decentralized flexibility in the past two years:
    1. Austrian Power Grid (APG) is collaborating with the Energy Web Foundation with a view to connecting 1 million decentralized energy devices to a flexibility market based on the decentralized identifier (DID) concept.
    2. EnBW, a German energy supplier, developed a white paper describing a blockchain-based authority model to introduce decentralized energy resources (DER).
    3. TenneT already runs projects with Sonnen batteries to use the devices for balancing purposes and congestion management. Moreover, together with Vandebron, they connected electric vehicles to the balancing market.
- The aforementioned TenneT initiative gave birth to Equigy, which aims to provide a cross-TSO platform to manage flexibility. It mentions the use of blockchain technology to log energy transactions, but no information has been found regarding the specific application (which data and when). Also, the concept is based on a private blockchain closed to the consortium of TSOs while the current project is targeting the use of a public/semi-public blockchain that is also open to other market players such as DSOs.
- Alongside this, all larger vehicle manufacturers are discussing and testing DID solutions for autonomous driving. Bosch and Daimler Trucks are already implementing blockchain wallets in cars and trucks and is testing the solution with a view to using it to pay for parking services, etc. Daimler Mobility set up a Mobility as a Service platform that uses trust through DID to offer a seamless mobility experience and customer-friendly payment services.
- Therefore, Elia is aiming to test the application of DID for pre-qualification as well as for delivery monitoring. This can be seen as an initial step in the process of giving the power sector access to energy IoT devices with DID.

Expected impact for Belgium

- Assuming that the use of a trusted decentralized ledger could accelerate the registration of new flexibility resources and the pre-qualification test from *CONFIDENTIAL* days in total (registration, consent mechanism and pre-qualification test) to *CONFIDENTIAL* days and that in the future we will have millions of decentralized flexibility means active each day, the use of a blockchain-based solution to onboard DER means, monitor the delivery (or to give a tamper proof record) could avoid an increase in back office of *CONFIDENTIAL* additional resources internally (purely therotical).
- In the future, the use of a blockchain-based DID could facilitate the convergence of different sectors by linking the energy-market identity to other identities (mobility, consumer, industry, etc.) and vice versa that could then facilitate new optimization based on better exchanges of data and greater insights.
- The blockchain-based solution could also facilitate exchanges between the market players and create transparency regarding the cross-cutting use of flexibility.

Starting point for Elia

- In 2019, Elia concluded an initial proof of concept with *CONFIDENTIAL* and *CONFIDENTIAL* regarding the development of a flexibility exchange platform using blockchain technology. This project showed that blockchain technology could easily be used to store trusted data in a shared ledger and quickly create a common platform for the use of flexibility. The whole project was carried out in a closed environment without direct interfacing with flexibility, the related hardware, or the Elia's legacy system. That's why these proof of concept still left many hypothesis to verify, especially when it comes to the implementation of digital identity or the physical integration.

- For this reason, the goal of the project here will be to gain more understanding of the application by integrating directly with flexibility resources and delivery monitoring and prepare the concept of pre-qualification tests.
- Several companies are showing interest in participating to the PoC which is a clear indication that the topic is of high relevance.

Uncertainties and risks

- The main risk is the interfacing between the blockchain technology, the connected hardware, and the TSO legacy system which is highly complex to handle.
- Another uncertainty relates to the performance and the cost of the transaction for each item of data stored on the blockchain. Linked to this is also the issue of the type of data stored on the blockchain as du to the immutability and cost of storage, only relevant data will be stored on the blockchain.
- Another assumption to be validated concerns the immutability of the data on the blockchain.
- The highest learnings would be achieved with the participation of car manufacturers or suppliers of automotive technologies. At this point in time collaborations are discussed but no contracts signed. Alternatively, the PoC can be done software based (simulations) or with microcomputers simulating real devices.
- The most important lessons would be learned if automobile manufacturers or suppliers of automotive technologies were to participate.
- The input from the car manufacturers also serves as a reality check. Since OEM are naturally trying to keep identities internally and are careful with regards to decentralized systems. The concept might need to adapt in order to test and validate a relevant solution.
- Finally, as data will be immutably stored on the blockchain, the question of the GDPR compliancy needs also to be validated/ assessed.

Project description

- The project focuses on how Elia can access decentralized energy resources and verify the delivery flexibility from these new flexibility means. In this case EVs have a very important potential, for ancillary services for which the help of digital identities to facilitate their introduction (identification, pre-qualification) and verification of delivery.
- Elia aims to answer the technical and market questions related to the use of digital identity, embedded in a blockchain, for introducing decentralized flexibility and delivery monitoring:
  On the technology side:
  - First of all, there is the compatibility of authentication options with the high security standards of market communication processes. This includes elliptical curve encryption standards and also the protection of personal data.
  - The latter is linked to the challenge of having a transparent decentralized system based on blockchain technology on the one hand and GDPR requirements under which personal data must be protected on the other hand.
  - An efficient identity management system is required to connect entities and verify information. Information such as technical skills, capabilities, and ownership information (DID document) need to be vetted to make reliable statements about the asset behind the digital identity. At the end, such a solution needs to prove its worth compared to centralized solutions in terms of availability and reliability. At the same time the DID owners needs to be protected. With technologies such as zero knowledge proof DID owners do not have to expose all private data to service providers who at the same time have sufficient trust to offer services.
  - Various technical solutions to build DID are available. The goal is to increase understanding of these options and their applicability.

- To develop the application, the following options will be considered for authentication of EVs:
  - Cryptographic chips firmly integrated and with built-in wallets
  - SIM cards that are integrated into cars (e.g. provided by Vodafone and are part of the Energy Web Foundation network)
  - Physically unclonable functions (PUFs) or unique fingerprints of microchips promise a software-based identification without any hardware required.
  - Authority models where OEMs authenticate their cars through hierarchical validation process based on smart contracts (developed by EnBW). This solution could be combined with PUFs.
- For authentication, the following options (for each option potential partners are identified) will be considered in the project:
  - Cryptographic chips (firmly integrated and with built-in wallets - Riddle&Code) ;
  - Cryptographic SIM cards that are integrated into cars (e.g. provided by Vodafone and being incorporated into the Energy Web Foundation network);
  - Physically unclonable functions (PUFs) or unique fingerprinting solutions provided by microchips hold out the prospect of software-based identification without the need for any hardware to be involved;
  - Authority models in which OEMs authenticate their cars by means of a hierarchical validation process based on smart contracts (developed by EnBW). This solution could be combined with PUFs.

- On the market side:
  - The project aims to validate the scalability of pre-qualification at manufacturer level with an embedded digital identity at vehicle level.
  - It also analyzes the prequalification process at Elia and assesses efficiency gains by digitizing the process. Even new ways of PQ might be discovered. Today's processes are optimized for larger power plants which does not mean that these processes should be applied 1:1 to more decentralized devices.
  - The initial proof of concept already showed that 80% of the steps involved in changing suppliers can be skipped thanks to the use of blockchain technology to forge decentralized trust via DID. What is special about electric vehicles is that their location changes and with it, the balancing responsible party (BRP). Current market processes do not provide an off-the-shelf solution for this 'roaming' issue.
  - Proof of delivery becomes crucial if small flexibility devices reach larger shares. Automated processes with verification on a blockchain promise trust and scalability.
  - This is a first step in integrating devices with DID into the power system. Use cases can be expanded to cover congestion management ('redispatching'), adequacy planning, e-roaming, wholesale market trading, etc.

- Approach: Elia will team up with the Energy Web Foundation to develop the blockchain application and aims at winning partners such as manufacturers, technology providers (crypto-chip provider, mobility service provider, etc.), or other market players (CPO, MSP, suppliers, TSOs, DSOs, etc.) to develop an end-to-end delivery monitoring and pre-qualification process using blockchain technology.

- Work packages and timing (M = month)
  1. *WP 1: Project scoping and selection of partners*
     - *CONFIDENTIAL* : Project scoping and strategic alignment; market research, interviews, and exchanges with industrial partners (*CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL* *CONFIDENTIAL*, *CONFIDENTIAL*, etc.)
     - *CONFIDENTIAL* : Tendering and selection of a strategic partner
     - *CONFIDENTIAL* : Mapping of the pre-qualification process (FCR, aFRR, mFRR) and stakeholders
     - *CONFIDENTIAL* : Project scoping with the strategic partner in the form of a 'kick-off' workshop with the marketing and communication departments

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        - *CONFIDENTIAL* : Final project scoping and selection of an industrial partner
2. *WP 2: Designing of a blockchain-based pre-qualification/delivery monitoring process and development of the blockchain framework*
    - *CONFIDENTIAL*: Designing and modeling of the existing PQ process*/delivery monitoring* (FCR, aFRR/mFRR) to be applied on a blockchain basis
    - *CONFIDENTIAL* : Development of a concept for the blockchain framework by assessing the applicability of existing open source solutions and protocols (i.e. Open Charge network, communication and DID standards, etc.)
    - *CONFIDENTIAL* : Development of the blockchain framework and definition of DID specifications
3. *WP 3: Creation of DID and connection of the hardware*
    - *CONFIDENTIAL* : Establishment and testing of the connection of DID embedded in selected hardware solutions. Ideally use cars fitted with wallets to create, adapt, and communicate DID. This will go hand in hand with the testing and selection of communication options (Wi-Fi, 4G, charging pole infrastructure).
4. *WP 4: Test pre-qualification and delivery monitoring*
    - *CONFIDENTIAL* : Implementation of a simplified flex activation and a delivery monitoring on blockchain
    - *CONFIDENTIAL* : Automated registration of devices and PQ tests. On-chain validation of PQ by Elia Group and integration of PQ certificate in the DID document of the device.
5. *WP 5.1: Roadmap towards activation (TBD)*
    - *CONFIDENTIAL* : Definition of technical requirements of a balancing power activation process in real environment, or more specifically, how devices with DID can bid automatically on the balancing market. Assessment of opportunities for the tokenization of balancing energy and transfer of tokens to the fiat currency. Planning of the roadmap for the first car to autonomously bid and provide balancing power.
6. *WP 5.2: Settlement (TBD)*
    - *CONFIDENTIAL* : Development and implementation of the roadmap to automate the full balancing power value chain from DID creation until settlement. Assessment of the possible ways to link the cryptocurrency layer to the Elia Group's accounting system.

- Deliverables and milestones
    - *CONFIDENTIAL* : Preliminary scoping of the project
    - *CONFIDENTIAL* : Choice of the partner
    - *CONFIDENTIAL* : Final scoping of the first PoC
    - *CONFIDENTIAL* : Definition of the required blockchain framework, which is then developed
    - *CONFIDENTIAL* : Selection of hardware, creation of DID, and establishment of communication
    - *CONFIDENTIAL* : First delivery monitoring on BC, automated registration of devices and PQ certificates linked on DID document
    - *CONFIDENTIAL* : Successful testing in real environment of the activation of balancing power
    - *CONFIDENTIAL* : Successful testing of token-based payment

Partners

- 50Hertz (for the test bed and the support), other TSO's as *CONFIDENTIAL* , *CONFIDENTIAL* to share experience
- Development of the blockchain application: *CONFIDENTIAL*
- Development of the hardware: TBD (potentially *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL* , *CONFIDENTIAL*)
- E-mobility specialists: *CONFIDENTIAL* , *CONFIDENTIAL*
- E-mobility market players: Charging Pole Operators, Mobility Service Providers
- Energy suppliers: TBD depending on the opportunity and the test-bed.

- Elia Customer Relations Department

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR	2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Project scoping and selection of partner	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Design BC-based pre-qualification process and develop the blockchain framework	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Create DID and connect the hardware	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Test pre-qualification	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP5	Activation & Settlement	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 11: Robotics for inspection in remote, difficult, or dangerous locations

Domain 3.2

2020 decision: Accepted

Trend: Digital revolution

Consequences: Digital tools and data use, aging of the infrastructure

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.2 Automate inspection onshore and offshore

Project-specific context

The initial need for the use robots at Elia is based on two main challenges related to asset monitoring: inspection automation, and operation in dangerous or remote situation – aspects that are becoming more and more important due to new and more complex systems:

1. Some assets are difficult to physically access assets because of their location in dangerous environments (as HVDC converter station) or involve long and costly trips (offshore).
    a. This applies to remote locations such as an offshore platform, which takes at least 24 hours to reach (including planning), and even longer in bad weather conditions. Moreover, it is very difficult to deal with emergencies in such places because of this **time factor and the cost** of the helicopter. In these situations, robots can be a useful tool to perform a quick assessment and carry out low-level activities.
    b. It also applies to places where it is difficult to move and that are **hostile for humans**. A good example is the ALEGrO cable tunnel where an outage is required for any inspection to be performed due to a lack of oxygen, the absence of lighting, and high voltages. Moreover, installing sensors along the tunnel would be far too expensive.
    c. This is also the case for **places that are dangerous for both humans and equipment**, such as the converter hall of the Nemo interconnector, where nobody can enter when it is in operation due to the strong magnetic field and where conventional cameras do not allow a failure to be detected. Thermo-cameras could perform such detection but would be too expensive to be fitted out throughout the converter hall (around €1 million).
2. We see that on top of hostile environments, the deployment of fixed sensors has its limitations in terms of access to digitalized/connected infrastructure. Here, robot would be an innovative way to transport sensors, responding to these two main issues:
    a. **Lack of flexibility** for remote sensors: In remote locations such as offshore platforms, fixed cameras cannot cover every angle of the whole area and therefore cannot detect every problem. An example is a water leakage that requires a moving camera to be detected on the ground. Flexibility can also be seen in the possibility of changing the sensor on the robot or upgrading to the most up-to-date technology instead of undertaking a major operation to change all fixed sensors.
    b. High **deployment costs** to cover particular areas: As mentioned before, the number of cameras required to cover a complex environment such as the Nemo Link converter hall (with many large converter modules) is huge and costs about €1 million while a robot costs about €80,000 (cost of the robot only).

Project-specific state of the art/literature review

- Robots on wheels or caterpillars have been in use since 2013, with a first deployment by State Grid of China to automate the inspection round in an onshore substation. Today, in total, more than 20 substations are currently covered and the robots are controlled by a central control room for infrared and visual inspections, replacing foot patrols. They have enabled a 75% decrease in the time required for infrared inspection and a 50% decrease in the operator's workload.
- TenneT also has also tested an 'animal-shaped' robot in an offshore substation. However, tests are still ongoing and there is still no clear conclusion regarding the potential of such technology. TenneT is now starting a five-year R&D program with a university and a supplier to assess the potential of such technology.
- In other business segments such as offshore oil rigs, use of a robot is becoming more and more common for multiple inspections. For example, Total is currently using its brand-new version of a robot on one of its sites in Scotland.
- Among the different sectors, such as the military sector, have been developing robots since years but focusing largely on hardware. These robots are able to do a lot in harsh environments but are mainly teleoperated and not benefiting from autonomous algorithm for industrial environment.
- Research has been conducted mainly into hardware, such as in army applications, and remote control.

Expected impact for Belgium

Robot technology, by addressing the issues mentioned above, can impact the efficiency and quality of maintenance and therefore avoiding risk of outages thanks to a more prcise and systematic inspection, thereby improving monitoring and operation, but also can affect safety by averting human exposure to danger.

- Based on a rough estimate, in the context of the ALEGrO project a robot being used to inspect the tunnel could halve the need for a planned outage.
- In the case of the Nemo Link, the use of a robot for an inspection in the converter hall could enable early detection of a fault in a power module, reducing the risk of an outage and therefore an imbalance for Elia and the related impact on the short-term market. Based on an assumed risk of default Elia could then in average avoid *CONFIDENTIAL* /year.
- The estimate of the impact for inspections in substations could be close to the State Grid of China case (a *CONFIDENTIAL* reduction for thermography) and we could avoid up to 20 trips to the offshore platform per year. However, we first need to better understand what the capability of robots in the Elia onshore and offshore substations would be.

Starting point for Elia

- Elia has no experience with robots.

Uncertainties and risks

- The main uncertainty surrounds not the robot itself since, as we mentioned before, the hardware is already developed and tested in the military sector for example, but rather the ability to perform tasks specific to Elia's core business. The main risk is then related to the robots' adaptation to our environment (e.g. substations onshore and offshore, air or gas insulated…).
- In the case of robots in substations, the primary uncertainty is that the robot can actually perform normal tasks required for inspections, ranging from opening 30-kg doors to climbing stairs in a substation or reading the various meters required. This relates to both hardware and software development capabilities.
- The software aspect is shrouded in great uncertainty because it requires specific development for our core business, while the hardware is challenged by many other sectors.
- In the case of the use of robots in the Nemo converter hall, a major risk is that robots will also operate in an environment with a strong magnetic field. Another resulting risk of this use case is that the manufacturer does not accept the

presence of robots in such an environment without affecting the terms of its guarantees. Finally, another risk could be that robots can also damage equipment by triggering electrical arcs.

- Finally, in all these cases an additional uncertainty is that in every situation, high-quality and stable communication must be maintained between robots and the control room, as must the battery range for the various robots.

Project description

- The project covers the three use cases mentioned above:
  - ALEGrO tunnel: tailoring the development of robots on wheels to perform remote inspections of corrosion and water leakage and check cable fixtures after a short-circuit;
  - Nemo converter hall: testing robots so that they can perform inspections regarding heat and leakages alongside general continuous inspections;
  - Onshore/offshore substations: testing of robots on wheels / caterpillar for basic inspection work and thermography.

  For the first two cases, the goal is to select a supplier and develop solutions tailored to the environment and then perform testing in real-life conditions to validate the capacity of the robots.
  For the last case, the initial goal is to understand the capabilities of the robots in a substation environment that might be followed by specific use cases.

- Approach: For each of these use cases, we will team up with an external provider to test existing robots and in some cases develop specific features. In the case of the Nemo converter hall, we have envisioned to partner with a laboratory for resistance to the strong magnetic field.

- Work packages and timing (M = month)
  1. *WP 1: Exploratory work*
     - *CONFIDENTIAL* : Research study and contact with market players
     - *CONFIDENTIAL* : Identification of use cases
     - *CONFIDENTIAL* : RFP for the most challenging use cases in order to select suppliers with the most appropriate capabilities
  2. *WP 2: Robots for tunnel inspection*
     - *CONFIDENTIAL* : Roundtable with the TSOs owning the ALEGrO tunnel and shortlisted suppliers with an off-site demonstration
     - *CONFIDENTIAL* : Selection of final suppliers
     - *CONFIDENTIAL* : On-site demonstration
     - *CONFIDENTIAL* : Performance of *CONFIDENTIAL* laboratory tests
     - *CONFIDENTIAL* : Final selection
     - *CONFIDENTIAL* : Robot development and adaptation through iterative steps
  3. *WP 3: Robots for converter hall inspection*
     - *CONFIDENTIAL* : Study of the problem
     - *CONFIDENTIAL* : Supplier identification
     - *CONFIDENTIAL* : *CONFIDENTIAL* study and laboratory tests
     - *CONFIDENTIAL* : Robot R&D
     - *CONFIDENTIAL* : Similar environment tests
     - *CONFIDENTIAL* : Decision on implementation
  4. *WP 4: Robots for substation inspection*
     - *CONFIDENTIAL* : Identification of scenarios
     - *CONFIDENTIAL* : Roundtable with other TSOs that worked with unmanned ground vehicles (UGVs)
     - *CONFIDENTIAL* : Online assessment of remote capabilities
     - *CONFIDENTIAL* : Scenario filtering 1

- *CONFIDENTIAL* : Off-site visit and first high-level use cases involving testing on current supplier work sites (*CONFIDENTIAL* l)
- *CONFIDENTIAL* : Scenario filtering 2
- *CONFIDENTIAL* : On-site test: AIS/GIS training
- *CONFIDENTIAL* : Scenario filtering 3: Selection of use and offshore adaptation study
- *CONFIDENTIAL* : Same procedure for offshore

Partners

- Supplier for the Nemo converter hall: *CONFIDENTIAL* (TBD)
- Supplier for the ALEGrO tunnel: *CONFIDENTIAL*
- Supplier for onshore/offshore substations: *CONFIDENTIAL*
- Consultant for project management support (bodyshopping)
- In parallel, *CONFIDENTIAL* has been consulted and there are ongoing discussions to assess the impact of robotics on offshore platform inspections.
- Elia Asset Maintenance Department, including the Transformation and Offshore teams

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Analysis of robotics for Tunnel inspection	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Robotics fr HVDC converter hall	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Robotics for on/offshore substation	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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Domain 3.3

Project 12: Test of predictive maintenance for critical asset

2020 Decision: Rejected

Trend: decarbonization & sustainability, digital revolution

Consequences: Digital tools & data use, ageing of the infrastructure

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.3 Predict and optimize preparation of the maintenance

Project Specific Context

- Currently the asset maintenance strategy within Elia is strongly time-driven, the conditioned based maintenance has started to be developed notably in the context of the ACC project (see project 2 in this document). This should be sufficient for main part of the grid equipment as the design of the transmission network has built-in redundancy. However not all element of the substations benefit from this guarantee or need to be very closely followed due to their criticality.
- The criticality of these maintenance will increase in the future for multiple reasons:

    1. Aging infrastructure and workforce with experienced technicians retiring drives more maintenance activity with less experienced people;
    2. As a result, time based maintenance becoming unsustainable as workload exceeds the capacity of the available technicians;
    3. Manually collected and entered inspection data is too limited and slow for the needed real-time monitoring of asset health;
    4. Outage arrangement and permission approval procedures constrain and limit access to take assets out of service for maintenance;
    5. Increasing risk of congestion following an unplanned to outage (and therefore more) due to the high renewables penetration and the intermittency and uncertainty of energy flow. This could also results ultimately in down-time for the end consumer.

- As a result of all these trends, it is foreseen that by 2022 the number of critical outages in the network will double.
- That's why Elia is investigating for certain class of asset (e.g. transformers) the use of artificial intelligence to better predict when these critical assets needs to be maintain in order to avoid an outage.
- This technic should apply to a certain test zone which it will be critical to extend life beyond 2023 in the 36/70kV network.

Project specific State-of-the-art/Literature study

- Different TSO's: Tepco, Red electrica and RTE are testing predictive maintenance but results are still unknown (class of asset and impact).
- Red electrica is using the module *CONFIDENTIAL* for predictive maintenance test.

Expected impact for Belgium

- Reduction of the Energy non served (the exact percentage still need to be quantified).

Starting point Elia

- As a starting point, Elia is setting up the condition based maintenance in the project ACC (project 2) where health index has been set-up.

Uncertainties & risks

- Different dimensions could be identified as risk/ uncertainty for the application to predictive maintenance for the infrastructure of Elia:
  - **Too little data**: firstly the data are not necessarily recorded since a long time or even do not exist at all. In parallel, the number of unplanned outage is generally quite limited leading to difficulty to train the model.
  - **Too little time**: Even when it's possible to create a predictive model, this is generally applying to a very limited time which will be too short to allow a rescheduling of a maintenance and enable effectively an active management of the unplanned outages.
  - **Too little impact**. The impact might also be limited for some asset that are redundant due to N-1 criteria.
  - **Too little savings**. Finally, the savings that could be achieved by such model needs to be evaluated and will depend on the potential of unplanned outage reduction of such predictive model which is highly uncertain.

Project description

- The project will consist on the development of a solution that predict automatically predict any maintenance needs for a certain type of assets starting from 2 specific zones (36kV network in the West of the grid and 70kV network in the South of the network).
- The solution should be based a pre-trained artificial intelligence algorithm developed internally in partnership with expert data scientist.
- Approach: The product will be led by an internal team but the development will be made in collaboration with an external provider.

- Work packages & Timing(M=month)
  1. *WP 1 Scoping*
     - *CONFIDENTIAL* : Scoping of the project and identification of the zone to apply the test
  2. *WP 2 Data acquisition*
     - *CONFIDENTIAL* : Identification of the data to be used
     - *CONFIDENTIAL* : Connectivity set-up and/or extraction of historical data
  3. *WP 3 Prototyping*
     - *CONFIDENTIAL* : Development of the algorithm
     - *CONFIDENTIAL* : Development of the interface of the solution
  4. *WP 4 Testing*
     - *CONFIDENTIAL* : Testing of the solution based on historical data on the identified class of assets for the selected zone
     - *CONFIDENTIAL* : Expand to other class of assets or locations
  5. *WP 5 Conclusion*
     - *CONFIDENTIAL* : Conclusion report

- Deliverables & milestones

  - *CONFIDENTIAL* : Scoping of the project
  - *CONFIDENTIAL* : Prototype results
  - *CONFIDENTIAL* : Final report

Partners

- The department of asset management will be in the lead of the project definition
- The digital department including innovation and the data department will contribute to the project for identification of the problem and the scope (innovation) and the extraction of the data for the training of the model (data)
- The artificial intelligence development will be led by an external consultant from *CONFIDENTIAL*.

Summary of project efforts in person months: per work package and per year

Total Project	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Scoping	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Data acquisition	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Prototyping	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Testing	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 5	Conclusion	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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Project 13: Training and collaboration in virtual and mixed reality

Domain 3.4

2020 decision: Accepted

Trend: Digital revolution

Consequences: Digital tools and data use

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.4 Secure and connected Workforce

Project-specific context

- The user experience offered by mixed reality (where a virtual element can be visualized and interact with the existing environment) and virtual reality (when the user is immersed in a completely virtual environment) is improving at breakneck speed. In recent years, multiple breakthroughs have made these technologies viable and useful in business environments. In many cases, they can help our workforce to improve workflows, operate more safely, and collaborate more effectively.
- For a few years now, at Elia we have been investigated the use of virtual and mixed reality in multiple facets of our day-to-day tasks. However, previous iterations of the technology were not user friendly and involved a complex configuration procedure, cumbersome hardware, and low image quality. The quality of the hardware and software available at the time meant they could not be used in a production environment.
- With the recent development and the democratization of the technology with new hardware solutions like the Hololens 2 and the Oculus Quest, all these issues disappeared. They are now portable and much easier to use and do not require a specific room or separate computer to be set up for them to work. They can work anywhere and anytime, and they can be set up in less than a minute. These new headsets are also much lighter and more comfortable to wear. All these improvements make them the perfect tool to achieve what the previous generation of hardware could not.
- Therefore, the mixed reality can be used for better collaboration and understanding of the existing environment (i.e. to communicate more efficiently in real time with experts in remote locations during an inspection), and virtual reality could be notably used to immerse Elia operator in dangerous conditions for training purposes (e.g. a strong magnetic field in the converter hall of an HVDC interconnection, offshore platform, etc.).

Project-specific state of the art/literature review

- Some corporations in various industries are already testing the technologies for manufacturing purposes, e.g. Sidel, Tetra Pak, PSA/VW/Renault.
- In late 2018, RTE tested virtual reality as a training tool, but no information is available regarding its use for offshore activities or climbing transmission towers.

Expected impact for Belgium

- Limitation of the number of FTEs participating in training (estimated reduction impact at *CONFIDENTIAL* FTEs)
- Reduction in maintenance costs:
  - reduction in experts' trips offshore (cost TBD);
  - reduction in team numbers and increase in efficiency onshore (quantification TBD)

- Decrease in commuting costs (assuming a cost of €*CONFIDENTIAL* /FTE for a 40-minute commute (round trip off-shore), this could amount to €*CONFIDENTIAL* /year) – a refined quantification will be part of the definition of use cases

Starting point for Elia

- Elia already has prior experience of this technology. Two years ago, the SARQA VR project replicated a substation in virtual reality to enable visualization of hazardous high-voltage areas and interactions with various items (a construction truck, a ladder, etc.).
  - This project taught us that the technology was not yet ready for day-to-day use at Elia and should be re-evaluated at a later date.
- We also held various workshops sessions involving external enterprises and various Elia departments to brainstorm a potential use case and assess the levels of interest and traction among end users. The result is the use case described in this document: collaboration and training
- The available technology, hardware and software are currently being evaluated.

Uncertainties and risks

- The technology is fairly new and changing rapidly; we are confident that it is now mature enough to form the basis for this project, but it has not been widely tested in a production environment.
- As the technology is new, end users' reaction to it and their take-up may vary. Recent breakthroughs have made the technology much easier and more comfortable to use but end users' perception of it may be affected by a previous impression that it was chunky and cumbersome to use. It will be a challenge to get end users to adopt the use cases without trying the technology themselves. Therefore, promoting and communicating about it will be major priorities.
- We will have to emphasize the quality of our 3D visualization and user experience to optimize user take-up.

Project description

We identified three areas that could really benefit from virtual and mixed reality. However, all of these share an initial technological exploration phase.

- Work packages and timing (M = month)

- WP 1: Technological exploration
  - *CONFIDENTIAL* : During this first phase we will meet existing suppliers and obtain test hardware and software licenses and evaluate them for the next phase.

- WP 2: Training: Improving our workforce's hard and soft skills with the aid of virtual and mixed reality
  - *CONFIDENTIAL* : Climbing Transmission Towers use case (hard skills): Working in a high-voltage environment is dangerous, leaving no margin for error. As a result, it is problematic to put our personnel in the kind of hazardous situation they might encounter during their career. Providing staff with a simulation and immersion tool so that they can experience these situations in a learning environment where they can make mistakes is a major step forward in terms of the quality of our training courses. Virtual-reality e-learning is an immersive process that is mature enough to be used in the initial projects that are under construction.
  - *CONFIDENTIAL* : Edison use case (soft skills, centered around Edison, Elia's training substation): Being able to react to a dangerous error made by a co-worker is an important skill within a team. Providing staff with a simulation of work colleagues' actions in a dangerous situation and asking them how to react will help them to prepare for a real-life work situation.

  Both use cases offer the same series of advantages. For example, they enhance training, enable repetitive training without the need for a trainer, reduce training time and costs, accelerate changes in behavior, etc.

- WP 3 Sharing in remote location to increase efficiency:Improving sharing and collaboration between teams in remote locations. This work package is even more important now following the COVID-19 lockdown. Elia was able to keep all its administrative operations going during lockdown because we had the modern tools to share and communicate information. Improving these tools through more immersion, easier sharing, and collaboration between personnel working together remotely is key to being prepared for the future. Moreover, enabling more remote collaboration will help to reduce our carbon footprint by avoiding unnecessary travel for meetings. It will also mean that remote support can be provided for both field work and offshore operations.

    - *CONFIDENTIAL* : Connected Screens in Substations use case: Up to now, most of the information and plans drawn up during work planning in the field are provided on paper. These documents are not always the latest version and cannot be shared for collaborative purposes with members of a team working elsewhere. Installing touchscreens in substations would be a big step in the right direction in this regard.

    - *CONFIDENTIAL* : Virtual Meetings between Sites use case: Elia personnel are wasting a lot of time traveling to meetings across Belgium as remote meetings are currently less efficient than all being in the same place. Allowing more interactive and immersive meetings between sites with virtual telepresence and collaborative tools will help to reduce the time lost on journeys to and from meetings.

    - *CONFIDENTIAL* : Virtual NCC Control Room use case: Currently, control rooms use a big wall to display a huge amount of information. It is impossible for operators to see all of this information remotely as no screen available to the general public is large enough to display all of it. Replicating this information in a virtual control room accessible in virtual or mixed reality would allow control-room operators to take action remotely in case of an emergency on the grid.

- WP 4 Improving maintenance, support, and work planning for our substation and sites:
    - *CONFIDENTIAL* : AR-impetrant use case: During construction work, knowing where to dig to avoid damaging existing infrastructure is vital. For instance, cutting a water line or gas line could cause catastrophic damage. Most infrastructure can be found on maps but it is sometimes complicated to interpret these in situ. This use case aims to make underground infrastructure visible in workers' field of view because it is much easier to avoid digging up a pipeline if you can see it. (November)
    - *CONFIDENTIAL* : Remote Support use case: Getting experts from the industry to resolve an issue at remote locations like the offshore MOG in the North Sea is sometimes complicated and takes a lot of planning. The expert sometimes needs to travel from another country and needs to have certification to enter the site. Mixed-reality technologies allow a normal field worker at the relevant location to share their ideas and collaborate remotely with an expert in order to carry out required maintenance and repairs on an asset without the need for the expert to be present in person. The use case will involve onshore testing before offshore testing.
    - *CONFIDENTIAL* (TBD): Closed-Off Planning use case: Elia often has to plan work for restricted areas. Some buildings or tunnels cannot be accessed easily as doing so would involve having to cut off part of the grid or conducting a lot of preliminary security/safety checks. By replicating the location in a 3D environment and allowing it to be explored and work there to be planned virtually, we aim to greatly facilitate the work of our field operators.

- Approach: Elia will test set of hardware and software required for each use case and will work with external suppliers and experts in the industry. It will be supported by a full-time expert consultant, who will help to manage and organize the projects.

- Deliverables and milestones
    - *CONFIDENTIAL* : Comparative report of various technologies
    - *CONFIDENTIAL* : Obtain and set up hardware for mixed reality and connected screens

- *CONFIDENTIAL* : working demo/proof of concept for the Remote Support use case
- *CONFIDENTIAL* : working demo/proof of concept for the Climbing Transmission Towers use case
- *CONFIDENTIAL* : working demo/proof of concept for the Closed-Off Planning use case
- *CONFIDENTIAL* : working demo/proof of concept for the Virtual Meetings between Sites use case
- *CONFIDENTIAL* : Have a working demo/proof of concept for the Edison use case
- *CONFIDENTIAL* : Have a working demo/proof of concept for the Connected Screens in Substations use case
- *CONFIDENTIAL* : Have a working demo/proof of concept for the Virtual NCC Control Room use case and an impact assessment
- *CONFIDENTIAL* : Have a working demo/proof of concept for the AR-impetrant use case

Partners

- Multiple hardware suppliers for the augmented-reality and virtual-reality headsets, connected screens, capture tools, cameras, LIDAR technology, and other necessary accessories
- Multiple software providers for tools for collaboration, operation, capture, etc.
- Experts from the industry to organize workshops and brainstorming sessions and help with planning proofs of concept
- Elia departments and teams, e.g. Assets management, infrastructure, offshore

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Technological exploration of Virtual and Mixed Reality	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Improve our workforce hard and soft skill training with the help of VR and MR	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Improve sharing and collaboration between teams in remote locations	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Improve maintenance, support and work planning for our substation and sites	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 14: Use of artificial intelligence to automate dispatching

Domain 2.3 Domain 2.5

2020 decision: Accepted

Trends: Decarbonization, supranational coordination, decentralized generation and new players, digital revolution

Consequences: Uncertainty of generation, intermittency of generation, new decentralized flexibility means, digital tools and data use

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.3 Predict and automate imbalance dispatching decision

2.5 Automate maintenance planning, the congestion and the outages

Project-specific context

- As described in section 3.2, the uptake of renewables (50% by 2030 following the ambition of the green deal) will increase the complexity of dispatchers' work, e.g.:
  1. an increased residual load;
  2. a risk of frequency instability due to low inertia;
  3. the need to replace 48% of voltage control from nuclear power plants with decentralized alternatives;
  4. a shift from dozens to hundreds of thousands of flexibility resources;
  5. an increase in forecast errors to 2 GW on an hourly basis for offshore activities, and an overall increase of 50% in flexibility resources.
  6. A ramp of up to 4GW/h in exceptional (considering 4.4 GW of offshore installed capacity)
- On top of this, decisions made by dispatchers are always collaborative, which means that many counterparts and interdependencies need to be considered. Dispatchers need to know all the grid constraints, especially as the grid is operated closer to the limit than before, while the role of voltage regulation must also be taken into account.
- In the future, the need for multi-dimensional optimization (voltage, imbalance, congestion) along with the volatility of the system will increase and result in many uncertainties: for example, a deviation from the wind production in a short-term forecast might mean that a planned outage will now create dangerous congestion that could trigger some re-dispatching and therefore have some impact on energy prices.
- Considering that the system will be operating closer to the limit and the emergence of a decentralized system, the number of decisions that need to be made in dispatching will dramatically increase (just for balancing, we could move from 50 to more than 1,000 activation messages), soon expanding beyond what can be handled by the human brain alone.
- With all this information in mind, Elia is looking at creating a smart dispatching system which can initially help the grid operator with their day-to-day decisions and operation process and ultimately automate these processes as much as possible.
- The smart Dispatching system could take on multiple forms, first by automating laborious tasks, and second by supporting Dispatchers in their decision-making process:
  - it would initially be used for accurate forecasting, eventually shifting into support for Dispatchers' decisions and finally full supervised automation;
  - it would also be deployed for various dispatching decisions: frequency regulation, voltage regulation, congestion and outage management, incident management, inertia, etc.
- In this context, the project is aiming to test artificial intelligence's ability to reduce the burden on the grid's Dispatcher so that the latter can make better decisions and not miss dangerous situations. The following tasks were identified:

- Automation of switching notes at regional control center level to reduce errors in planned outage management at regional level;
- Forecasting of the imbalance to improve frequency control management;
- Automatic alarm filtering in case of an incident, making the response to any incident safer and more systematic;
- Subsequent identification of other use cases.

Project-specific state of the art/literature review

- Today, the state of the art is not very well documented. We see many European TSOs working in this direction, but practical implementation will depend largely on the TSO-specific context.
  - AI is not an unknown quantity. We see it in digital applications such as Google Maps and Uber, and applications such as the autopilot in commercial aircraft have also adopted it.
  - ENTSO-E developed a roadmap targeting a fully automated control center as part of *ENTSO-E RDI Flagship 6*. Indeed, one of the work packages for after 2020 is called *Virtual control centers and AI-based decision support systems*.
  - The Electric Power Research Institute (EPRI) notes that "ML [machine learning] methods can provide significant value to future grid operations".[5] However, this value still has to be harvested.

Expected impact for Belgium

- As set out in the context section for this project, the system complexity will increase. For instance, by 2030 the residual load error will rise , half of voltage control will need to be sourced among new resources (after the nuclear phase out) and the number of flexibility resources will move from dozens to hundreds of thousands.
- Automation will limit the risk for the operator:
  1. Imbalance forecasts could enable better decision to be made in term of volume activated (this could result in a potential decrease of several % in the activation cost). On top of that, they should increase grid resilience as normally higher margins should be available on the most dynamic (fastest) assets.
  2. Among the notes prepared for the outage operation, currently, 60% of switching notes need to be revised, and the goal is to achieve 90% correct switching note in an initial phase, using artificial intelligence or implemented business rules.
  3. Alarm filtering will reduce the time required to identify the root cause and provide a solution to an incident, thereby reducing their impact (and associated costs) and indirectly support the adequacy of the grid.

Starting point for Elia

- A first initiative was performed at Elia in 2017 to test the use of artificial intelligence in forecasting imbalance. The results were encouraging, but it took a long time to train the model (3 months). We are now aiming in the first WP of the project to achieve more efficient training of the forecast algorithm.
- Elia is gaining maturity in the field of artificial intelligence. We know that the field is already quite advanced externally, with many new applications making use of AI, but none have been implemented at Elia. We are integrating knowledge via partnerships and thereby building up our expertise.

Uncertainties and risks

[5] EPRI – Control Center of the Future. EPRI European Virtual Workshop Week 2020, April 20, 2020

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- The first uncertainty, of course, surrounds whether in each case artificial intelligence can provide the quality of data we need (e.g. error levels in imbalance forecasts, correctness of switching notes, correctness in filtering alarms).
- The second uncertainty relates to whether the algorithm can be trained for continuous learning when the situation is changing all the time.
- Another unknown is how long such computation could take.
- We need to make a clear decision on how we deal with black-box models, or whether we only accept 'explainable AI'.
- We need to ensure that, where relevant, human supervisors will be able to overrule decisions made by AI.
- Data quality and availability is always a big issue, following the 'garbage in = garbage out' principle.

Project description

- The main aim of the project is to further integrate automation based on artificial intelligence, more specifically machine learning, into the system's management tools.
    1. We started off working on the aspect of forecasting system imbalances. After defining the proper input parameters for a machine learning-based model, the model is being trained and analyzed, with a view to making better dispatching decisions.

    Results so far: We were able to forecast the imbalance using multiple data sources. We studied which predictors had the biggest impact on the system imbalance. We also assessed the length of the training period, with a view to incorporating recent changes in the grid. We have an idea of the frequency at which the model should be retrained. A benchmark was established making a comparison with the tools currently used in Dispatching and with freeware. This is now being passed on to the business departments, where it is being offered as a discretionary incentive.

    2. The second part of the project aims to develop a tool to automate the creation of switching notes. If switching notes could be created automatically, the dispatcher would be able to spend the time freed up by this on other, high-return work. We want the tool to create switching notes for 'standard' situations automatically (e.g. 80% of all notes), with only exceptional situations probably still being handled by a human.

    Results so far: Half a year into the development of the tool, we can now create some types of switching notes. We have clustered the process into different operations, such as isolating and connecting to earth, and different grid topologies such as lines with multiple extremities, transformers, and busbars. We aim to put in place a pragmatic mix between applying business rules and enhancing the results with AI. We are incorporating feedback from actual Dispatchers to assess and improve the performance of the tool. We are also thinking about various subsidiary items, such as visualization of the steps suggested by the tool, indicating a confidence level for the notes created, and further digitalizing the whole switching process (from paper to digital devices, etc.).

    3. Third, following an incident, the dispatcher needs to act quickly and restore the grid by solving the problems that have occurred. However, in case of incidents, the SCADA system retrieves a large amount of information. In most cases, most of this information is not relevant to the operator. Worse still, some of it has no real meaning because of its aggregation at field level. This makes it very difficult for the operator to assess and react to the situation, resulting in a risk of a late reaction. Several developments are planned as part of this project:
        - Development of an intelligent alarm filtering system to display only those alarms that are relevant to the operator, highlighting the root cause of the incident;
        - Automatic suggestions of corrective measures issued to the operator, summarizing the advantages and disadvantages of each of them;
        - Automatic application of corrective measures.

- Approach: For the first project we want to team up with a vendor of innovative artificial intelligence algorithms (*CONFIDENTIAL*). The other two projects (automation of switching notes and filtering of alarms) will be developed internally in partnership with an external expert on artificial intelligence (*CONFIDENTIAL*).

- Work packages and timing (M = month)
  1. *WP 1: System imbalance forecasting*
     - *CONFIDENTIAL* : Scoping and problem analysis
     - *CONFIDENTIAL* : Data gathering and development
     - *CONFIDENTIAL* : Training and tests in Dispatching
     - *CONFIDENTIAL* : Test results, analysis of feedback, closure of the POC phase
     - Future: Process of industrialization
  2. *WP 2: Automation of the switching notes in the regional control center*
     - *CONFIDENTIAL* : Analysis and modeling
     - *CONFIDENTIAL* : Data gathering and initial model building
     - *CONFIDENTIAL* : Testing of and feedback on easy use cases
     - *CONFIDENTIAL* : Integration of feedback, increase of complexity
     - *CONFIDENTIAL* : Closure of the POC phase
  3. *WP 3: Incident management*
     - *CONFIDENTIAL* : Scoping
     - *CONFIDENTIAL* : Interviews and desk research
     - *CONFIDENTIAL* : Feasibility check
     - *CONFIDENTIAL* : Reporting and launch of development
     - *CONFIDENTIAL* : Testing and validation

- Deliverables and milestones for 2020
  - *CONFIDENTIAL* : Presentation of imbalance forecast results (WP1)
  - *CONFIDENTIAL* : Decision on imbalance forecasting for a discretionary incentive, implementation
  - *CONFIDENTIAL* : Switching notes keynote 1: First implementation (WP2)
  - *CONFIDENTIAL* : Switching notes keynote 2: Increased complexity
  - *CONFIDENTIAL* : Switching notes keynote 3: View on integration into business
  - *CONFIDENTIAL* : Final switching notes tool ready, roadmap for integration into business available
  - *CONFIDENTIAL* : Kick-off for incident management (WP3)
  - *CONFIDENTIAL* : Initial incident management tool ready, proof of concept finalized, roadmap for the future
  - *CONFIDENTIAL* : New opportunities for automated dispatching identified

Partners

- Solution provider for the artificial intelligence algorithm: *CONFIDENTIAL*
- External expert for the partnership regarding internal artificial intelligence development: *CONFIDENTIAL* via the Elia Group's Center of Excellence on Artificial Intelligence (CoE AI)
- Elia's national and regional control centers
- 50Hertz's transmission control center

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Imbalance (NCC)	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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WP 2	Operational notes automation (RCC)	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Incident management (RCC)	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 15: Analyzing vibration sensors for our infrastructure monitoring

Domain 3.3

2020 decision: New – not submitted

Trend: Digital revolution

Consequences: Aging of the infrastructure, digital tools and data use

Challenges: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.3 Predict and optimize preparation of the maintenance

Project-specific context

- Elia operates about 22,000 high-voltage transmission towers across Belgium made of lattice structures interconnected by power lines. Some of these towers are quite old considering that 20% of the grid are more than 80 years old, and 80% of towers are more than 40 years old which very high compared to the European average. Nowadays, targeted audits are performed, providing periodic non-continuous data about structures while visual inspections are costly, time consuming and difficult to objectively quantify. Moreover, detailed drawings are often missing, and records of repairs carried out a long time ago are incomplete.
- At the same time the IoT technological breakthrough and the democratization fo the technology are offering new opportunity. Therefore, a low-cost monitoring strategy, based on an IoT solution and advanced data processing algorithms, should be developed to track in continuous the physical parameters of a tower which can be linked to its in-situ structural behavior.
- These data-driven reduced digital twins should make it be possible to detect changes over time, compare the behavior of comparable structures within the fleet, and objectively and quantitatively assess the structural reliability of each asset.
- Finally, all the towers need to be painted regularly to prevent corrosion. Therefore some damages cannot be visible by human eyes or camera during an inspection. It's why an alternative solution inspected the internal and global behavior can completes a traditional analysis.
- The project will also result in safer working environments as structural integrity can be determined before workers access structures and so put themselves potentially at risk. Climbing work on towers in a normal state is covered by working methods and intrinsic safety devices. However, all these precautions are only valid if the structure is in an acceptable condition, and that is what we would like to evaluate with this new technology.

Project-specific state of the art/literature review

- Ambient vibration test of Rainbow Bridge, in Tokyo, performed by the University of Exeter (UK) and the University of Tokyo
- Research collaboration on asset management of bridges between the University of Exeter's Vibration Engineering Section and the University of Cape Town (contact: Prof. *CONFIDENTIAL* (University of Cape Town))
- Test of Com&Sens monitoring of offshore wind turbines

Expected impact for Belgium

- For Elia, this is an opportunity to make headway on its digitalization projects for its infrastructure in the years to come and integrate the initiative in a wider IoT perspective (see project 17).
- The tracking of the infrastructure health will also benefit to the capex cost reduction and the decrease of outage risk.

- The project also results in safer working environments as the structural integrity can be determined before workers potentially run a risk by accessing structures. Indeed the precautions from standard methods used currently are only valid if the structure is in an acceptable condition, and that is what we would like to evaluate with this new technology.

Starting point for Elia

- For one and a half years, Elia has been looking at the state of the art for vibration analysis. The initial approach was to find objective data to determine towers' aging and reduce the impact of human advice. During this research, we have started to work with *CONFIDENTIAL* and *CONFIDENTIAL* solutions and have already installed a prototype on two new towers. The idea was to validate the design of these new towers, but we decided to also take this opportunity to collect vibration data. The initial results look promising for further research and the launch of this project.

Uncertainties and risks

As this technology does not currently exist, multiple technical aspects could result in failure, such as:

- Climate effects (wind, temperature, etc.) that can affect the results, leading to uninterpretable results;
- The impact of the natural vibrations from the conductors;
- The level of details that need to be available for a vibration analysis.

Project description

- A twofold strategy is proposed based on the fleet-leader concept. Under this concept, various assets will have an extensive measurement set-up that should make it possible to develop a better understanding of the envisioned structures. Alongside these, a fleet-leader low-cost monitoring solution will be developed that could be rolled out across the entire fleet. Combining the knowledge of the fleet leaders with data coming from the entire fleet, a fleet-wide comparison and assessment can be made using advanced machine-learning algorithms. This should make it possible to significantly improve current Operations and Maintenance (O&M) decision support, reduce visual inspections, cut maintenance and repair callouts, and – most importantly – lower the risk of (catastrophic) failures and potentially extend the operational lifetime of the monitored structures by taking the appropriate corrective action.
- <u>Approach</u>: Vibration analysis has already been shown in various specific domains that it can be used for predictive maintenance by detecting damage before critical problems occur and before there are visible with the eyes.. This technology is already well known for operating engines but not for static structures subjected to climate factors. A small-scale partnership between *CONFIDENTIAL* , and *CONFIDENTIAL* has already been studying this technology for wind turbines, resulting in an initial monitoring solution for these in an offshore environment. After discussions with all of them, we decided to work further together on identifying what could be done for HV towers. The approach involves each specific partner handling its field of competence:
    1. Elia: Knowledge of the grid and towers
    2. *CONFIDENTIAL*: Theoretical research and in-depth knowledge of vibration analysis
    3. *CONFIDENTIAL*: Knowledge of the data and platform implementation and captors

- Work packages and timing (M = month)

    Part 1: Development of a monitoring approach for the fleet leaders, focusing on the assessment of strain and vibration measurements

    - Strain measurements to work out load and fatigue parameters
    - Vibration measurements to work out vibration levels and dynamic parameters (frequencies, damping values) of both the tower and the lines

    Part 2: Development of a low-cost monitoring solution for the entire fleet

    - Optical accelerometer/strain (IoT solution) (Com&Sens)

- MEMS accelerometer (IoT solution) (*CONFIDENTIAL*)
- Work on the requirement for a mobile solution

Part 3: Development of a fleet-wide data analysis approach

- Fleet-wide model training tools translating monitoring data into condition/health parameters
- Fleet-wide comparison tools translating monitoring data into condition/health parameters

Part 4: Creation of an automated data pipeline in the cloud for data collection, storage, analysis & visualization

- Data collection and storage
- Data analysis
- Data visualization

Part 5: Development of O&M decision support tools

- Predictive maintenance rollout

- Deliverables and milestones:
  - *CONFIDENTIAL* : Production of a number of instrumented fleet leaders (1-3)
  - *CONFIDENTIAL* : Toolbox for deriving structural parameters from strain and vibration measurements (damage-related fatigue parameters, dynamic parameters: frequencies, damping values)
  - *CONFIDENTIAL* : Report on loads and dynamics to improve the general understanding of these structures under different operating conditions with comprehensible decision support
  - *CONFIDENTIAL* : Low-cost monitoring solution for a number of structures (5-10)
  - *CONFIDENTIAL* : Python toolbox for fleet-wide data-driven models and anomaly detection
  - *CONFIDENTIAL* : Python toolbox for fleet-wide comparison and anomaly detection
  - *CONFIDENTIAL* : Policy on predictive maintenance or end of life based on results

Partners

- Academic research: VUB
- Supplier of the accelerometer: to be defined
- Elia's infrastructure and innovation department

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR	2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP1 Development of a tower's monitroing by vibrations	Development of a tower's monitroing by vibrations	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
TBD	**NON-IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	**Total Incentive**						

Project 16: Mixed and virtual reality to improve public acceptance

Domain 4.2

2020 decision: New – not submitted

Trends: Decarbonization, digital revolution

Consequences: Digital tools and data use, development of infrastructure to carry a substantial influx of RES

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.2 Accelerate the public acceptance

Project-specific context

- Elia shows the values of mutual respect and empathy in finding the best solutions for society and the environment in areas surrounding our infrastructure projects. We firmly believe that involvement of stakeholders early in the process is vital for the success of the energy transition and of the important projects needed to make it happen. But despite our best efforts, it is sometimes complicated to communicate the impact of our infrastructure projects on the Belgian landscape. Plans, maps and 2D visualizations can be hard to grasp and apply to the real world.
- By using augmented reality, virtual reality, and a new way of displaying 3D information on holographic screens, we aim to simplify the communication of future work and our collaboration with local authorities. We aim to be able to show in the real world the result of a project before the project starts. Local authorities should not have to imagine the result of a planned project but should be able to see it, as they can see anything else in the world.

Project-specific state of the art/literature review

- Virtual reality is already used in the architectural sector and the construction industry (mainly use for virtual site visits).
- The use of virtual and mixed reality for public acceptance is less common, although we do find some proofs of concept involving mixed reality being used to more effectively present the implementation of wind farms (e.g. a company called Mazars has supported a wind-turbine project in France using mixed reality for interactive visualization).

Expected impact for Belgium

- The acceptance of new infrastructure is a long process that can call for substantial resources (potentially hundreds of thousands of euros for major infrastructure projects) and result in lengthy time frames. Use of mixed or virtual reality could shorten these time frames and therefore reduce the total cost of the infrastructure and the effort required to win over stakeholders.

Starting point for Elia

- For a few years now, Elia has been working on capturing many of its installations in the form of 360° images and making these easily available in internet search engines, although of course there are already some basic virtual-reality headsets on the market. In the meantime, we have built up some expertise in reproducing reality in such images.
- As the first stepping stone of the project, this work should continue, and we can take it much further.

Uncertainties and risks

- Modeling work in 3D before it gets underway is sometimes a complicated business. While 3D models of planned work exist in many formats, they are often too heavy and not suited to an augmented-reality (AR) or holographic display. Therefore, finding the best tools and processes may be complicated.
- AR headsets and holographic displays are becoming much more user friendly and comfortable, but they are still new to the general public, who may not readily adopt them.

- Scanning the real world in 3D may be a challenge, and so we will work with experts in the relevant field, but we will have to weigh up the cost against the benefits.

Project description

- Work packages and timing (M = month)

  1. *CONFIDENTIAL*: Exploratory study of display technologies: While the project will be split into multiple work packages, it needs to start with an initial investigation of the available technologies. During this investigation, we will also meet industry leaders and experts.
  2. *CONFIDENTIAL* : Visits to most of our key infrastructure using 360° video technology: We need to capture most of our key infrastructure in 360° to be able to share the images with the general public and local authorities when needed. This work started with a few selected sites but still needs to be continued and refined (to be determined, depending on the situation with COVID-19).
  3. *CONFIDENTIAL* (TBC): Use of virtual/augmented reality for key existing infrastructure or ongoing discussions,. Some specific projects will be selected for a full AR or virtual-reality (VR) display of the final result to the target audience. This will require more in-depth modeling of Elia's assets and of the project's setting. (July)
  4. *CONFIDENTIAL* : Use of holographic screens to display 3D models of planned modifications to the relevant locations and their surroundings. We will test and install holographic screens to build on the previous work package and enable several people to simultaneously look at and interact on the basis of a 3D representation, fostering an ongoing discussion without the need for a headset. This solution is less immersive than the AR headset but has the potential to be more collaborative and more intuitive.

- Approach: Elia will acquire a set of required hardware and software to perform the testing of each use case, work with external suppliers and experts in the industry, and be supported by a full-time expert consultant in managing and organizing the projects.

Deliverables and milestones

- *CONFIDENTIAL* : Compile a comparative report of various technologies
- *CONFIDENTIAL* : Obtain and set up hardware
- *CONFIDENTIAL* : Have multiple key infrastructure sites digitalized in 360° video technology
- *CONFIDENTIAL* : Have at least one key infrastructure site digitalized in a virtual/augmented reality environment
- *CONFIDENTIAL* : Assess the use of 3D holographic displays for public acceptance purposes and use one in a public acceptance forum if the technology has been shown to be ready

Partners

- Elia's Public Acceptance department and innovation.
- Hardware suppliers for AR headsets, 3D screens, capture tools, cameras, LIDAR technology, and other necessary accessories
- Multiple software providers for visualization and modeling tools (e.g. Glue,
- Experts from the industry to organize workshops and brainstorming sessions and help with planning proofs of concept
- Other Elia departments: Communication

Summary of project efforts in person months (per work package and per year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Technology exploration of display technologies	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Visit of majority of our key infrastructure using 360 video technology	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
0,25	Total Incentive						

WP 3	For key existing infrastructure or on-going discussions use virtual / augmented reality	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Use of holographic screen to display 3D model of planned modification to the landscape and environment	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 17: Connected Infrastructure to increase maintenance efficiency

Domain 3.1

2020 decision: New – not submitted

Trend: Digital revolution

Consequences: Digital tools and data use, aging of the infrastructure

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.1 Connect and cyber secure our asset and substation

Project-specific context

- Remote monitoring to ensure efficient maintenance is becoming more and more complex due to the new types of assets, accessibility, the number of assets… However, it is also becoming critical due to the aging of the asset and the need for grid reliability, real-time operation, the demand for flexibility, and environmental uncertainties. Remote monitoring means connecting assets, and doing that requires three elements to be in place: sensors, connectivity, and ingestion. This can be challenging but in recent years, development in the Internet of Things (IoT) has led to new ways to do this with new technologies, making remote monitoring possible and giving rise to new innovative use cases.
- The innovation lies in the use cases related to the technology but also in the new approach brought by the IoT value chain (acquiring a data centric mindset of connecting everything together and making devices 'talk' to each other in a data-centric system, or new groundbreaking technologies such as the low-power wide-area network (LPWAN) which penetrate deep into our underground facilities without the need for any power supply source).
- In this context, three use cases are in the pipeline, but many more could arise. These three use cases have been emerging directly form the business as they already see today the impact IoT could have in supporting their operation:
  1. The first use case: leveraging temperature sensors to detect and avoid overheating potentially due to climate change, heat spikes are becoming more and more extreme every year. This case has multiple goals:
     - objective measures for different equipment to quantify the overheating problem;
     - analysis of the results to work out solutions;
     - assessment of the solutions;
     - assessment of current temperature sensors.

     To be noted that one of the challenge is that we want to assess a lot of substations but not at the same time, which is why we would like to deploy movable sensors. This is a huge challenge, involving avoiding multiple cables (whether power or data cables). This implies difficulties as a direct connection to the IT systems but also having a long battery life for example.
  2. The second use case: acoustic analysis of switching devices, where the main challenges lies in the selection of the appropriate sensors in order to generate and ingest meaningful data.
  3. The last use case: create a light digital twin for our underground cables to avoid the need for regular maintenance in every space and also to prevent failures and avert outages. This requires a huge amount of work on sensors and communication because, being underground, pressure, oil temperature, external temperature, and cable load all need to be measured.
- On top of that for each use case, appropriate advanced analytics will be developed, which makes sense because this forms part of the IoT value chain.

Project specific state of the art/literature review

- As mentioned previously, the move to IoT has been a well-known trend in recent years. This involves a lot of innovation and solutions in the software system (ingestion, visualization, and authentication) and also on the hardware side (sensors, edge computing, etc.).
- Small organizations have found it easy to introduce IoT. For larger organizations however, while some have done this, integration is always challenging.
- More specifically:
    1. Temperature monitoring: Sensors and connectivity are mature, but ingestion and algorithms need R&D (no existing use cases found).
    2. Acoustic analysis: We are involved in an ENTSO-E program cooperating mainly with *CONFIDENTIAL* on this use case, but we are also testing a wider range of solutions. Some sensors are available, but they need to be assessed in our environment (EMC, outdoors, etc.). The acoustic analysis itself is not mature. It appears that there are some solutions in the areas of connectivity and ingestion, but they are still challenging to implement in our systems.
    3. Underground pressure monitoring: Sensors seems to exist. The main challenge is the integration of the whole solution. No similar cases have been identified.

Expected impact for Belgium

- Temperature: the avoidance of incurring substantial costs due to equipment damage, a better understanding of our substations' behavior (digital twins); flexible solutions that can be used for many future use cases
- Acoustic analysis: preventive monitoring to avoid costs/outages due to damage and to ensure that we can maximize use of our equipment
- Oil pressure monitoring: in contrast to today, when a lot of personnel's time is taken up measuring pressure in our underground facilities and when we are in reactive mode, shift to preventive maintenance to avoid damage and outages, by digitalizing our infrastructure
- Also, growing maturity in Elia regarding IoT will be beneficial for future use case (including the development of an IoT platform that could accelerate next IoT adoption).

Starting point for Elia

- Elia has now been dealing with connecting assets for many years, like other businesses around the world. The main difference here is the way to do it, namely the IoT approach. Both IoT and the use cases are new to Elia, making a lack of experience a risk.
- For temperature monitoring, we have been looking for sensors and assessed some of them for one year. Now we want to start initial real-life deployment. However, all the relevant data analysis still has to be carried out, starting with the supplier assessment.
- The starting points for the other two use cases have been covered in the literature.

Uncertainties and risks

- General uncertainties and risks
    1. Security is a major issue because Elia is a critical business and it is hard to control the whole value chain from the sensor to the application, especially for new technologies as IoT. The fact that we are dealing with new technologies is complicating this issue.
    2. Having the wrong or not enough partnerships with players in the relevant industries is a risk due to the limited number of players on the market and the lack of any standout leaders, especially at this stage of development, when the requirements have not been fully identified.
    3. In general, there are different uncertainties surrounding a feasibility study regarding sensors, connectivity, and ingestion as we have not found solutions on the market, and some aspects of the relevant technologies are not yet mature.
- Temperature monitoring
    1. A first risk lies in Elia's ability to manage the data efficiently as we look for an innovative way to connect devices.

2. Elia’s ability to make correlations between temperature and equipment impact is another uncertainty, nor are we able to analyze data to find solutions.

- Acoustic analysis of switching devices
    1. As mentioned previously, acoustic analysis has generally not reached a state of maturity yet, at least not when it comes to our use cases. There are a lot of uncertainties facing us regarding the feasibility of both the relevant sensors and data analysis.
    2. The price of the sensors poses a risk as it has been Elia's strategy for many years not to invest in remote monitoring of low-cost equipment. However, with the emergence of various and low cost IoT sensors, monitoring all kinds of equipment, is now becoming possible which might improve the business case for wide sensor implementation.
- Pressure monitoring
    1. Levels of connectivity as underground facilities could be a challenge and we want to assess new technologies that have just emerged in the IoT landscape.
    2. As this use case has never been attempted before, we are uncertain whether it will be possible to remotely maintain the cable with the data we provide. The undertaking is based on assumptions gleaned from consulting cable experts, but these still need to be proved.

Project description

- As described above, the project is orchestrated around three use cases through the conventional innovation process, namely monitor, test, and validate: temperature monitoring, acoustic analysis of switching devices and cable pressure monitoring.
- Of course, connecting assets is not limited to these use cases but may involve a lot of different scenarios, technologies, people, and departments. Different potential new use cases are in ideation phase at the moment and could follow such developments in the future while benefiting from the experiences of the current use cases described here. That is why it is important to bring together such use cases as part of a high-level common project.
- Approach: such developments could not be achieved without strong partnerships with business players. That is why in so far as possible we are promoting developments in collaboration with external suppliers, experts, and the local network provider (*CONFIDENTIAL*). Moreover, the acoustic use cases are being developed in collaboration with operators in other ENTSO-E countries, such as *CONFIDENTIAL*, to avoid duplicating costs and promoting knowledge sharing (especially given that *CONFIDENTIAL* has been investing millions in IoT for a few years now). Of course, this collaborative approach will be achieved through internal and stable resources, allowing knowledge to be capitalized on and increasing our maturity in these areas which may be quite similar to all the other issues related to digitalization.

- Work packages and timing (M = month)

    WP 1: Leveraging of temperature sensors to avoid overheating
    CONFIDENTIAL
    WP 2: Acoustic analysis for switching devices
    CONFIDENTIAL
    WP 3: Digital remote monitoring of pressure in challenging environments
    CONFIDENTIAL
- Deliverables and milestones
    - *CONFIDENTIAL* : Initial installation of an SCOF solution (underground cable pressure monitoring)
    - *CONFIDENTIAL* : Assessment of sensors for all use cases
    - *CONFIDENTIAL* : Deployment of temperature sensors
    - *CONFIDENTIAL* : POC for switching devices with *CONFIDENTIAL*
    - *CONFIDENTIAL* : Installation of SCOF solution v2
    - *CONFIDENTIAL* : Temperature data analysis
    - *CONFIDENTIAL* : Conclusion of POCs for acoustic analysis regarding sensors
    - *CONFIDENTIAL* : Conclusions on temperature and potential solutions to avoid overheating

Next steps: To be determined, depending on the outcome of the initial POCs

Partners

- Technology suppliers: *CONFIDENTIAL*, *CONFIDENTIAL*
- Sensors: *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL*, *CONFIDENTIAL* (temperature sensors)
- IoT platform: *CONFIDENTIAL*
- IoT network: *CONFIDENTIAL* (*CONFIDENTIAL*), *CONFIDENTIAL*

Summary of project efforts in person months (by work package and by year)

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Leverage temperature sensors for overheating avoidance	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 2	Accoustic analysis for switching device	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP3	Digital pressure remote monitoring in challenging environment	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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Project 18: Use of innovative digital technologies for the Automation of Finance

Domain 6.3

2020 Decision: New – not proposed

Trend: Digital revolution

Consequences: Digital use & data use

Challenge: 6. Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization

Domain: 6.3 Automation and analytics for corporate functions

Project Specific Context

- As related to the projects stated in this document (e.g. digital backbone – project 6, smart pricing – project 23, etc.) Elia's operational business functions are facing increasing data volumes and new market players as well as business models and therefore an increasing complexity of data flows.
- We believe there is a direct correlation between accessing decentralized flexibility, smart and fast system operation, and flexible and automated maintenance, which all lead to an increase in the complexity of data management and therefore an administrative system that has to react to higher demand related to data production and control while ensuring efficiency and sufficient productivity.
- As complexity and real-time data volumes increase, costs must be reduced while ensuring that processing takes place quickly, otherwise the innovation provided by the core business will never be translated into real gain for Elia and therefore for society.
- Elia's finance-related IT architecture and landscape of end-to-end processes, such as purchase to pay (P2P), order to cash (O2C), and record to report (R2R), need to offer a high level of automation and must keep up, across the board, with innovation in the core-business activities.
- On top of this, there must always be quality assurance of all data and processes, not only because of a need to fulfill regulatory or legal obligations, but also in the interest of society.
- To achieve this, Elia will test new technologies such as hyperautomation. This not only involves implementing tools to manage tasks but requires collaboration between humans as well. This translates the fact that the digital transformation is first about human acceptance before being a technology question.

Project specific State-of-the-art/Literature study

- It exist various studies by reputable consultancy firms looking into the benefits of digital technologies, such as artificial intelligence (AI) and robotic process automation (RPA), e.g.:
    - the Gartner article and report on *The Future of Finance Planning and Analysis*, and Gartner's *2020 Strategic Roadmap for Cloud Financial Planning and Analysis Solutions*;
    - Oliver Wyman's *Digital Transformation of the Finance Function* (2019);
    - McKinsey's *Get in front of digital finance – or get left back*.
- These articles/reports point out, among other things, the considerable potential of artificial intelligence coupled with automation which could lead to a drastic reduction in OPEX (up to 80% in certain functions), which will act as a bulwark against a dramatic rise in administrative cost due to the increasing complexity of TSO activities in the future (increase in activations, number of players, number of products and services, etc.).

- RPA technologies are being rolled out in various industries (take, for example, the ENGIE RPA application), but the application of hyperautomation (coupling artificial intelligence and RPA) is under development and will need to be tailored to relevant enterprises' processes.

Expected impact for Belgium

- The result should be a supportive digital process environment to ensure operational implementation of digital and innovative initiatives in the core business.
- Overall, the expected impact is a decrease in project overhead costs by automating financial processes for the most part (potential of easy gains of *CONFIDENTIAL* – also in accounting). This could represent a key answer to the complexity increase (due to decentralization acceleration) and an important cost avoidance for the society.

Starting point Elia

- Elia has gained experience in RPA technology in some processes, such as in accounting, the settlement of credit-card expenditure and checking creditors' solvency (for VAT purposes), for instance. At the same time, it has garnered experience of artificial intelligence via the AI Center of Excellence, which has developed multiple applications for the business (smart planning of maintenance, smart creation of switching notes, etc.).

Uncertainties & risks

- It is not yet clear to which extend technologies can be combined and mesh to promote end-to-end automation, indeed the hyper automation is at an early stage and the tailor-made development by the Elia's internal Center of Excellence (AI and RPA) is unknown.
- Another risk for the project is the resources unavailability and lack of required competencies and capabilities in the company.
- Finally, the easy access to the relevant data and the adoption from the employees is a major unknown.

Project description

- For the 2020-2023 period the project will be subdivided into three stages: automation of sub-processes, enabling of data analytics, and end-to-end process digitalization via complementary technologies throughout the process chain. At every stage three constraints will be taken into account: efficiency, quality, and security. These pillars will provide the framework for further digitalization in the financial activities and will at the same time be the focus for significant improvement or change.
  The project, which is split into multiple stages, will require an initial investigation of the available technologies. During this exploratory phase, we will also meet external providers as well as making use of internal centers of excellence (AI, RPA, mainly). Elia will also need to acquire the hardware and software needed to deal with each use case in all project stages.
- Approach: In an initial stage, Elia will assess the use cases' potential and identify the need for further development, weighing this up against solutions already available on the market. External partner will then be leveraged to develop tailor made solutions where needed for Elia.

WP 1 – Automation of sub-processes: This stage mainly focuses on achieving more efficiency by implementing new technologies such as robotic automation and machine learning for specific financial sub-processes. The required increase in the level of automation is based on the increasing data complexity due to extended digitalization of the core business.

- *CONFIDENTIAL*: Ideation/use cases
- *CONFIDENTIAL*: Development and sandboxing based on historical data
- *CONFIDENTIAL*: Demonstration and industrialization, and cost-benefit analysis
- *CONFIDENTIAL*: Training and development of digital skills

WP 2 – Data analytics: This stage will aim to maximize the impact by increasing data quality and to improve the decision-making process by focusing on data enrichment, analysis, and governance. Through the use of new technologies, such as AI, Elia wants to obtain more precise forecasts, including KPI/cash forecasts, as well as detecting anomaly data. It takes into account the objective of ensuring high data quality and compliance.

- *CONFIDENTIAL*: Ideation/use cases
- *CONFIDENTIAL*: Development and sandboxing based on historical data
- *CONFIDENTIAL*: Demonstration and industrialization, and cost-benefit analysis
- *CONFIDENTIAL*: Training and development of digital skills

WP 3 – Integrated digital finance system: In this stage the two previous stages will be merged to develop an integrated digital finance system. Elia needs to develop intelligent business processes, including end-to-end automation. As an example, this will lead to an automation of P&L, and risk and performance analysis.

- *CONFIDENTIAL*: Ideation/use cases
- *CONFIDENTIAL*: Development and sandboxing based on historical data
- *CONFIDENTIAL*: Demonstration and industrialization, and cost-benefit analysis
- *CONFIDENTIAL*: Training and development of digital skills
- Deliverables and milestones
    - For each stage described above (the end of the phase should be regarded as the delivery date):
        - proofs of concept (POCs)/design of pilots;
        - implementation procedures;
        - a cost-benefit analysis;
        - training materials;
          feedback

Partners

- Elia's Accounting and Controlling Department
- Elia's Digital and Data Department: the AI and RPA Centers of Excellence
- Potentially solution providers

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Automation of sub-processes	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

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WP 2	Data analytics	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 3	Integrated digital finance system	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

Project 19: Assessing the impact of local generation and prosumption strategies on the grid infrastructure

Domain 3.3

2020 decision: New – not submitted

Trends: Decarbonization, decentralized generation and new players and new players

Consequences: New decentralized flexibility resources, increase in maximum use as well as variability of the use of grid infrastructure, need to update grid security rules and resilience rules in the interest of society, interface with new players

Challenge: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

Domain: 1.4 Predict and incentivize DER's

Project-specific context

- Overall, due to the uptake of wind and solar power, technologies of an intermittent nature that have various uncertainties surrounding them, there is growing interest in further incentivizing coordination between grid prosumers, e.g. through renewable-energy communities or other market arrangements.
- The challenge for Elia is that strategy, specifically the parties with whom flexibility will actually be achieved in the future, is having a significant impact on upstream transmission costs (through grid upgrading decisions that may change due to local strategies), and therefore on general social welfare. For instance, if we consider a scenario in which each prosumer aims to minimize its electricity bill through an optimal response to wholesale prices, prosumers' local batteries will be discharged in periods of high prices (and charged in periods of low prices). In this way, if a grid contingency occurs at the end of the day (when there is no PV generation), the battery is likely to be empty since the energy was sold at peak prices during the evening. In this case, the security of supply of end users may be jeopardized if no grid upgrading decisions have been made. By contrast, when prosumers are driven by a policy that maximizes their own consumption, the same contingency may not lead to significant problems since the batteries will have energy reserves (from the PV generation during the day), thereby ensuring continuity of supply.
- Interestingly, the optimal long-term transmission grid upgrading policy that needs to be applied in these two cases is completely different, meaning that it is vital that new tools be developed that properly quantify the impact of new load behaviors on the continuity of electricity supply in normal and contingency conditions.
- As the role of these decentralized flexibility resources will substantially impact the optimization of the grid investment, it is important to gain a better understanding of the real impact they could have and the opportunity they could provide depending on the type (heating, EVs, batteries) and consumers' behavior.
- Therefore, this project aims to evaluate how local economic interests and behaviors, which are becoming more and more important in an increasingly decentralized context, affect general social welfare in Belgium.
- The project has been submitted to the energy transition fund, and a response from the federal government is pending.

Project-specific state of the art/literature review

- A look at the literature and the electricity sector clearly shows there is a lack of a grid upgrading tool combining both these features: local economic interest and consumer behaviors. However, the state of the art at least points us in the right direction for scenario-based stochastic programming [1], chance-constraint programming [2], robust optimization [3], and distributionally robust optimization [4].

- [1] A. Shapiro and D. Dentcheva, *Lectures on Stochastic Programming: modelling and theory*, SIAM, 2nd edition, 2014.
- [2] A. Nemirovski, *On safe tractable approximations of chance constraints*, in European Journal of Operational Research, vol. 219(3), pp. 707-718, 2012.

- [3] D. Bertsimas, D. B. Brown and C. Caramanis, *Theory and applications of robust optimization*, in SIAM Review, vol. 53(3), pp. 464-501, 2011.
- [4] H. Rahimian and S. Mehrotra, *Distributionally robust optimization: A review*, 2019. [Online]. Available: https://arxiv.org/abs/1908.05659

Expected impact for Belgium

- The main application of the project can be found in coming up with a structure for the power system and prosumption strategies to achieve the planned shift in Belgium's energy mix on time and in a cost-efficient way. By providing tools for optimal decision-making for grid investment as well as instruments to calibrate prosumer strategies taking into account societal impact at national level, the project will support the energy transition in Belgium.
- Furthermore, the expertise developed in the context of the project is of national and international interest and will be anchored in Belgium, which is where all the enterprises that are partners in the project are based. As such, it will directly benefit the Belgian economy and competitiveness.
- To illustrate the impact of decentralized flexibility on grid development, in 2018, the Norwegian DSO *CONFIDENTIAL* claimed it had achieved a grid deferral of *CONFIDENTIAL*by setting up a local marketplace with their partner *CONFIDENTIAL* in order to steer decentralized flexibility appropriately.

Starting point for Elia

- Today, when grid development is proposed, it is based on an assumption of predictable customer behavior or on customers reacting to global market signals and not on them responding to local strategies and local signals.
- Models for charging EVs are based on a uniform share of domestic charging and workplace charging and of fleet EVs in all regions.

Uncertainties and risks

- As the project only looked at fundamental research, there is complete uncertainty about the output, based on which a clear pattern could be identified to create a robust model for forecasting the availability of flexibility associated with a quantification of social welfare.
- We are currently applying for subsidies. If we do not receive financial support, the costs of the academic study will be taken over by Elia, who will require a more detailed cost-benefit analysis, but this will pose a risk for the project.

Project description

- The project aims to enhance grid planning, focusing on two specific objectives that are key to a successful and cost-effective energy transition:
    1. Objective 1: Improving the time series (for a typical year) of hourly consumption profiles at the interface between the High-Voltage (HV) and Medium-Voltage (MV) levels. These time series are informed by the local strategies used to harness the available flexibility (e.g. maximizing local self-consumption using battery scheduling, etc.). This procedure makes it possible to quantify the amount of flexibility that may be leveraged at the local level to mitigate the unexpected loss of a major transmission-grid component. To that end, we will rely on macro-scenarios of the future national share of conventional and local renewable generation (associated with new economic incentives for renewable sources), on market functioning rules and on new prosumption habits (electric mobility and local storage via the new mechanism for fully harnessing the distributed flexibility).
    2. Objective 2: Adapting the methodologies and tools that drive decisions regarding grid upgrading to accommodate the growing share and importance of prosumers and demand-side response (including storage and decentralized generation). More precisely, we will develop a decision-making tool to support grid upgrading decisions, taking into account uncertainties associated with, in particular, the development and use of various decentralized technologies. To achieve this objective, recent advances in risk-conscious approaches will be leveraged to better accommodate uncertainties, while integrating the notion of risk. In this respect, a promising approach is based on the regret theory approach (such as the 'minimax regret' [14]), which focuses on making decisions with the tightest possible optimality guarantees when dealing with uncertainties.

- Approach: A four-year academic project with tasks divided between Elia and the industrial and academic partners.: The University of *CONFIDENTIAL* will provide researchers, who will focus mainly on time-series generation and grid upgrading methods, while the industrial partner will concentrate on supporting data extraction.

- Work packages and timing (M = month)
    1. *WP 1: Data collection*
        - *CONFIDENTIAL*: Data collection
    2. *WP 2: Time-series generation*
        2.1 Definition and modeling of flexibility-management strategies
        - *CONFIDENTIAL*: 2.1.1 Traditional strategies based on the current market framework
        - *CONFIDENTIAL*: 2.1.2 Disruptive flexibility-management strategies
        - *CONFIDENTIAL*: 2.2 Modeling of mobility patterns and their impact on available flexibility
        - *CONFIDENTIAL*: 2.3 Multi-scenario generation for the application of flexibility-management strategies
    3. *WP 3: Grid upgrading methodologies and tools*
        3.1 Methods and prototype for an academic test case
        - *CONFIDENTIAL*: 3.1.1 Multi-scenario decision-making approaches to grid upgrading
        - *CONFIDENTIAL*: 3.1.2 Approaches to modeling the impact of prosumer flexibility on grid design
        - *CONFIDENTIAL*: 3.1.3 Implementation and application to an academic test case
        3.2 Extension of grid upgrading methodologies and tools to a real-life grid
        - *CONFIDENTIAL*: 3.2.1 Upscaling of methodologies and updating of the prototype
        - *CONFIDENTIAL*: 3.2.2 Implementation of methods in preparation for real-life use case
    4. *WP 4: Case studies and social welfare*
        - *CONFIDENTIAL*: 4.1 Definition of Key Performance Indicators (KPIs) for a social welfare evaluation
        - *CONFIDENTIAL*: 4.2 Combination of new time series and scenarios in grid upgrading tools
    5. *WP 5: Coordination, communication, and dissemination*
        - *CONFIDENTIAL*: Coordination, communication, and dissemination

- Deliverables and milestones
    - *CONFIDENTIAL*: Test and use cases and long-term trajectories
    - *CONFIDENTIAL*: Tool for better quantifying consumption profiles at the transmission/distribution interfaces
    - *CONFIDENTIAL*: Models for mobility patterns
    - *CONFIDENTIAL*: Multi-scenario generation
    - *CONFIDENTIAL*: Prototype of a multi-scenario (grid reinforcement) decision-making tool
    - *CONFIDENTIAL*: Extension of the prototype to become a tool compatible with real-life issues
    - *CONFIDENTIAL*: Definition of KPIs for social welfare assessment
    - *CONFIDENTIAL*: Report assessing the impact on Belgian social welfare

Partners

- Elia's partners for this project will be the University of *CONFIDENTIAL* and *CONFIDENTIAL*.
- Elia's Grid Development Department will participate in the various work packages.

Summary of project efforts in person months (by work package and by year)

Total Project	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Data collection	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	**Total Incentive**						

WP 2	Time series generation	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Grid Reinforcement methodologies and tools	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Case studies and Social Welfare	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 5	Coordination, communication and dissemination	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 20: Operation of a carbon neutral grid

Domain 5.2

2020 Decision: New – not proposed

Trend: Decarbonization

Consequences: Decarbonization will change the way in which the grid is operated. The system will further move away from centralized fossil fuel plants towards renewables, storage and decentralized generation units. This has an impact on the operation of the grid, e.g. in terms of frequency and voltage stability.

Challenges: 5. Make the TSO business (market facilitation, system operations and asset management) more sustainable

Domain: 5.2 Sustainable system operations

Project Specific Context

- Europe has projected carbon neutrality by 2050. This means that over the upcoming decades, the electricity system will undergo many changes. Indeed, high shares of renewables will impact the power system. Their intermittent character (and non-perfect forecasts) of renewables will lead to new challenge on different time frame to guarantee the stability of the system in term of frequency but also on voltage control. Moreover the power electronics linking the green sources to the grid will bring inertia and oscillations questions as the role of traditional synchronous generators will decrease.
- As Elia is operating the Belgian grid, it is important to better understand the constraints and the implications of a full carbon neutral system on the energy system in term of stability and dynamic.
- This project aims at increasing our understanding of what would be needed to operate a carbon neutral grid (and which resources could fulfil those functions). It will be based on a literature study and own study/reflection.

Project specific State-of-the-art/Literature study

- A significant amount of studies have been performed on the impact thereof on the operation of the system but rarely with a high focus on Belgium. This project will build on state-of-the-art studies available in literature to get a clearer view of the impact of a carbon neutral system in Belgium on the operation and management of the system.
- As examples:
    1. Implications of a high percentage of solar and wind in the power system – DNV-GL, Group technology & research, white paper 2018
    2. Is a 100% renewable European power system feasible by 2050? - Author links open overlay panel William-Zappa Martin Junginger Machteld van den Broek, 2019
    3. Integrating High Levels of Variable Renewable Energy into Electric Power Systems - Benjamin Kroposki – NREL, 2018
    4. Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union, D. Connolly, Henrik Lund, Brian Vad Mathiesen, 2016

Expected impact for Belgium

- The study will contribute to identify the further needed preparation for Belgium to enable a carbon-neutral electricity system.
- The study will also identify what are the main risk and opportunity of a fully decarbonized Belgian energy system.

Starting point Elia

- Elia will build on its vast experience in operating electricity systems and studies available in literature on impact of a decarbonized electricity system as inertia (like grid dynamics project (8) and voltage automation analysis (7)).
- Elia will also start from the last adequacy and flexibility study issued in 2019.

Uncertainties & risks

- Unclear which challenges will be identified and whether solutions are available to manage them.
- In addition, the complexity of the calculation and the medialization to be performed would be a risk for the achievement of meaningful and sufficiently detailed results.
- The availability of required data and scenarios might also be complex to aggregate/summarize.
- Finally, the study itself is uncertain as it is today unclear how the system will exactly evolve towards 2050, hence there might be a need to work with different scenarios depending on:
    - Political decisions
    - Technology evolution
    - Social evolution
    - Regulation impact

Project description

- The project will investigate the impact of operating a decarbonized electricity system and identify which services are required and which resources could provide those.

- Approach: We will start by setting the scene (i.e. a clearer picture of how the electricity system could look like), followed by a literature study on the topic (i.e. operation of a 100% decarbonized grid). On this basis, we will elaborate a clear problem statement (i.e. which areas we need to investigate/study in more depth) and perform the study work. Potentially the modelization and calculation will be performed to provide objective analysis to the situation. To close the project, we will have a critical reflection and define clear follow-up steps.

- Work packages & Timing(M=month)
    1. *WP 1: Setting the scene*
        - *CONFIDENTIAL*: Set the overall scope of the study
        - *CONFIDENTIAL*: Identification of the partners and relevant stakeholders
        - *CONFIDENTIAL*: Definition of the workpackage split and objectives
    2. *WP 2: Literature study*
        - *CONFIDENTIAL*: review of the existing studies and identification of the missing assumptions
    3. *WP 3: Problem description*
        - *CONFIDENTIAL*: Definition of the problem statement
    4. *WP 4: Investigation / study*
        - *CONFIDENTIAL*: Modelization of the system
        - *CONFIDENTIAL*: Definition of the scenarios
        - *CONFIDENTIAL*: Analysis of the results and iterations is necessary
    5. *WP 5: Critical reflection & conclusion*
        - *CONFIDENTIAL*: Drafting of the conclusions and implication for the operations of the network

- Deliverables & milestones
    - *CONFIDENTIAL*: Planning of the projects and objectives
    - *CONFIDENTIAL*Literature study report and the problem statement
    - *CONFIDENTIAL*: Modelization and scenarios
    - *CONFIDENTIAL*: Conclusions and recommendations

Partners

- Consultancy and/or academic (not defined yet)
- Elia internal department to be consulted: System of the future, Market design, System operations, Grid development and Strategy

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Setting the scene	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Literature study	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Problem description	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Investigation / study	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 5	Critical reflection & conclusion	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 21: Internal innovative idea incubator

Domain 6.1

2020 Decision: New- not proposed

Trend: digital revolution

Consequences: Digital tools & data use

Challenge: 6. Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization

Domain: 6.1 Embed digital capabilities and training

Project Specific Context

- The accelerating pace of technological change coupled with the energy transition is leading to the redefinition of many industries, forcing businesses to make innovation their priority.
- This innovative potential will not be unlocked by itself and will require a set of tools to be made available to employees and will need the creation of an entrepreneurial mindset. In this light, Elia will establish a new corporate digital idea incubator. This will try to offer Elia's employees a risk-free environment where promising new innovative ideas that can improve the efficiency, quality/flexibility, or security of Elia activities can be prototyped very quickly in Agile fashion.
- In the incubator, employees will learn about the Agile methodology and digital technologies with a view to leveraging the lessons learned in their normal business after the experience, on top of developing an effective idea.
- This incubator therefore intends to dramatically increase the innovative potential of the company that will be much required in an energy system that is changing at an ever more breakneck speed, given the energy transition and the evolution of the relevant technologies.
- Specifically, the incubator will be characterized by two rooms (to start with) where Agile project teams will work on new ideas in a time frame of typically 6 to 12 weeks.
- The ideas will be selected by an Elia panel based on pre-defined criteria (in terms of provability, impact, etc.) and will be developed by a cross-functional team, including digital profiles like data scientists, UX/UI designers (from the Digital and Data department), experts (from business departments), and an Agile coach.
- By developing the capabilities of the Elia employees to develop entrepreneurship, innovative ideas, and digital skills, the innovation will transition to a bottom-up/decentralized model that will make it possible to scale up much more dramatically than a straightforward top-down/centralized approach where innovation department is pushing project to the business.

Project specific State-of-the-art/Literature study

- Studies show that large established enterprises whose goal is initially to develop radical innovations while pursuing incremental gains have begun to set up internal incubation structures allowing these businesses' employees or outsiders to pursue and develop risky business opportunities. Corporate idea incubators are thus considered an ideal way to create new skills or new innovative models. In this regard, see in particular:

- M. L. Tushman and C. A. O'Reilly III (2004). *The ambidextrous organization*, Harvard Business Review, 82(4), pp. 74-81.
- S. Ford, E. Garnsey and D. Probert (2010). *Evolving corporate entrepreneurship strategy: technology incubation at Philips*, R&D Management, 40(1), pp. 81-90.
- B. Becker and O. Gassmann (2006). *Gaining leverage effects from knowledge modes within corporate incubators*, R&D Management, 36(1), pp. 1-16.
- W. Vanhaverbeke and N. Peeters (2005). *Embracing innovation as strategy: corporate venturing, competence building, and corporate strategy making*, Creativity and Innovation Management, 14(3), pp. 246-257.

Expected impact for Belgium

- Directly, the idea incubator will enable the validation of multiple innovative ideas that could be implemented.

- Indirectly, via learning of the Agile methodology and the digital capabilities, additional ideas could be developed even outside of the incubator.
- In any case, both of these effects will support the same goal as the other innovative projects presented in this report: bring efficiency, quality, and security in Elia business.

Starting point Elia

- Elia has already set-up various tools for developing new digital ideas, such as:
    1. An Artificial Intelligence Center of Excellence, which provides on-demand resources and expertise related to data science;
    2. A portfolio of innovative digital projects where we gain experience: blockchain, IoT, drones, virtual reality;
    3. The digital backbone components for innovative data-based use cases;
    4. The Lean and Agile Office.

Uncertainties & risks

- Setting the incubator will not be enough by itself, and an effective change of mindset cannot be achieved without a broader cultural change, which Elia has embarked on in recent years and which need broader support from the leadership.
- The type of ideas and the possibility to prototype and test in a short time frame is also a completely unknown quantity that will require careful calibration of the selection criteria.

Project description

- The goal of the project will be to set up the incubator taking into account multiple dimensions:
    - governance: developing principles for selecting ideas to ensure that we focus on doing the right things, connecting strategy to investments in digital innovation in a dynamic way, and orchestrating the incubator internal resources and budgeting properly;
    - methodology: encouraging creativity-fostering ways of working in the incubator and strong collaboration across departments, internal/external ecosystems and experts to have the right capabilities available at the right time;
    - cultural change: driving cultural change, fostering an innovation mindset (with a key focus on early and transparent communication) and defining the HR support framework to make participation in the incubator possible and attractive for all employees;
    - working environment: setting up a working environment in the incubator encouraging creativity and collaboration and making available IT tools and an IT platform that are flexible.

- Approach: The design phase will be supported by an external consultant, and then the teams (or squads) working on innovative projects will leverage some internal and external resources that will be selected via body shopping. Initially, the rooms will be located on Elia premises, with the possibility of expanding to an external incubator in the future.

- Work packages and timing (M = month)
    1. *WP 1: Design*
        - *CONFIDENTIAL*: 'As is': Definition of the current status of innovation practice in the enterprise based on an assessment of the competencies, the mindset, and the tools in place
        - *CONFIDENTIAL*: Definition of the blueprint for the internal incubator, including the governance of ideas, the methodologies to apply in the incubator, the tools, the environment, and the evolution of roles
        - *CONFIDENTIAL*: Recommendations for setting up the incubator and discussions with the different stakeholders about the actions to take to this end
    2. *WP 2: Setting up of the incubator*
        - *CONFIDENTIAL*: Layout of the physical location and the potential digital environment
        - *CONFIDENTIAL*: Governance implementation

3. *WP 3: Testing*
    - *CONFIDENTIAL*: Initial pilot projects
    - *CONFIDENTIAL*: Recommendations from the pilot projects
    - *CONFIDENTIAL*: Challenge to source new ideas
    - *CONFIDENTIAL*: Second wave of projects.

Partners

- The design of the incubator will be supported by *CONFIDENTIAL*
- The culture change: HR department and the lean and agile office
- The IT support (data scientists, developer…) will be provided by the Digital, IT and innovation department with the participation of some external providers as *CONFIDENTIAL*for the data scientists

Summary of project efforts in person months: by work package and by year

Total Project	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Design	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Set-up	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Testing	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resources - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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Domain 3.1

Project 22: Connect our infrastructure to increase the security and safety

2020 Decision : New – not proposed

Trend: Digital revolution

Consequences: Digital tools & data use

Challenges: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.1 Connect and cyber secure our asset and substation

Project Specific Context

- The complexity of the grid is increasing all the time, in part because of the new asset technologies and the large number of stakeholders actively involved in Elia's infrastructure (notably subcontractors).
    - This is making the 'zero incident' safety objective more complex.
    - There are many other activities, such as working with a specific pump, which can lead to an incident, in this case the pump making contact with an overhead line.
- Moreover, the price of copper is attracting more and more bold and innovative thieves (even cutting loaded high voltage lines).
  This increase in the number of copper thefts, which may involve the perpetrators either cutting overhead lines (at a cost of €*CONFIDENTIAL*per year) or stealing cable reels directly from substations.
- These 2 challenges are putting into danger the reliability of the grid that could result in major outages.
- On the other hand, emerging technologies which is becoming more and more affordable provide new opportunities to increase safety and security solutions, namely Internet of Things (IoT) solutions, which are related to project 17.
- This concept provides new integrated solutions for sensors, connectivity, and ingestion. Once the data are gathered, this concept will enable advanced analytics and data-driven decisions.
- In this particular context, four innovative use cases have emerged:
    1. testing of acoustic cameras in substations to help to detect noises made by thieves, e.g. using a grinder;
    2. testing of radar sensors on transmission towers: the aim is to use military radar to detect people stealing overhead cables with the help of AI;
    3. asset tracking: the aim is to use low-cost innovative GPS trackers with a long battery life to detect unexpected movements and keep track of cable reels. This can be combined with temperature and humidity sensors to remotely monitor cable condition with a view to increasing the health of cables and the efficiency of logistics;
    4. high-voltage detection: the idea is to develop sensors and connect them to workers in order to prevent collisions/an electric arc between equipment/workers and overhead lines.

Project specific State-of-the-art/Literature study

- The state of the art will be described by use cases:
    1. The acoustic camera technology is very recent/of a technical nature and therefore help may well be needed from universities to work out the specific state of the art from a technological point of view. Indeed, it seems that detecting the origin of a sound should not be an issue but the identification in a specific context is still a challenge.
    2. Radar is a highly developed tool in the military sector, but it has never been used for theft detection according to a Belgian radar firm. This should use AI – an area where the state of the art is at an advanced stage due to the hype of the past decade.

3. Asset tracking technology has been widely used for a few years now. However, the state of the art in this area seems to be in flux right now because of the new IoT technologies (connectivity, sensors, ingestion, etc.) disrupting the world of connected infrastructure.
4. The precise state of the art from a technological point of view has yet to be defined and is being worked out with a high-tech partner, such as *CONFIDENTIAL*. In terms of solutions, some suppliers have claimed that they offer good, reliable equipment but after testing this turns out not to be the case, both in terms of the ability to detect the field and with regard to their reliability in determining distances close to equipment. This technology does not seem to exist currently and therefore require new innovative development.

Expected impact for Belgium

- Reduction of costs by preventing/detecting thefts (*CONFIDENTIAL*/y);
- Increase in grid reliability by detecting thefts at an early stage and by avoiding line outages (specifically for critical lines);
- Increase in the safety of workers and avoidance of injuries/deaths by detecting dangerous situations;
- Decrease in costs due to incidents (e.g. a pump hitting a crane) and avoiding line outages;
- Increase in safety and security data about our grid, with a view to boosting efficiency.

Starting point Elia

- In general, connecting the world when it comes to safety and security using IoT solutions is a new challenge for Elia. Further details about the use cases:
  - We are starting from scratch, except for a few discussions with *CONFIDENTIAL* and its experience with that technology.
  - We have had no radar experience up to now, and so we have a long way to go.
  - The proof of concept (POC) has already been produced with an off-the-shelf solution. We need to reiterate our experience with IoT technologies and actual use cases by incorporating these into our systems.
  - As mentioned in the state of the art section, a few off-the-shelf solutions have been tested, but the results have been disappointing. This led to this innovative track, which is necessary to tackle this challenge.

Uncertainties & risks

- All use cases share various uncertainties relating to the general effective impact of digital technologies for security purposes. This is quite a new area for Elia, especially with regard to IoT.
- General uncertainties and risks
  - We can see general risks and uncertainties in the similarities between the use cases relating to the connection and remote monitoring of infrastructure in general.
  - The complexity of the technology is also a challenge to make sure the full value chain is secured.
  - Having the wrong or not enough partnerships with players in the relevant industries is a risk due to the number of players on the market and the lack of any standout leaders, especially at this stage of development, when the requirements have not been fully identified.
  - In general, there are uncertainties surrounding a feasibility study regarding sensors, connectivity, and ingestion as we have not found solutions on the market, and some aspects of technologies are not yet mature.
- Use cases
  - Acoustic cameras may not yet be mature enough to be used on the market, or the price for adoption by Elia could be too high.
  - The main uncertainty relates to whether the integration of an overall solution is affordable, reliable, and sustainable. The standalone technologies do work already, but it is unclear how AI will be included with radar in low-cost communications and so on to ensure affordable rollout
  - There is a risk that the new technologies related to IoT communication and tracking solutions do not fit Elia's requirements (feasibility in our environment, reliability, etc.).
  - The main uncertainty is technological feasibility.

Project description

- The project has a lot of similarities to project 18 as it also aims to connect the grid through innovative IoT use cases. As a result, some of the points below may be the same as for that project.
- The aim of the project is to develop the four use cases through the conventional innovation process, namely monitor, test, and validate. As mentioned in the context section, these are not at the same level of development but rather undergoing a process of innovation, partially because of the uncertainties.
- Of course, connecting assets is not limited to these use cases but may involve a lot of different scenarios, technologies, people, and departments. Many potential use cases that are still ideas at the moment can follow such developments in the future and will benefit from the experiences of the current use cases described here.
- Approach: Elia is promoting developments in collaboration with external suppliers, experts, and the local network provider (*CONFIDENTIAL*). Of course, this collaborative approach will be achieved through internal and stable resources, allowing knowledge to be capitalized on and increasing our maturity in these areas which may be quite similar to all the other issues related to digitalization.

- Work packages and timing (M = month)
    1. *WP 1: Acoustic cameras*
        - *CONFIDENTIAL*
    2. *WP 2: Testing of radar for tower theft detection*
        - *CONFIDENTIAL*
    3. *WP 3: Asset tracking*
        - *CONFIDENTIAL*
    4. *WP 4: High-voltage detection*

       CONFIDENTIAL
- Deliverables and milestones
    - *CONFIDENTIAL*: Document detailing partnership with *CONFIDENTIAL* and *CONFIDENTIAL*
    - *CONFIDENTIAL*: Action plan for radar
    - *CONFIDENTIAL*.: Initial theoretical solution for radar
    - *CONFIDENTIAL*.: Conclusions regarding the feasibility study for voltage detection
    - Forecasts covering more than three months need more in-depth study.

Partners

- Sensors specification: *CONFIDENTIAL* and potential other providers
- Sensors providers: *CONFIDENTIAL*, *CONFIDENTIAL*
- IoT platform: *CONFIDENTIAL*
- IoT network and data integration: *CONFIDENTIAL*
- Accoustic camera: *CONFIDENTIAL*

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
Total Project		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Test accoustic camera in substation	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Test of radar sensors on pylons to detect theft	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Asset tracking to increase security on the field	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 4	High voltage detection	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

Domain 1.4

Project 23: Smart pricing

23 Decision 2020: Accepted

Trend: Digital revolution, decentralized generation and enw players

Consequences: Digital tools & data use

Challenge: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

Domain: 1.4 Predict and incentivize DER's

Project Specific Context

- As presented in the section 3.1, the uptake of the renewables coupled with the decentralization and the decreasing role of thermal generation will required an increase of the flexibility needs due their intrinsic uncertainty and intermittency.
- At the same time the progressive phase out of nuclear coupled with low marginal price will limit the role of centralized flexibility, requiring to leverage new flexibility means as EV's, heat pumpsmore and more to cope with the need of the grid.
- The electrification of the society will therefore constitute a pool of flexibility that should be taken into account in our operations.
- As a result in the future, compared to a classical merit order of power plants where the marginal price is known in advance, the consumer behavior will lead to variable flexibility profile but also changing appetite for the participation to the energy market.
- As an example, EV drivers will most likely see no problem that their car participate to the regulation of the grid during the night but will request quite high remuneration to accept impacting the charging level when they leave home in the morning. Or people with heat-pump will more easily accept to set down the level of their heat pump when temperature is 10°C outside than if it is -10°C.
- As a result of these changing behavior, the price to set-up to trigger a proper reaction is a complex question that cannot be considered as stable and easy to foreseen.
- Elia is then launching a project to better understand the reaction of decentralized flexibility to an implicit price signal.

Project specific State-of-the-art/Literature study

- Different studies are looking at the energy price elasticity but generally not for real-time and implicit set-up.
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- O. Corradi, H. Ochsenfeld, H. Madsen and P. Pinson. Controlling electricity consumption by forecasting its response to varying prices. IEEE Transactions on Power Systems, 28(1):421–429, 2013.
- Council of European Energy Regulators. Recommendations on dynamic price implementation, 2020.
- CREG. Etude (F)160503-CDC-1459 sur les moyens à mettre en oeuvre pour faciliter la participation de la flexibilité de la demande aux marchés de l'électricité en Belgique - Rapportfinal, 2016.
- R. D'hulst, W. Labeeuw, B. Beusen, S. Claessens, G. Deconinck and K. Vanthournout. Demand response flexibility and flexibility potential of residential smart appliances: Experiences from large pilot test in Belgium. Applied Energy, 155:79–90, 2015.
- G. Dorini, P. Pinson and H. Madsen. Chance-constrained optimization of demand response to price signals. IEEE Transactions on Smart Grid, 4(4):2072–2080, 2013.
- Ecofys. Dynamic electricity prices, 2018.
- EcoGrid EU. From design to implementation. A large scale demonstration of a real-time marketplace for distributed energy resources, 2013.

- EcoGrid EU. From implementation to demonstration. A large scale demonstration of a real-time market for demand side participation, 2015.
- Eurelectric. Dynamic pricing in electricity supply. A EURELECTRIC position paper, 2017.
- O. S. Grande, S. Pineda, P. Nyeng, K. Kok, S. Otjacques, M. Cuk, J. Sprooten, B. Hebb and F. Niewenhout. Task Force EcoGrid EU market model - Final report, 2013.
- K. Heussen, S. You, B. Biegel, L. H. Hansen and K. B. Andersen. Indirect control for demand side management - A conceptual introduction. In 2012 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), 2013.
- B. Jansen and al. EcoGrid EU - A prototype for European smart grids. Deliverable D3.3: Implementation-level system architecture with design of market place at implementation level,2015.
- A. Jokic. Price-based optimal control of electrical power systems. PhD thesis, Technische Universiteit Eindhoven, 2007.
- S. J. Kim and G. B. Giannakis. An online convex optimization approach to real-time energy pricing for demand response. IEEE Transactions on Smart Grid, 8(6):2784–2793, 2017.
- I. Lampropoulos, N. Baghina, W. L. Kling and P. F. Ribeiro. A predictive control scheme for real-time demand response applications. IEEE Transactions on Smart Grid, 4(3):2049–2060, 2013.
- G. Le Ray, E. M. Larsen and P. Pinson. Evaluating price-based demand response in practice - With application to the EcoGrid EU experiment. IEEE Transactions on Smart Grid, 9(3):2304–2313, 2018.
- P. Lund and al. EcoGrid EU deliverable 6.7: overall evaluations and conclusions, 2016.
- J. Saez-Gallego and J. M. Morales. Short-term forecasting of price-responsive loads usinginverse optimization.IEEE Transactions on Smart Grid, 9(5):4805–4814, 2018.
- M. Schutten. Balancing imbalances on using reinforcement learning to increase stability in smart electricity grids. PhD thesis, University of Groningen, 2016.
- R. Tabors, G. Parker, P. Centolella and M. Caramanis. White paper on developing competitive electricity markets and pricing structures, 2016.
- M. D. Trong, M. Salamon and I. Dogru. Experience with consumer communications and involvement in smart grid - With examples from EcoGrid on Bornholm. Summary and recommendations, 2016.

Expected impact for Belgium

- As described in the section 3.1, the decentralized flexibility is necessary to achieve the 5GW of flexibility needed by 2030.
- Better understand the price sensitivity and develop algorithm to compute price signals triggering the right reaction and then guarantee the adequacy of the system.
- On the system point of view, smart pricing could support the incentivization of decentralized flexibility and its benefit in the grid operations in the context of a new implicit market design.
- More specifically, test the following use cases: peak load reduction and load shifting to match consumption with RES production periods. It could be achieved through being able to better manage the congestion and balancing problems, operate the grid more to the limit.
- Having new ways of dealing with constraints without obviously build new infrastructure that will take too much time to be ready.
- Investigate a new type of market: implicit market (in opposition with the actual explicit market).
- Final consumers (residential and SME) to enter and to participate to the wholesale market (which was not possible before). It goes with a risk transfer from retailers towards final consumers with the goal to, in fine, reduce their energy bills by shifting their power demand to low-cost periods. The goal of smart pricing is to reduce energy bills of flexible consumers but it comes with an increased exposure of final consumers to the energy price volatility on the market. Therefore, some cases could lead to an increase of the energy bill.

Starting point Elia

- Elia has set up an artificial intelligence lab in 2018 with the aim to develop the usage of these technics within the group. When starting the initiative, several interviews with experts have been realised and ideas were clustered. This one was one of the main ideas for the market cluster.

- In parallel pre-analysis of the concept of implicit pricing was performed in 2017
- Elia has launched in 2017 a prospective study : the Long Term Market Design (LTMD) whose purpose was to explore the possibilities of market design beyond 2030, i.e. in an extreme decentralized and decarbonized energy landscape. The conclusion of this study has emphasized the growing importance of real-time markets. 2 approaches were considered to build further on this conclusion: one exploring more the concept of Real Time Explicit Markets (RTEM) and and the other one, Real Time Implicit Markets (RTIM). As RTIM concepts are quite different than the current approach to market design , Elia wanted to investigate and deepen the concept of RTIM in particular to validate different elements such as the capability to correctly estimate the price sensitivity curve of flexible demand, the capability to produce a price in line with a desired reaction from the flexible demand and finally the capability of the demand to react.
- Elia has decided to leverage from the IO.E initiative to engage in the project Sensa with other members (Ores, Engie, Laborelec, NRB, One Smart Control, Automation, N-Side) to further explore the concept of Real Time Implicit Markets. In other words, Elia develops its knowledge about smart pricing within the framework of the Sensa project. Information that are presented in this section are related to the Sensa project. The Sensa project is initially a project related to the development of an implicit real time market for integrating residential households to the wholesale energy market. The Sensa project is currently undergoing the sandboxing phase. The sandboxing phase has started in October 2019 and is planned to go until September 2020. The aim of this phase is essentially to build knowledge about user's appetite for real time price signals and assess the technical feasibility of the solution.

Uncertainties & risks

- On the project point of view
  - The initial uncertainty is the technical feasability of such a solution. Is it possible to predict properly the grid needs (imbalance, congestion, etc) and then transform this into a price signal to trigger the reaction of the decentralized flexibility
  - For the project itself, a risk is linked to the connectivity and the interfacing between the different equipment.
  - Electrical appliances at disposal to participate to this market.
  - The return for the participants vs the investment needed.
  - Lack of implication of external partners within the project team.
  - High cost of the hardware.
  - Uncertainties about the design of dynamic pricing.
- On the general dynamic pricing point of view
  - Insufficient smart meters roll-out.
  - Too low awareness of consumers with respect to dynamic pricing and/or too high risk aversion of consumers who do not want to apply for dynamic (and smart) pricing contracts.
  - Limited market potential: the full benefit of dynamic pricing and related demand response can only be achieved if a critical mass of users opts for this type of contract. There might be many households that do not want to adapt their consumption pattern because of personal constraints.
  - Limited impact of the energy component of the retail energy price.

Project description

The project aims to develop a range of tools to address the issue of how best to capitalize on flexibility, especially residential flexibility. It does not set out to develop a single product targeting just one type of player (e.g. grid operators, consumers or the management of systems for the consumption of self-generated energy) and while it may only resolve a small part of the problem, it may provide a solution addressing the entire issue through its various sub-projects and tools.

The project is aiming to assess different parts of the value chain of smart pricing:

1. *Home technologies*: *CONFIDENTIAL*, *CONFIDENTIAL* and *CONFIDENTIAL*will act as the technology leads in developing the smart node, ensuring it works properly and guaranteeing that it can be installed in

end consumers' homes to control their flexible assets. *CONFIDENTIAL* leads the development of a consumer portal for interaction with the project team and for real time follow-up of the appliances consumption and signal prices.

2. *Smart price signals*: Elia will act as the technology lead for the development of a price engine model. *CONFIDENTIAL*will contribute its knowledge of algorithms (Artificial Intelligence, machine learning, big data) and its experience of developing industrial solutions. The partners who may generate price signals for a specific use case (e.g. balancing, general and local congestion, BRP portfolio balancing) will be involved in jointly developing smart-pricing algorithms. Elia will work on use cases related to the issues facing TSOs, *CONFIDENTIAL* on DSO-related use cases, and *CONFIDENTIAL* on use cases connected with the activities of BRPs and managers of community schemes for sharing self-generated power. Elia, *CONFIDENTIAL* and *CONFIDENTIAL* will contribute both the data required to develop the algorithms and the business experience that will make it possible to use the data more easily and interpret the results.

3. *User engagement*: During this project, a market survey will be conducted to understand the end users' appetite and willingness to participate in such solution. Other assessments will be made to quantify the amount of flexible residential devices in Belgium.

4. *Pilot project*: A demonstration phase is planned to test the solution in real life configurations. All the consortium partners will undertake recruitment activities to maximize the chance of success (participants will mainly be recruited from consortium partners employees on the territory of Ores and preferably from *CONFIDENTIAL*'s customer portfolio. *CONFIDENTIAL* will contribute to the pilot project with its experience in implementing demonstrator projects (gained through other similar projects financed by public bodies or in-house) and its testing resources (laboratory testing or mobile equipment for on-site testing), as well as over 10 years' experience of energy flexibility in the residential segment. *CONFIDENTIAL*will work with Elia and ORES to adjust the tools developed at earlier stages in the project based on their behavior during testing.

- Approach: the consortium including *CONFIDENTIAL* and *CONFIDENTIAL* was put together to address all the target players: potential managers of systems for the consumption of self-generated energy, BRPs, DSOs, TSOs, suppliers and end customers. The consortium's makeup means that it blends capacity for technical and algorithmic innovation, business experience, market knowledge and a customer portfolio that will allow the tools developed in the project to be tested in a real-life environment, with the partners' work on smart nodes, smart pricing, response and settlement, feeding into a comprehensive pilot project.

- Work packages & Timing(M=month)
    1. WP 1 Website – *CONFIDENTIAL*
        - This WP relates to the design and development of the website of the Sensa project. It includes a public website for communication purposes and also a connected area to allow testers of the project to access their personal consumption data.
    2. WP 2 Smart pricing – *CONFIDENTIAL*
        - This WP relates to the development of the price engine algorithm using AI i.e. the market based tool implementing the implicit real time market.
    3. WP 3 Smart node – *CONFIDENTIAL*
        - This WP relates to the development of the smart gateways of the project. These smart gateways (called smart nodes) are installed in user's homes and are able to steer flexible devices based on the real time price signal generated and sent out by the price engine.
    4. WP 4 Recruitment and engagement – *CONFIDENTIAL*
        - This WP relates to the market analysis to determine the user's appetite and engagement to smart pricing. It includes also among others the material linked to the economic and business analysis to

determine the economic feasibility of the project, the elaboration and management of the different contracts and legal documents needed between the members of the consortium and with the private users/customers and the actions related to communication and knowledge sharing events with other use-cases of the IO.E eco-system.

5. WP 5 Pilot project – *CONFIDENTIAL*
   - This WP relates to actions related to the demonstration phase of the project.

- Deliverables – The deliverables expected at the end of the sandboxing phase (*CONFIDENTIAL*) are:
  1. A 10-pager report summarizing the status as well as the lessons learned of the project so far
  2. A presentation in front of a panel of experts to collect feedback about the project

Partners

- *CONFIDENTIAL*: in charge of big data analytics and AI implementation for the project;
- Elia: partner in the development of smart-pricing technologies (jointly with *CONFIDENTIAL*). Elia also brings its energy market expertise and highlights TSO grid management interests;
- *CONFIDENTIAL*: key role in developing home technologies and associated tools for consumers (Part 1) and setting up the demonstrator project (recruitment, smart node installation, data reporting, end-user interface);
- *CONFIDENTIAL*: key partner in the implementation of the demonstrator project, using recruitment;
- *CONFIDENTIAL*: partner shedding light on the collective and societal challenges facing distribution system operators: Construction of innovative incentive-based solutions in line with the system's needs, and provision of expertise (consistency with existing decrees – smart meters, technical flexibility, energy communities) and application to customers connected to the grid in the area supplied by *CONFIDENTIAL*;
- *CONFIDENTIAL*: development of the project website and client portal
- *CONFIDENTIAL*: hardware home technology provider
- Automation: hardware home technology provider

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
Total Project	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Website	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

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WP 2	Smart price engine	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Smart Nodes (gateway at home)	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Recruitment and engagement	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 5	Pilot project	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 24: Tracking of green ancillary services

Domain 5.2

2020 Decision: New – Not proposed

Trend: Decarbonization, digital revolution

Consequences: Sustainability in our business

Challenge: 5. Make the TSO business (market facilitation, system operations and asset management) more sustainable

Domain: 5.2 Sustainable system operations

Project Specific Context

- More and more sectors are concerned by the sustainability of their business which includes generally the renewables source of the consumed energy.
- While certificates of origin are nothing new in the energy business, many companies are now putting into questions if the acquisition of such guarantee is categorizing an energy which at the end is not effectively produced by renewables energy. Indeed the physical characteristics of renewables source depend highly on weather condition which of course does not correspond to the normal consumption pattern.
- As a consequence corporate power-purchase-agreements linked to wind or solar plants are rising the last years and we observe an increased scrutiny over the source of carbon-free kilowatts.
- The problem is that it is difficult to prove that a kilowatt of consumption corresponds exactly to a kilowatt of production from a remote renewable energy plant.
- To answer this growing request from the industry, last years have seen the emergence of new solutions based on blockchain to guarantee the source of a delivered energy. Indeed, the intrinsic property of the blockchain allows to certify new data from an unknown source. This certified immutability of the data creates the trust between counterparts and can therefore enable (micro-) transaction without the need of a trusted intermediary as a bank or an authority guaranteeing the source of the energy. As a consequence, the decentralized ledger can establish this trust in a very short time frame and with a high granularity, making the solution very scalable and suitable for micro (green) energy transactions.
- When blockchain is coupled to the IoT technology, as smart meters, it offers a way of tracking energy production in a much more granular and timely way than is possible with traditional methods. These classical methods involve audits to check that the power consumed within a PPA matches the production of a given renewable plant or portfolio. Therefore it has the potential to create an effective green energy exchange where the effective consumption is allocated to the green energy production.
- Alongside the pure commodity to decarbonize completely the energy system, the operations needs also to rely on renewables sources (solar, wind or stored green energy in battery/ EV).
- Consequently, as for the commodity, a tracking system based on a certification from the ancillary sources could bring the transparency and the guarantee from the ancillary services source.
- This would complement the green energy deliver and complete the full decarbonization of the energy supplied.
- The goal of this project will therefore to develop the concept and implement a first proof of concept for the tracking of the ancillary services (to be defined what would be the best use case among the different ancillary services: aFRR, mFRR, FCR).
- The project is linked to the project 20 with will aim to evaluate the requirements for a fully decarbonized energy system.

Project specific State-of-the-art/Literature study

- A short list of start-ups are offering blockchain based solutions for the tracking of green energy. Among the best example,

  - EW Origin is a development pack based on the Energy Web Chain that can be deployed to guarantee the source of specific energy meter
  - the startup FlexiDAO is tracking 3 terawatt-hours per year across nine countries offering a differentiating added-value to corporate green PPA.
  - The Energy Origin (TEO) is offering certification to corporate client through Engie as supplier
- Though none of them are currently offering the tracking of ancillary services sources.

Expected impact for Belgium

- Demonstration of the feasibility to track the green ancillary services and the potential to guarantee a 100% decarbonized Belgian energy system and a promotion of the green sources to balance the grid.

Starting point Elia

- Elia has performed a first proof of concept where a proof of concept of a blockchain based market place has been developed. This allowed to gain understanding of the technology and the related constraints. However no test has been made at hardware level.

Uncertainties & risks

- The implementation of the energy tracking technology (most likely blockchain) which will interface with the energy management system, especially for retrieving the data, is foreseen as being a major uncertainty/risk for the test.
- The possibility to embed the tracking on green ancillary services equipment (wind solar or decentralised flexibility sources as battery, EV or heat-pump) is also a major technical unknown considering the specific aspect of the ancillary services compared to a pure energy tracking.

Project description

- Preliminary description (to be refined later during the proper scoping of project)
- The project will consist in the development of a solution to track the renewables source from an ancillary services source.
- This solution, most likely based on blockchain solution as the energy tracking solution (similar to EW Origin, FlexiDAO…) will be developed first based on the principle of green energy tracking adapted to the use case of the ancillary services.
- First test will be performed in a “lab-environment” i.e; without being directly connected to assets.
- Test assets will then be identified (location to depend on the availability of renewables sources for the test) and will be connected to the tracking solution and a test environment to simulate activation of ancillary services.
- Ultimately, if possible, test will be performed in real conditions (in a test environment) including activation, and certification of the delivery.

Approach: the solution will be developed in collaboration with a specialist company, as Energy Web Foundation that has already developed a solution for green energy tracking, EW Origin. The selection of the green sources for the test will be defined later.

Workpackage (preliminary)

WP 1: Scoping of the project

- *CONFIDENTIAL*: Workshops to refine the problem statement including ancillary services requirements
- *CONFIDENTIAL*: Writing of project requirement
- *CONFIDENTIAL*: Planning of the project and selection of the partners

WP 2: Development of the solution and test in “lab-environment”

- *CONFIDENTIAL*: iterative development of the solution

WP 3: Connection of asset

- *CONFIDENTIAL*: Selection of the partners and identification of the test assets (cars/ charging poles) and sites for the test
- *CONFIDENTIAL*: Development of the necessary hardware and test interfacing with the solution for the management of the energy system
- *CONFIDENTIAL*: Installation of the hardware
- *CONFIDENTIAL*: Test connectivity and interfacing with the energy management system.

WP4: Test in real condition

- *CONFIDENTIAL*: Test of ancillary services tracking

WP5: Conclusion and next steps definition

- *CONFIDENTIAL*: Writing the final report.

Deliverables and milestones:

- *CONFIDENTIAL*: results of the scoping workshops
- *CONFIDENTIAL*: scoping document
- *CONFIDENTIAL*: Solution developed
- *CONFIDENTIAL*: report from the connectivity test and interfacing with the EMS
- *CONFIDENTIAL*: Communication of the results

Partners

- Definition of partners is still undefined: most likely *CONFIDENTIAL* will support the project including their solution *CONFIDENTIAL*
- The internal department to be involved in Elia: Customer centricity department, innovation department and market design

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR	2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

WP 1	Scoping of the project	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 2	Development of the solution and test in "lab-environment"	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 3	Connection of asset	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 4	Test in real condition	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

WP 5	Conclusion and next steps definition	2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Domain 4.3

Project 25: Smart Wires

2020 Decision: New – not proposed

Trends: Decarbonization**,** digital revolution

Consequences: Ageing of the infrastructure, Develop infrastructure to flow important RES infeed

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project Specific Context

- The purpose of this project is to test, through a proof of concept (POC) being rolled out on our grid, a new technology called 'SmartValve' developed by the company Smart Wires.
- This new technology allows the impedance of connections to be dynamically increased or reduced by injecting a voltage in quadrature with the current. In a similar way to a phase-shifting transformer (PST), this technology makes it possible to control power flows running through overhead lines.
- This technology has already been deployed on a fairly massive scale in the United States but tends to be only at the testing stage in Europe (Ireland, France).
- It should be noted, however, that this technology is not intended to replace PSTs on cross-border 380-kV lines. While it is true that while the higher the level of current, the greater the impact of a Smart Wire module, it can be also be very useful for connections carrying a lower current.
- Elia has already identified part of its grid where this technology could potentially be tested and be highly beneficial, namely the 150-kV Koksijde-Slijkens cable, as this would avoid shutdowns at Herdersbrug (costs estimated in the future at €1.7 million per year). Moreover, once the Ventilus project is completed, the cable would no longer face overloads. Unlike a PST, the Smart Wires module could then be disassembled and reused elsewhere.
- However, before deploying this technology on a very critical line in our grid, we propose initially performing a POC on the 70-kV mesh network in which overload limitations are also identified. This POC would allow us to test whether the device operates properly, identify any limitations, and check whether the device behaves appropriately in the event of a fault, to ensure that faults are dealt with appropriately.
- To do this, we propose installing this module in series on the 70-kV Cierreux-Houffalize line. The installation of this module in the eastern loop would reduce the need to call on the flexibility of connected renewable production units or make it possible to consider connecting more production units, in particular at the Cierreux substation. Therefore, in the event of the loss of the 70-kV Cierreux-Brume cable, this module would mean that the relevant flows could be forced north of the loop, preferentially onto the Cierreux-St. Vith line rather than the Cierreux-Houffalize line.

Project specific State-of-the-art/Literature study

- Based in the San Francisco Bay area and with offices in the United States, the United Kingdom, Ireland, and Australia, Smart Wires is the leader in grid-optimization solutions that leverage its patented modular power flow control technology. Smart Wires solutions can be deployed quickly, enabling utilities to react fast and address pressing problems.
- Smart Wires' technology was developed by utilities for utilities, led by a consortium of large US utilities at the National Electric Energy Testing Research and Applications Center (NEETRAC). This core group of utilities, which included Southern Company and the Tennessee Valley Authority (TVA), defined the vision for the original modular power flow control solution. PG&E, EirGrid (Ireland), Minnesota Power, Central Hudson, and Western Power (Australia) are just some of the other utilities leveraging Smart Wires' solutions in this domain.
- Smart Wires teamed up with EnerNex to study the implications of the SmartValve and SmartBypass for sub-synchronous resonance (SSR). EnerNex found that active voltage injection from the SmartValve provides reactive compensation at line frequency like conventional series capacitors, but its actions do not extend to other frequencies. For more information, please refer to the study *Comparative Performance of Smart Wires SmartValve with EHV Series Capacitor: Implications for Sub-Synchronous Resonance*, available on the Smart Wires website.

Expected impact for Belgium

- This is a flexible AC transmission system that is similar to PSTs, but having the following advantages:
    - lower costs;
    - quick installation (around one year);
    - modular technology (modules to be connected in series depending on the required flow control);
    - ease of redeployment: if the strain on the network is eliminated, the module can be easily disassembled and redeployed elsewhere, even for a different voltage level;
    - no need for transportation as an abnormal load.
- It could be an alternative solution for PSTs in the sub-150-kV grid or be combined with them.
- It enables renewables' penetration to increase in some regional networks/an increase in the time frame for upgrading the grid from 70 through 110 kV.
- It could ease brief periods of congestion (e.g. works).
- It could be an alternative solution to overly short time frames for conventional solutions (e.g. PSTs).

Starting point Elia

As explained above, this project is new and a proof of concept. It is the first time that Elia has used such technology and therefore the idea is to learn a lot about it by doing so.

Uncertainties & risks

- There is a risk of involuntary bypass activation, requiring a quick modification of power fluxes in the lines.
- Risk mitigation:
    - For the POC: In planning and operational criteria, take into account 'n-1' smart wires (= involuntary bypass activation) to ensure that the grid can cope.
    - Take an in-depth look at the documentation produced by Smart Wires (explanations of bypass mode activation and advice regarding settings).
    - Check whether protective devices are working and/or malfunctioning.
    - Examine the possibility of historical data for I0 and I2(?).
    - To be discussed with Smart Wires: Possibly combine of the two detection functions (VDC supervision and I0/I2).
    - Contact other users for feedback about communication and bypass activation.

Project description

The purpose of this project is manifold:

- to carry out a feasibility study for installing such a module at the Houffalize substation, doing so in series on the Cierreux-Houffalize line; this feasibility study means establishing a multi-departmental working group: AM (HV, Powerlinks, LV, and the telecommunications and communications aspects with the Dispatching), Infrastructure, GD, Safety, MAC, Netop
- to purchase the Smart Wires module (3 Ω) and install it;
- to make the appropriate adjustments to the 70-kV Cierreux-Houffalize line (descents and installation of an insulator to allow the module to be installed in series on the line);
- to analyze and implement the control of flows on the grid from Elia Dispatching (remote management);
- if necessary, to move the 70-kV cable of the Houffalize 220/70-kV transformer if it is in the module's installation area.

- Work packages and timing (M = month)

    1. *CONFIDENTIAL*Preliminary study
    2. Permit application

3. RFP preparation

- Deliverables and milestones
    - *CONFIDENTIAL*
        1. Detailed project specifications
        2. RFP selection
        3. Issue of the permit
    - *CONFIDENTIAL*: Implementation.

Partners

- Smart Wires

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

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		2019	2020	2021	2022	2023	Total
WP 1							
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
50%	Total Incentive						

Project 26: Universal Cable joint

Domain 4.3

Decision 2020: New – not proposed

Trend: Decarbonization, digital revolution

Consequences: Develop infrastructure to flow important RES infeed

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project Specific Context

- Underground cable systems are widely installed on the Belgian network. Specific test programs are performed to qualify these cable systems, and this for the different voltage levels and cable suppliers. This in order to have a reliable system on the long term. Up till now, no qualification has been performed between cables from different suppliers due to the differences in design, materials used, etc.
- In order to have more flexibility for projects building further on existing cable links, the idea has risen to qualify transition joints between different qualified cable suppliers in order to connect cable systems from two different suppliers with a qualified universal cable joint. This universal cable joint can also be used to perform repairs on an existing cable system with another cable supplier than the installed system. The starting point for the universal cable joint is the 150kV cable system on the Belgian grid.

Project specific State-of-the-art/Literature study

- No know similar study or project except an initiative launched by Tennet a few months ago

Expected impact for Belgium

- To have more flexibility for new projects which are building further on existing underground cable links and have the possibility to connect cables from another cable supplier to this existing underground cable link. This will bring more competition in the selection of cable providers and therefore decrease the total cost of the infrastructure.
- The flexibility of using multi-suppliers will also allow to make repairs of existing underground cable links independent from the cable supplier who has installed the initial underground cable link. This will therefore enable more competition between companies repairing the cables and also shorten the time for a repair (then decreasing the risk of an extended outage of a critical infrastructure and support the adequacy).

Starting point Elia

- This universal cable joints should be able to connect not only cables from different cable suppliers, but also cables with different design, conductor materials (copper and aluminum), conductor cross-sections and different types of metallic screens. The combination of all these things in one universal cable joint makes it quite complex.

Uncertainties & risks

- As the solution will bring more competition, a first uncertainty it then to have a full cooperation of all involved parties, since exchange of material of different suppliers is needed
- Another risk is of course the technological possibilities to develop a design of cable junction that is able to combine the different requested parameters as described above
- Finally, as any innovation the test in real conditions might show some operational challenges. Qualification test of this universal cable joint, could then possibly lead to identification of unforeseen issues.

Project description

- Design and qualification of a universal cable joint for 150kV.
- Given the changing environment with different stakeholders and the expansion of the underground cable network, Elia needs to find innovative solutions and the universal cable junction is one of these.

- Work packages & Timing(M=month)
    1. *CONFIDENTIAL*: MOU with involved parties
    2. *CONFIDENTIAL*Start negotiations for FA for the RTJ
    3. *CONFIDENTIAL*Determine final types of accessories and test loop setup
    4. *CONFIDENTIAL*Material acquisition for test loop
    5. *CONFIDENTIAL*Selection of test facility for type test
    6. *CONFIDENTIAL*Qualification test

- Deliverables & milestones
    - *CONFIDENTIAL*Signed MOU + selection of cable supplier
    - *CONFIDENTIAL*Outline frame agreement agreed upon
    - *CONFIDENTIAL*List of accessories and test loop defined
    - *CONFIDENTIAL*Material and test facility ready + installation test loop
    - *CONFIDENTIAL*Test report ready

Partners

- Cable supplier and test facility to be selected

Summary of project efforts in person months: by work package and by year

	Budget & timeline in EUR						
		2019	2020	2021	2022	2023	Total
Total Project	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
	Total Incentive						

		2019	2020	2021	2022	2023	Total
WP 1	**IT Cost (€)**						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

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WP 2		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP 3		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

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WP4		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

WP5		2019	2020	2021	2022	2023	Total
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						

		2019	2020	2021	2022	2023	Total
WP6							
	IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Software/Licence						
	NON-IT Cost (€)						
	External resource - Bodyshopping						
	Material						
	External Services						
	Total external costs						
	Internal resources (FTE)						
	Internal resources (€)						
	Internal resources (PM)						
	TOTAL Costs+Internal resources(€)						
25%	Total Incentive						