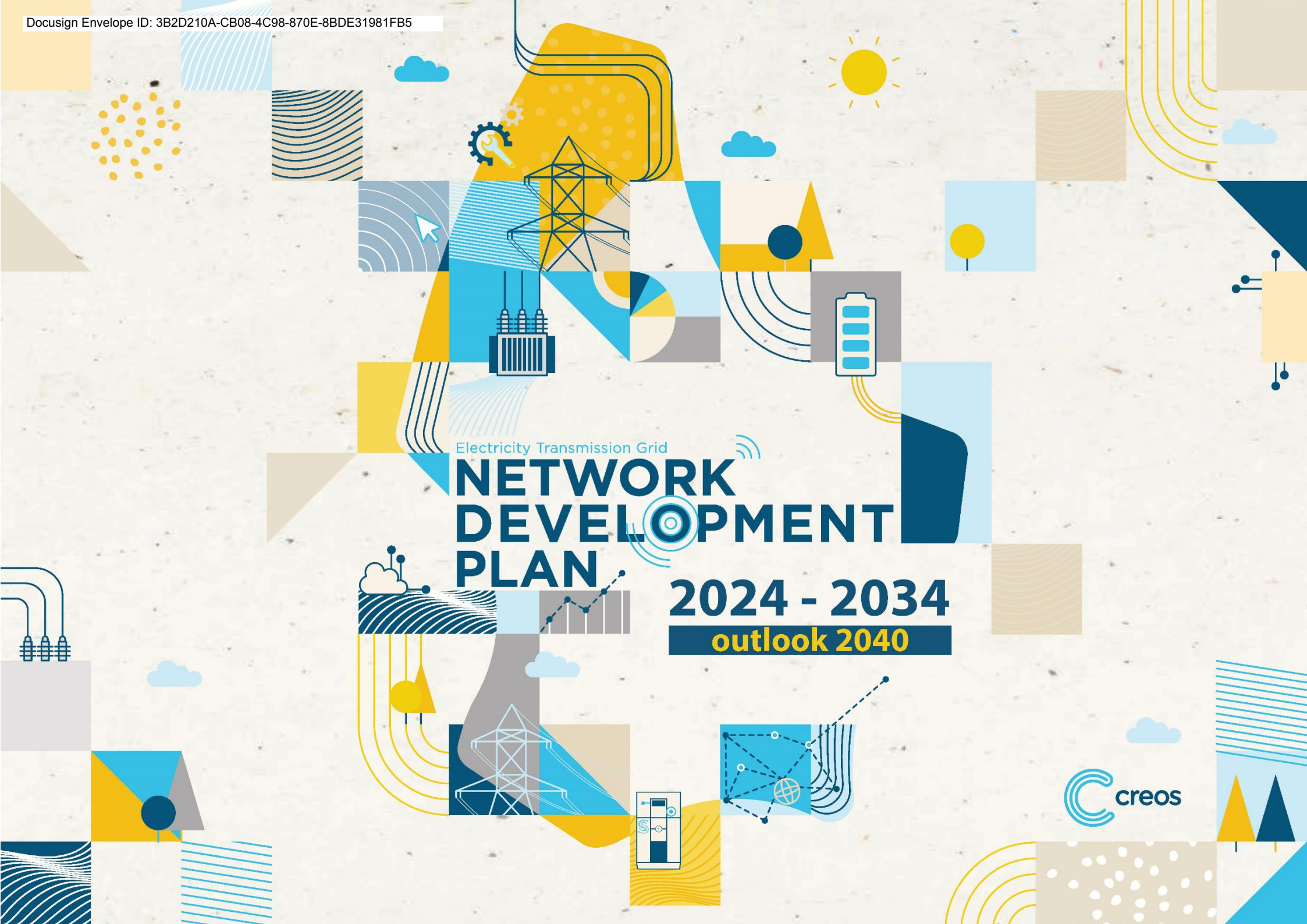

Electricity Transmission Grid

NETWORK DEVELOPMENT PLAN

2024 - 2034

outlook 2040

creos

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Executive Summary

Electricity and hydrogen are key energy carriers to build a future integrated energy system and to decarbonise transport, heating and industrial processes. As transmission and distribution system operator of electricity and gas grids, Creos Luxembourg plays a central role to enable the energy transition in Luxembourg.

Creos Luxembourg is fully aware of the need to optimise utilisation of its electricity transmission and distribution grid infrastructures, to increase overall efficiency and to enhance grid capacities when needed, in order to facilitate the decarbonisation process.

Besides ensuring security of energy supply, the general commitment of Creos Luxembourg is to create the necessary electrical infrastructure to enable the energy transition and help achieve the targets of the National Energy and Climate Plan. To do so, the following guiding objectives have been drawn up for the elaboration of network development projects: Security of supply, Sustainable development, Cost efficiency and Innovation. Also, the application of the NOVA* principle during the planning process ensures that optimisation methods are considered before reinforcement solutions and grid expansions.

The planned grid modifications described in this network development plan are justified and should be seen as no-regret investments into Luxembourg's future electrical energy infrastructure. Power system flexibilities and electricity storage solutions have been imperatively considered during the planning process, and during the definition of the appropriate grid modifications and related investments. The projects described in the frame of this network development plan aim to achieve adequate grid capacities over the next 20 years to securely supply all of Luxembourg's electricity consumers and to integrate a maximum of electricity generation from renewable energy sources.

The secured import and transmission capacity of the existing electricity supply lines coming from Germany is currently limited to 980MW. The concept and design of these supply lines was created over 50 years ago, at a time when the peak power demand reached only 10% to 15% of the secured import capacity. Today, about 75% of the import and transmission capacity from Germany is already used during peak import.

During winter months when domestic generation is lowest, future import needs for electricity consumption purposes could rise up to 1600MW in 2040, driven by economic growth, digitalisation, and decarbonisation of various end-use sectors such as mobility and heating. On the other hand during spring and summer months, ambitious indigenous electricity generation targets could lead to excess generation up to 1400MW in the future. Reductions due to activation of flexibilities in the power system and a certain amount of electrical energy storage have been considered and are included in those figures. The development of the transmission grid is imperative and Creos Luxembourg established a network development plan to satisfy the current and future needs.

It is intended to achieve a substantial capacity increase on the transmission grid and an improvement of Luxembourg's security of supply by replacing the 220kV electricity supply lines coming from Germany with a 380kV infrastructure.

In a first step, it is planned to build a new 380kV infeed replacing one of the two 220kV overhead lines coming from Germany. Also, two new 380/220/110(65)kV transformer substations are planned to transform the transmitted energy and to connect existing high voltage transport and distribution infrastructures to the 380kV infrastructure.

** NOVA is a German acronym for 'network optimization and grid strengthening before grid expansion'*

More specifically, the most immediate and important project on the transmission grid level is the planned construction of a new 380kV double line between Aach (Germany), Bofferdange and Bertrange in replacement of the existing 220kV overhead lines 'Trier - Heisdorf' and 'Heisdorf - Bertrange'. Associated with these works, is the construction project of a 380/220/110(65)kV transformer substation in Bofferdange. To guarantee the security of supply on short and mid-term in case of an unavailability of the 380kV infeed, it is also planned to replace the conductors of the 220kV overhead line between Roost and the future station Bofferdange, thus completing the initiated reinforcement with high performance conductors (HTLS*) on the 'northern' 220kV connection. It is intended to achieve the commissioning of those projects, representing the first milestone of the development strategy, by the end of the year 2029.

Because of the expected increase of electricity demand in the capital city, its surroundings and in the south of Luxembourg, the installation of a second 380/220/110(65)kV transformer substation is projected at Bertrange (expansion/modification of the existing substation Bertrange). This additional 380kV substation will be supplied with the help of the 380kV infrastructure already prepared during the preceding grid development. The commissioning of this second 380kV substation is intended around 2035-2036, and the completion of the project can be seen as milestone 2 of the development strategy.

Over the longer term, a further strengthening of the 380 kV connection with the German 380 kV transmission grid is being considered. The 'northern' 220kV grid connection capacity is limited by certain constraints on the 220kV voltage level in Germany. Therefore, it is currently projected to replace the existing 220kV double line between Bofferdange, Roost, Flebour and the country border near Vianden / Bauler with a 380kV infrastructure, in compliance with the German grid development projects in this region.

**HTLS conductors: High temperature low sag conductors*

Although multiple solutions for the network development were discussed, analysed and evaluated during the network planning process, several grid development alternatives, such as the creation of a 3rd 220kV infeed from Germany, a reinforcement of the 220kV connection with Belgium and the replacement of the conductors of the two 220kV interconnection lines with Germany with high performance conductors, could not be validated due to various reasons.

The current grid development strategy of Creos Luxembourg is the product of years of analysis refinement, of combined know-how and expertise, and will be continuously reevaluated and further developed.

In total, the investments related to the network development projects documented hereafter amount to 350 million Euros, spread over the next 10 years.

2024 - 2034 in figures

350 million EUR*
of planned investments on transmission grid 380kV & 220kV

300 million EUR*
investments for the realization of the 380kV overhead lines and for the stations Bofferdange & Bertrange

50 million EUR*
investments on voltage level 220kV (compensation installations included)

- 200 million EUR* for milestone 1
- 100 million EUR* for milestone 2

New 380kV infrastructure
+ 50km overhead lines
+ 170 pylons
+1x 380kV substation (Bofferdange)
(+1x 110(65)kV substation Steinsel)

Replaced 220kV infrastructure
- 75,4km (220kV & 65kV)
- 225 pylons
-1x 220/65kV substation (Heisdorf)

** Provisional cost assessment, may be subject to revision*

Introduction

The mission of Creos is to ensure the security of supply of the energy transport and distribution networks and to serve the customers in the Grand Duchy of Luxembourg in a non-discriminatory way with transparent and regulated tariffs. This role is executed equally with respect to all suppliers and by respecting the company's public service and environmental protection obligations. Aware of the economic, social and environmental issues at stake, Creos has a long-standing commitment to the principles of sustainable development.

The planning of a sustainable, future-proof electrical infrastructure is becoming increasingly challenging due to the uncertainty regarding future economic, social and environmental developments. In addition to higher electricity consumption, the electrical grids of tomorrow will be strongly influenced by the desired decarbonisation process in the European Union. In order to stay in line with the EU targets of reduced greenhouse gas emissions, intensified use of renewable energies and improved energy efficiency, electricity grids must be adapted accordingly. The transition to a post-carbon society will bring huge changes in the industrial, tertiary, residential and transport sectors and will strongly influence the electrical energy needs.

The current trend indicates that the shift towards a much higher percentage of volatile electricity generation from renewable energies may happen even faster than the increase of electricity consumption, thus intensifying the need for strong electricity transmission and distribution grids. Volatile, uncontrollable power generation and high electricity consumptions will put electrical grids at all voltage levels to the test during times of peak consumption and generation.

Enabling flexibilities on the demand and supply side is a priority, as it can help reduce generation and consumption peaks. A higher rate of self-consumption of the electricity generated by renewable energies and optimised interplay between generation and load must be targeted in the future with the help of smart grid devices and electricity storage systems.

Key figures that are relevant for future electricity needs have been identified from the National Energy and Climate Plan in its version from 2020 and were used to establish forecasts. The details and the summarized forecasts have been documented in the report 'Scenario Report 2040' - version 2022, which provides an outlook on the future power demand, power generation, excess generation and future electricity transmission needs in Luxembourg. Those forecasts are relevant for the grid dimensioning of the transmission and distribution grids of Creos Luxembourg.

The present document, the 'Network Development Plan 2024-2034', provides a comprehensive view on the planned modifications of the high voltage transmission grid of Creos Luxembourg over the period 2024-2034, using descriptions and illustrations of the intended reinforcement projects. Bottlenecks on the existing infrastructure and risks for security of supply have been analysed in relation with the projected increase of power demand and electricity generation. Reductions of the power flows, due to enabled flexibilities and storage systems, have been duly considered.

It should be noted that the national energy and climate plan for Luxembourg is currently in the process of being updated and that Creos Luxembourg will review and update its subsequent documents after finalization of the new version of the NECP. The next versions of the 'Scenario Report' and of the 'Network Development Plan' will be based upon the updated version of the NECP.

Scope of document

Creos Luxembourg plans, builds, operates and performs the maintenance of electricity grids on several voltage levels in Luxembourg.

As Transmission System Operator (TSO), Creos Luxembourg currently operates a grid infrastructure on a voltage level of 220kV, further referred to as high voltage transmission grid or high voltage transport grid.

As Distribution System Operator (DSO), Creos Luxembourg operates several regional grids on a voltage level of 65kV, further referred to as high voltage distribution grids, and operates additionally multiple distribution grids on the medium and low voltage level. Creos Luxembourg operates its distribution grids on the medium voltage level with a voltage of 20kV, and the low voltage grids, which are distributing the electrical energy to the households, small farms and businesses, with a voltage of 400V.

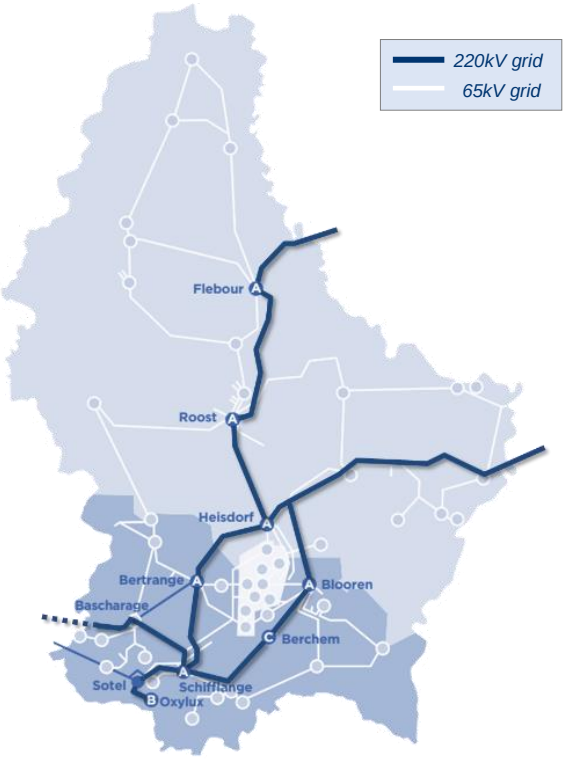
Besides Creos Luxembourg, there are currently 3 other distribution system operators in Luxembourg, which are operating local electricity distribution grids open to the public on a voltage level of 20kV and 400V. And, in the south of Luxembourg, there is also an operator handling and maintaining a private electricity grid for industrial purposes.

Transmission / Transport	*220kV* *High Voltage Transmission*
Distribution	*65kV* *High Voltage Distribution*
	20kV *Medium Voltage Distribution*
	400V *Low Voltage Distribution*

The scope of this network development plan is limited to the high voltage transmission grid of Creos Luxembourg.

Network Development Plan 2024-2034
Electricity Transmission Grid (TSO)

220kV - High Voltage Transmission Grid



Context

Energy transition

It has been largely recognised that global greenhouse-gas emissions must be brought to zero to limit global warming and preserve a liveable climate. Fossil fuels used for transport, for heating, in the industry and in the energy sector are the largest source of carbon emissions and global greenhouse gas emissions. It is therefore necessary to achieve the transition from fossil fuels to low carbon and renewable energy sources to reduce greenhouse gas emissions.

European Green Deal / Fit for 55 / REPowerEU

Being aware that greenhouse-gas emissions must be brought to zero, the European Union launched a transformational change at the end of 2019 by presenting the European Green Deal. The European Union has the ambition to be the first climate neutral continent by 2050 and the European Green Deal is the roadmap to transform the European Union into a modern, resource-efficient and competitive economy.

To implement the European Green Deal, the European Commission adopted a set of legislative proposals, the 'Fit for 55' package, on 14 July 2021, to make the European Union's climate, energy, land use, transport and taxation policies ready for achieving a substantial reduction of greenhouse gas emissions by 2030, and climate neutrality in Europe by 2050. The European climate law makes reaching the EU's climate goal of reducing EU emissions by at least 55% by 2030 a legal obligation.

Furthermore, in response to the global energy market disruption caused by Russia's invasion of Ukraine, the European Commission presented the REPowerEU Plan in May 2022. The measures of this plan aim to end the European Union's dependence on Russian fossil fuels, which are used as an economic and political weapon. With the REPowerEU Plan, which also aims to tackle the climate crisis by accelerating the energy transition, the objectives of the 'Fit for 55' package have been raised, completed and enhanced to save more energy, to diversify energy supplies and to accelerate the roll-out of renewable energies.

Energy transition in Luxembourg

In accordance with the European Green Deal Roadmap, Luxembourg specified goals for the reduction of greenhouse gas emissions, for raising the renewable energy share and for improving energy efficiency, written down in the National Energy and Climate Plan (NECP).

The energy transition in Luxembourg is proceeding apace and electricity is playing a major role in the decarbonisation of the country's energy system. Electricity generation from renewable energy sources is continuously growing, especially from solar PV installations, energy end uses such as heating and mobility are being electrified and new services are emerging due to innovative digital technologies and business opportunities. In this context, Creos Luxembourg in its position as transmission system operator is a key player for enabling the energy transition going forward.

Legal framework

On the National level, the law of the 1st of August 2007 relative to the organisation of the electricity market in Luxembourg (memorial A - N°152 / 21 August 2007), which has been modified and complemented successively thereafter between 2009 and 2023, clarifies the responsibilities and obligations of grid operators, electricity producers and suppliers.

The law states that grid operators have to establish network development plan(s), in accordance with the dispositions stipulated in article 27bis, which show the intended network modifications and related investments over the next ten years.

More specifically, transmission system operators and distribution system operators have to establish ten-year network development plans that provide information about the planned modifications and reinforcements with indication of budgeted costs per listed project. Network development plans have to be set up or updated at least every two years.

The network development plan on the transmission system level has to be based upon forecasts of electricity consumption and generation, with the assumption of multiple scenarios that take the demographic, economic and social development into account. Especially, long-term European climate and energy-related objectives, and their national strategic implementation measures must be considered foremost. The document summarizing and illustrating the forecasts has to be the object of a public consultation.

The network development plan on the transmission system level has to indicate the major grid reinforcement and grid expansion projects that are planned during the next ten years, including a time-schedule and the intended investments for those projects. The network development plan has to take fully account of the use of demand response, energy efficiency, energy storage facilities and all other resources that could be used as alternatives to system expansion.

Additionally, relevant Pan-European and regional interconnection projects between the neighbouring countries must be considered. In this regard, the European Network of Transmission System Operators for Electricity (ENTSO-E) is establishing a ten-year network development plan (TYNDP), which is the European electricity infrastructure development plan. It links, supports and complements national grid development plans and provides a wide European vision of the future power system. It investigates how power links and storage can be used to make the energy transition happen in a cost-effective and secure way.

The TYNDP plays a central role in the development of electricity transmission infrastructure in Europe, which is needed for achieving the European policy goals.

After having consulted all stakeholders, transmission system operators shall submit their network development plan to the national regulation authority every two years, to be reviewed and possibly commented for modification by the national regulation authority and by the Minister responsible for energy.

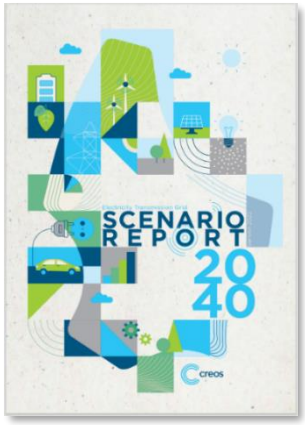
After final modification and approval, the updated network development plan for the transmission system has to be published on the internet site of the system operator and has to be sent to the national regulation authority, to the ministry of energy and to the government's commissioner for energy.

To fulfil the legal obligations and to meet the expectations from all competent authorities, Creos Luxembourg is regularly establishing several complementary documents containing the required data and information:

The 'Scenario Report 2040' is providing a view upon various possible developments of Luxembourg's upcoming electricity needs until 2040, specifically those that are relevant for the transmission and distribution grids of Creos Luxembourg. The Report is based upon target values, key statements and assumptions gathered from the National Energy and Climate Plan for Luxembourg (NECP LU) and it has been complemented with own assumptions and insights concerning e-mobility, decarbonisation with electricity and hydrogen, electricity generation, electricity storage, energy system flexibility and the geographical location of different assets. Quarter-hourly measurement values of consumption and generation were analysed and used, with due consideration of all the enumerated complements, to build different potential consumption and generation profiles for the future. The resulting forecasts of future power demand, electricity generation, import needs and excess generation have been summarized in this document.

The values from the forecasts from the 'Scenario Report' are used to analyse the impacts on the existing electricity infrastructure and to assess the risks for security of supply on short, mid and long-term. This analysis is helping to determine the appropriate investments and grid infrastructure for the future. The network development plan contains efficient measures in order to guarantee adequacy of the system and security of supply.

In this context, the present document 'Network Development Plan 2024-2034 – Electricity Transmission Grid' is outlining the planned development of the high voltage transmission grid of Creos Luxembourg until 2034, with an outlook until 2040, and describes and illustrates the major reinforcement projects, with the intended timeline and the related investments.



The 'Scenario Report 2040' in its version 2022 is based on the national energy and climate plan - Luxembourg published in 2020. The national energy and climate plan has been reviewed and updated during the year 2023 and a final version is expected to be issued during the year 2024. A preliminary draft of the updated NECP has been released at the end of March 2023, after the publication of the 'Scenario Report 2040 – Electricity Transmission Grid' from Creos Luxembourg.

This document, the 'Network Development Plan 2024-2034 – Electricity Transmission Grid' is based upon the projections and scenarios from the Scenario Report 2040' version 2022 and so on the national energy and climate plan published in 2020. However, Creos Luxembourg analysed the data from the preliminary draft of the updated NECP from 2023 and verified the consistency of relevant values, such as total electricity consumption, electricity consumption of the transport sector, targeted electricity generation and projected hydrogen needs, with the values and projections of the 'Scenario Report 2040'.

Creos Luxembourg assessed that relevant values from the draft of the updated NECP do not differ significantly enough to impede the use of the projections from the 'Scenario Report 2040' version 2022 for the elaboration of the present network development plan. The next versions of the Creos documents will be based upon the updated NECP after its finalization.

Methodology

Guiding principles of the Network Development Plan(s)

In order to make the targeted energy transition a success, the future energy system needs to be reliable, sustainable and affordable. The planned investments and projected reinforcements presented in this network development plan are important for ensuring electricity supply and improving the security of supply and are essential for the connection of centralised and decentralised renewable electricity generation plants. By promoting and making use of innovative technologies to enable all possible flexibilities, it is intended to benefit from the existing grid capacities at best to prevent unnecessary costs for the general public.

With the aim of concretising the general commitment to create the necessary electrical infrastructure for enabling the energy transition, Creos Luxembourg specified four major principles and objectives upon which its network development is based:

1) Security of supply

One of the most important objectives of the grid development of Creos Luxembourg is to ensure the security of supply. However, the costs for achieving a certain level of security of supply must remain economically reasonable. On the high voltage level, transmission and distribution grids must be designed and built to fulfil the N-1 criterion, which means that an outage of one grid component must not lead to an interruption of supply. On the transmission grid of Creos Luxembourg, the N-1 criterion has been extended to include line pylons with two installed line systems. In general, grid planning must be aligned with the common planning and operation principles defined by ENTSO-E, however the individual socio-economic and geographical characteristics of Luxembourg must be taken into consideration.

2) Sustainable development

Creos Luxembourg always favours technical solutions which have the lowest possible impact on the environment and in terms of land use. The integration of a growing number of renewable energy plants is an inherent part of the grid development strategy.

3) Cost efficiency

Creos Luxembourg actively collaborates with the neighbouring system operators in order to realise / extend the integrated energy market on the European level and particular care is taken to ensure that grid access for consumers, suppliers and producers is non-discriminatory, transparent and fairly priced. Before
The projected grid modifications and/or reinforcements have been subject to a cost comparison between different implementation variants in order to determine the optimal solution and to limit the costs for the general public.

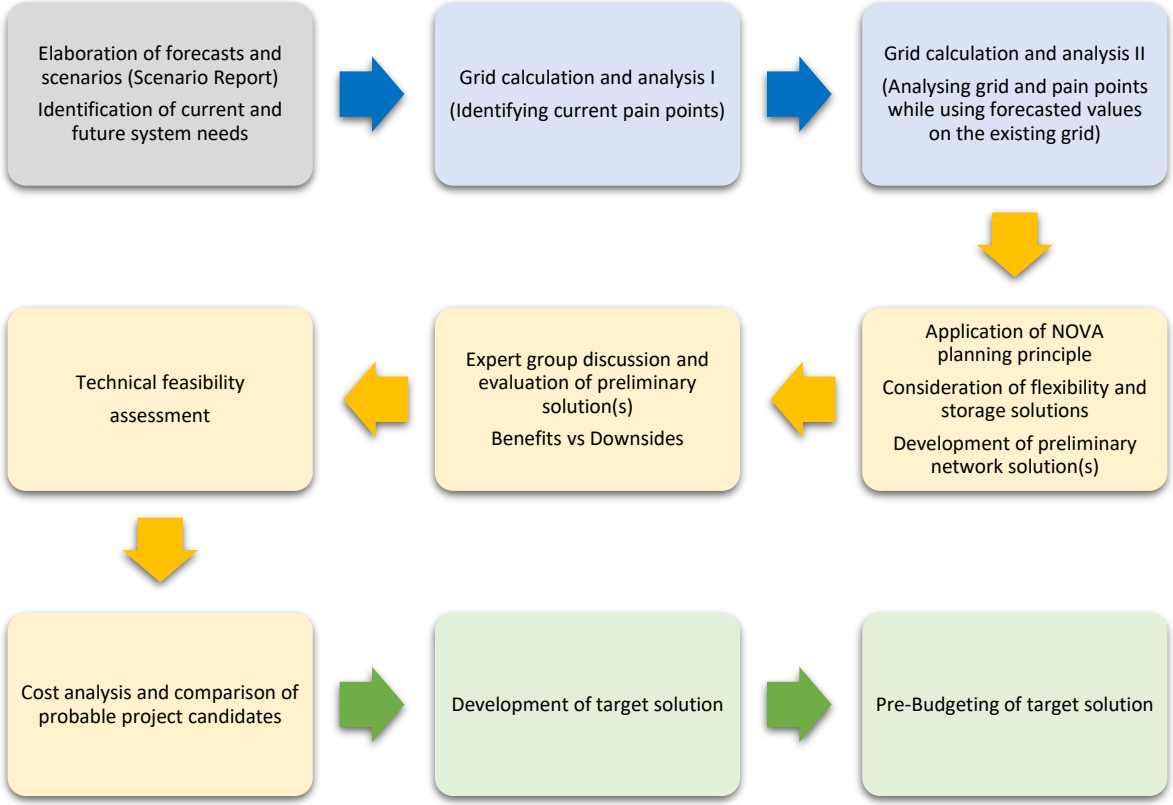
4) Innovation

To enable the flexibilities on the demand side, on the generation side and from the grid, the deployment and use of new technologies, which increase the degree of insight and reactivity of the grid, are essential. Creos Luxembourg has the strong will to promote all innovative means to fully use the capacity of the existing infrastructure and to prevent unnecessary reinforcements.

Network planning process

The network planning of the high voltage grids of Creos Luxembourg is subject to the specifications and criteria contained in the document *'Critères de planification à long terme des réseaux électriques haute tension (version mars 2023)'*, which can be found on the website of Creos Luxembourg. (LINK: https://www.creos-net.lu/fileadmin/dokumente/downloads/conditions_generales/pdf/fr_planification_reseaux_ht.pdf)

For a better understanding of the network planning process which is applied within the Asset Management department of Creos Luxembourg, the different steps of the planning procedure are illustrated hereafter.



In a first step, after all necessary forecasts relevant for grid dimensioning have been established, future system needs are identified more in detail.

The current bottlenecks and pain points on the existing infrastructure are then determined by grid calculation and analysis.

In a next step, further grid calculations on the existing grid infrastructure are made using the forecasted future values and time series. This might reveal new bottlenecks and weak grid elements.

After those calculation and analysis steps, a preliminary network development solution is drawn up while taking general planning principles, NOVA methodology and flexibility into account.

This preliminary development solution is discussed and evaluated in common by several divisions of the Asset Management department before first technical feasibility assessment studies are launched. At this point, cost estimations and variant comparisons are also made to find the best socio-economic implementation form.

Finally, a target solution of the network development is established and documented, which is then pre-budgeted.

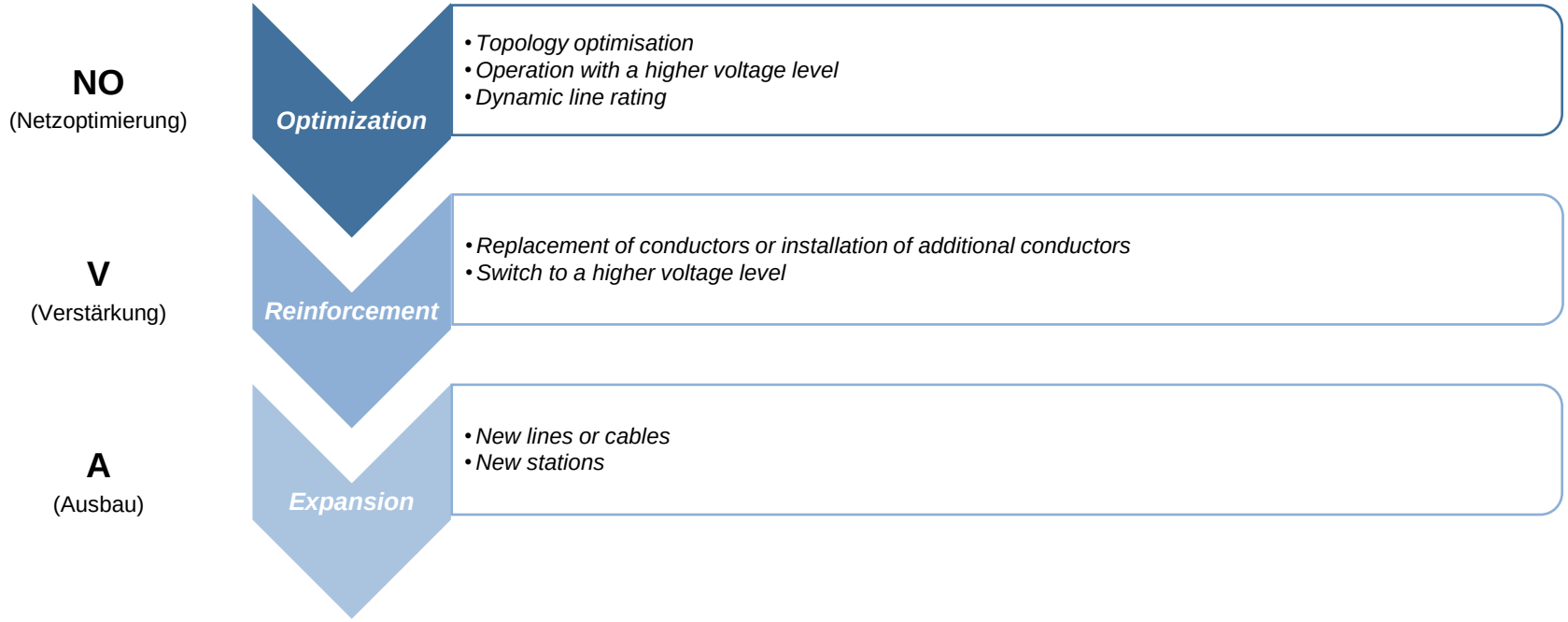
NOVA Principle

During the process of the network development of the transmission and distribution grids, Creos Luxembourg applies the so-called NOVA planning principle. NOVA is a German acronym for 'network optimisation and grid strengthening before grid expansion' under which every effort is undertaken to fully use the existing grid capacities through innovative technologies and equipment, such as topology optimisation, operating existing lines at higher voltage levels, using dynamic line ratings or replacing the conductors on existing lines with advanced conductors.

Applying NOVA to a grid extension project means to consider possible grid optimisation first. If grid optimisation fails to meet the needed requirements, then a reinforcement of the existing infrastructure is analysed. At last, if reinforcement of the existing lines is not technically or economically feasible, or cannot be done because of environmental reasons, then a grid expansion is examined as an alternative. The studies on the feasibility of a grid expansion are only beginning after optimisation and reinforcement measures no longer ensure the necessary grid capacity on the existing infrastructure.

In this way, grid expansion is not considered unless it has been made sure that possible modifications to the existing infrastructure are no longer sufficient to ensure the future security of supply and system stability.

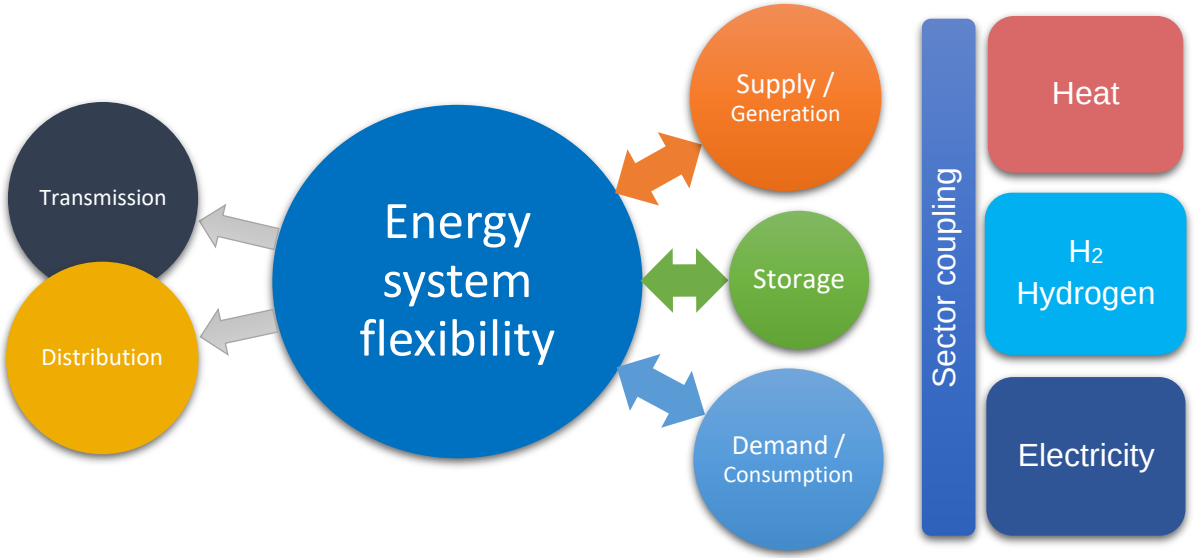
As a result, the grid reinforcements and expansions indicated in the section 'Network development projects 2024-2034' should be seen as a necessity and as no-regret investments on the way to a post-carbon society. Power system flexibilities and electricity storage solutions have been imperatively considered during the planning process, and during the definition of the appropriate grid modifications and related investments.



Flexibility

The energy transition and the ensuing increase of the share of renewable energy sources will bring the current electricity system to its operational limits. Due to the significant share of renewables in the power system, transmission system operators might have to fall back on non-market based measures to secure system stability in the future. On the distribution level too, due to the rising share of renewable energy sources and the upcoming E-mobility, system operators will need flexibility on the supply and demand side in order to avoid overloads and voltage issues, and to optimise the operation of the power system.

An integrated energy system that links all energy sources, consumption sites, storage systems and transport/distribution infrastructures together is needed. Based upon renewable energies, this energy system will require flexibilities from all involved parties to be as effective as possible. For its implementation, it is primordial to achieve an encompassing sector coupling on the demand and supply side and for energy storage. The combination of end-use sector coupling and cross-vector integration will increase the flexibility of the whole energy system and optimise the use of renewable energy when it is abundantly available.



Creos Luxembourg is actively working to promote and enable the use of flexibility options on its grids. The use of smart grid technologies will allow to activate certain flexibilities on the demand-side, on the generation side and from the grid infrastructure itself to reduce power flows when necessary and to help avoid congestions.

Flexibility procurement mechanisms

Creos Luxembourg intends to obtain flexibility over different ways, using the four coordination mechanisms defined by the Council of European Energy Regulators – CEER, with methods to intervene directly or indirectly depending on the actual grid state and situation.

Network tariffs | ***Market-based procurement*** — *Indirect intervention*

Connection agreements | ***Rule-based mechanisms*** — *Direct intervention*

Time-of-Use (ToU) or capacity dependent network tariffs can be useful to incentivise customers to change their behaviour of using the grid.

Networks tariffs, as a flexibility mechanism, represent a higher-level mechanism that can be applied to optimise the grid utilisation in general. The target is to increase or stabilise the utilisation hours of the grid, which have steadily decreased over the last 20 years.

Although network tariffs are proposed by system operators and discussed commonly, they must be approved by national regulation authorities.

Market-based procurement means that system operators acquire flexibility products according to their needs via different flexibility market mechanisms, for example with public tendering procedures or with the help of a flexibility market platform.

In December 2023, the EU reached an agreement on a revised Electricity Market Design which provides an explicit framework for flexibility procurement by transmission system operators. Also, EU DSO Entity and ENTSO-E are currently working on a new network code 'Demand Response', which will define a set of high-level rules for flexibility markets.

Connection agreements, which are designed by system operators in a non-discriminatory way and proposed as opt-in or opt-out clause to all relevant customers, are contractual arrangements between system operators and customers to take influence on flexibility to a certain degree. Those contractual arrangements can include financial incentives.

System operators must clearly express their flexibility requirements in those agreements and must be able to signal them explicitly when there is a need for flexibility.

Rule-based mechanisms are regulations which impose requirements on grid users to make flexibility available to the system operator in a non-discriminatory way.

This can be achieved by reducing the consumption or the feed-in of active power or changing the consumption of reactive power. System operators should foremost inform and incite customers to become flexible and grid-friendly but should not take an active role in the power management of the customer.

Only in case of an emergency or under specifically defined conditions, system operators are allowed to perform partial or full load-shedding of flexible assets.

The different mechanisms can be activated successively if needed: Network tariffs aim to increase the grid utilisation during normal operation, the connection agreements and the flexibility market are intended to solve first grid issues via direct and indirect market mechanisms and the activation of rule-based mechanisms will protect the grid assets and all its users when no other intervention helped resolve the issue.

Normal grid state:
System operator does not need to intervene. This grid state should be complemented by **network tariffs** encouraging flexible and grid-friendly behaviour.

Critical grid state:
System operator activates **connection agreements** and capacities on the **flexibility market** to reduce congestions and / or voltage issues.

Emergency grid state:
System operator activates **rule-based mechanisms** by intervening directly on consumptions or generations with the objective to prevent substantial physical damages to grid assets or its users

Flexibility procurement sources

More specifically, Creos Luxembourg takes proactive actions to be able to access flexibility from the following sources in the future:

E-mobility

There is a severe risk that grid congestions will arise in the future due to uncontrolled charging events of EVs. To make best possible use of the existing grid infrastructure, to avoid unnecessary grid reinforcements and to achieve a helpful shifting of peak load, flexible charging behaviours and automated smart charging systems are required.

By now, smart charging systems have been made mandatory for residential buildings with more than 3 flats and new grid tariffs, which aim to influence the charging and consumption behaviour positively, are currently being prepared.

The development plan explicitly considers the flexibility delivered by those measures. As documented in the Scenario Report 2040, peak demand reductions between 10% and 30% might be achieved, depending on the connected number of electric vehicles. The number of EVs and the relative flexibility contribution were determined and considered for each examined grid regions and feeder line.

Beyond the measures described here before, private charging devices must be equipped with a relay so that load-shedding is possible. In extreme grid situations, grid operators might be forced to intervene by activating this load-shedding to reduce the load locally, regionally or country wide.

Industry & SMEs

High energy costs and requirements to improve energy efficiency will induce industries and SMEs to reconsider their consumption patterns, review their energy supply and electrical equipment, and optimise their processes when possible. Those companies might then accept or offer a more flexible energy consumption, enabling load shifting and peak shaving of their electricity needs.

As the study 'FlexBeAn' (Flexibility Behaviour Analysis) of Creos Luxembourg, LIST and SnT, which aims to better assess the potential of demand-side flexibility of industry, among others, in Luxembourg, has not yet been completed, an exhaustive German study 'Regionale Lastmanagementpotenziale: Quantifizierung bestehender und zukünftiger Lastmanagementpotenziale in Deutschland' from the Forschungsstelle für Energiewirtschaft (FfE) has been used to estimate the reduction potential of the power demand in industry. (LINK Regionale_Lastmanagementpotenziale_DE2.pdf)

Provided that all necessary measures have been put in place, a reduction of 15% of peak demand might be achieved with load management systems in industry.

This has been considered during the grid planning process on all the concerned grid regions, especially where grid connections of industries are dominant.

Heat pumps

Heating systems using a heat pump are viewed as key technology to implement the energy transition in residential, commercial and administrative buildings and are therefore promoted.

Heating systems very often have a thermal storage capacity that allows to shift the electric power demand of the heating system / heat pumps over a few hours in time without any loss of comfort. Hybrid heat pump systems offer even more flexibility as it is possible to switch between electricity and gas or heating oil. At times when electricity prices are low, those systems can run entirely on electricity and when electricity is scarce, they can be fully gas- or fuel-fired.

To enable flexibility from heat pump systems in the future, price incentives that reward flexibility are needed and heat pump systems must be prepared and connected for flexible control. A rising number of heat pumps in the future might then increase flexibility offered by those systems. At present, only the latest models of heat pumps are digitally connected and controllable over distance.

It is not intended to interfere directly to obtain flexibility from heat pumps, only using indirect methods. However, a reduction or time-shifting of the future power demand due to flexible control of heat pumps has been assumed and considered in the network planning process.

Electricity generation

Due to the energy transition, more flexibility is needed in the entire energy system, also in relation to future electricity generation. The increasing share of wind power and solar PV generation in the future electricity mix will generate electricity in a volatile manner. The related peak generation could lead to extreme grid situations during certain hours of the year.

Better control of generation assets and flexibility from electricity producers will be needed in the future during times of low power demand and high generation. A so-called feed-in management will limit peak generations of wind turbines and solar PV installations to a certain level during the few hours when grid congestions arise due to increased excess generation.

However, flexibility and control on the supply side must avoid impeding the injection of renewable energies in the electrical grids as effectively as possible to keep the loss of feed-in remuneration at a minimum for the electricity producers.

Reductions of peak generations due to feed-in management systems and other flexibility mechanisms have been considered during the planning process of the network development plans.

Creos Luxembourg also actively works to be able to communicate its flexibility needs to electricity producers and to be technically able to reduce electricity generation during extreme grid situations caused by high generation flows.

Dynamic Line Rating

'Dynamic Line Rating' (DLR), which can be considered as grid-side flexibility, represents a possibility to operate overhead lines slightly beyond their nominal capacity limits during beneficial weather conditions (cold and/or windy). However, accurate dynamic line rating requires the measurement of the conductor temperatures of overhead lines and of the weather conditions (ambient temperature and wind speeds). This can be technically and financially challenging when applied to the entire grid infrastructure.

Nevertheless, as it is certain that the thermal capacity of overhead lines is generally enhanced during cold and windy weather, it is possible to apply a generalised, methodical approach of DLR for planning purposes. A matrix of enhanced transmission capacities can be set up for every analysed load and generation situation on all suitable overhead lines, using data of the ambient temperature and wind speeds. Defining regional variations and including safety margins due to mid-/long-term uncertainties, are still possible with this methodology.

This described methodical DLR has been applied during the process of the network development plans of Creos Luxembourg. On suitable overhead lines, enhanced capacities of 110% to 120% during beneficial weather conditions have been taken into account.

Electrical Energy Storage

In the integrated, carbon-neutral energy system of the future, in which there will be a high share of electricity generated by renewable energies, electrical energy storage will be fundamental. Besides a growing need for flexibility such as demand-side management, storage solutions will be necessary to balance the whole energy system.

Concerning electrical energy storage, Creos Luxembourg considered the following systems, their probable future development and their impact on the electricity infrastructure:

'Behind-the-meter' batteries

Currently there are very few battery storage systems installed in Luxembourg and all of them are small-sized 'behind-the-meter' batteries in residential homes. However, it seems very likely that the occurrence of such small-sized battery storage systems will strongly rise in the future, especially in residential buildings equipped with a solar PV installation.

'Behind-the-meter' batteries can help reduce the load on the electrical grid during peak demand if the storage capacity is adequate and the system is functioning in a 'grid-friendly' way. Also, paired with an installation generating electricity, such battery systems are efficiently contributing to the system adequacy and are helping to integrate more renewable energy sources into the power system.

In the frame of the network development plans, the effects of a better utilisation of the electricity grid and of a peak load reduction on the grids due to small-sized battery storage systems have been taken into account by the assumptions made in the Scenario Report 2040. A general reduction of the peak consumption and peak generation values has been assumed due to 'behind-the-meter' batteries.

Grid Boosters

Medium or bigger-sized battery storage systems, installed on the grid side and denoted as 'Grid Boosters', can potentially reduce the need for conventional network reinforcements by injecting or absorbing critical power flows in case of a system component failure. 'Grid boosters' could effectively contribute to the security of supply.

Creos Luxembourg assessed that the installation of such storage systems on its existing transmission grid would not be sufficient to cope with the projected consumption and generation increase on the long-term and that conventional network reinforcements would be needed.

On the distribution system level, Creos Luxembourg considers grid boosters as an alternative or complement to conventional grid reinforcement. Although several potential installation locations for grid boosters have been examined in the process of the network development plans (on the distribution level), specific projects for grid boosters have not yet been planned nor launched. The technical and economic viability of grid boosters must be further examined in detail.

Power-to-X

'Power-to-X' storage facilities like power-to-hydrogen and power-to-synthetic fuel/gas seem promising and offer the possibility of sector coupling.

Creos already received a connection request for a medium-sized 'Power-to-X' storage system which would be capable of storing electricity over one or several seasons by converting electricity to another energy form. The primary purpose of this project is to produce green hydrogen with the help of renewable energies. In a second step, it is intended to enhance the project so that electricity can be generated with a fuel cell and the stored hydrogen and provided back to the power grid when there is a consumption need. It is planned to start producing green hydrogen on this site by the year 2025. Such electricity storage methods could indeed help smooth the consumption and generation peaks.

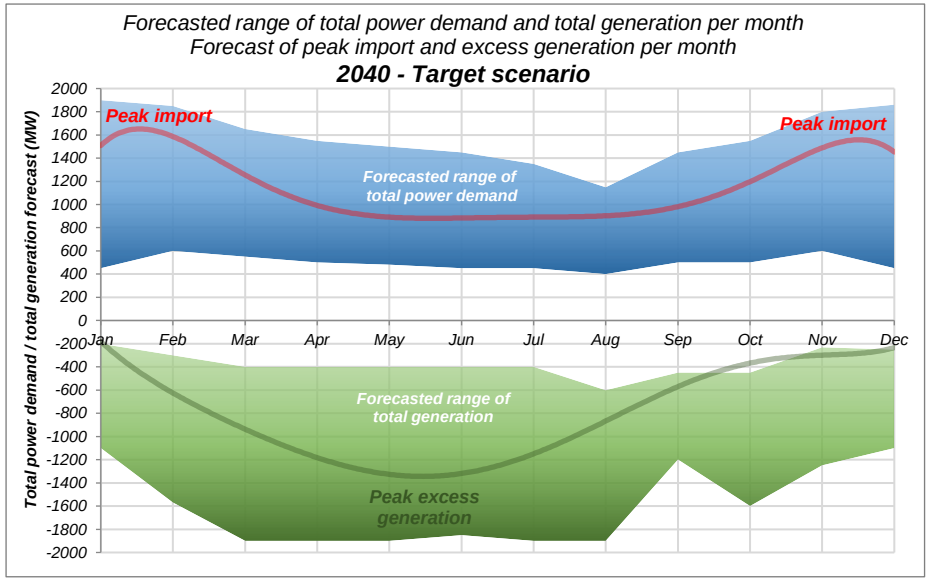
During the process of establishing the network development plans, 'Power to X' storage systems and their effect on the respective grids have been specifically considered, on the distribution system level in particular.

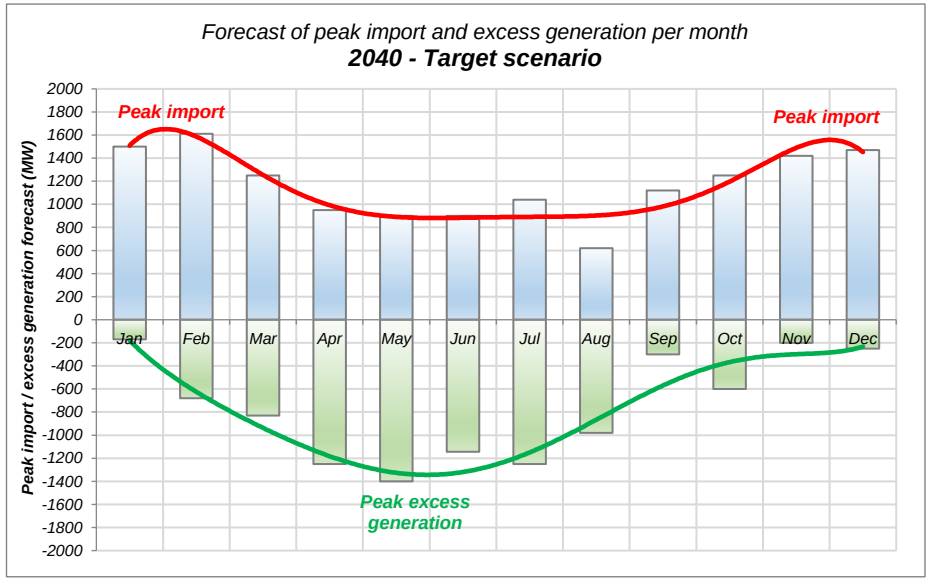
Identification of needs

Electricity transmission grid - Future peak import and excess generation forecasts

The most relevant values for the dimensioning of the high voltage transmission grid of Creos Luxembourg are the future peak import and the future peak excess generation. Under due consideration of grid flexibilities, a forecast of those values has been established in the document 'Scenario Report 2040', which was published at the beginning of the year 2023 on the website of Creos Luxembourg, after due public consultation. Creos Luxembourg set up quarter-hourly profiles of future power demand and future generation for 3 different growth scenarios, while considering several climate years (2025, 2030, 2035, 2040). The forecasts were verified with the help of the 'Demand Forecasting Toolbox' of ENTSO-E.

Please note that the values from the **'Target' scenario from the Scenario Report / NECP** have been used for the elaboration of the present document.





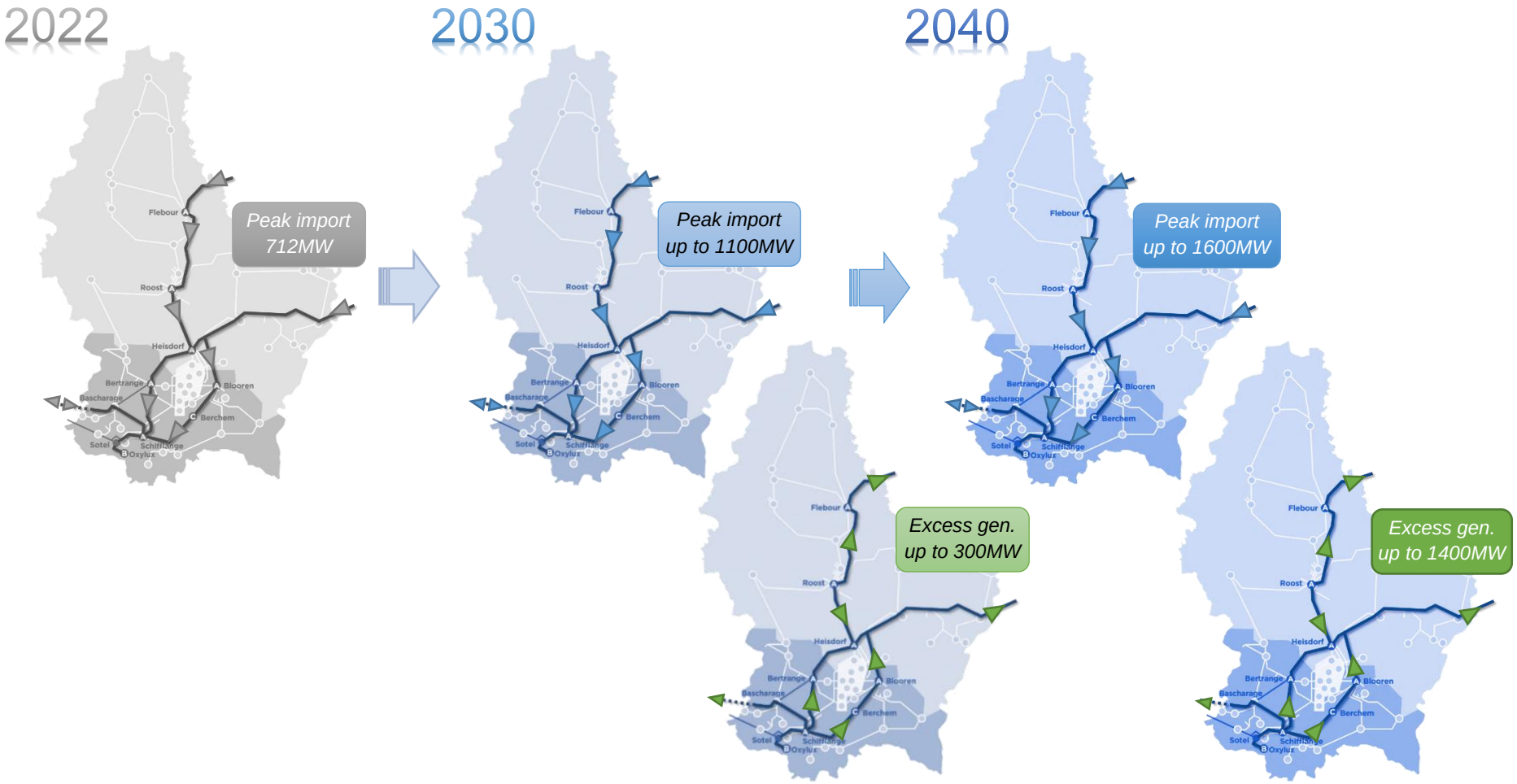
Source: Scenario Report 2040 - Creos Luxembourg

The charts here above show the forecasted range of values and peak curves for the year 2040 for the 'Target Scenario'. It can be assumed that during times of maximum power demand, that there will always be a minimum generation and during times of maximum generation, there will always be a minimal power demand on the transmission grid, leading to a peak import in the winter months and a peak excess generation during spring or summer.

*For the 'NECP Target scenario', a **peak import of 1600MW** and a **peak generation of 1400MW** has been forecasted on the high voltage transmission grid for 2040*
(Reductions due to flexibility and storage systems are included)

During 2022, the maximum import for electricity consumption purposes on Creos grid was 712MW, resulting from measurements on the overhead lines coming from Germany and from measurements on the interconnection line with Belgium.

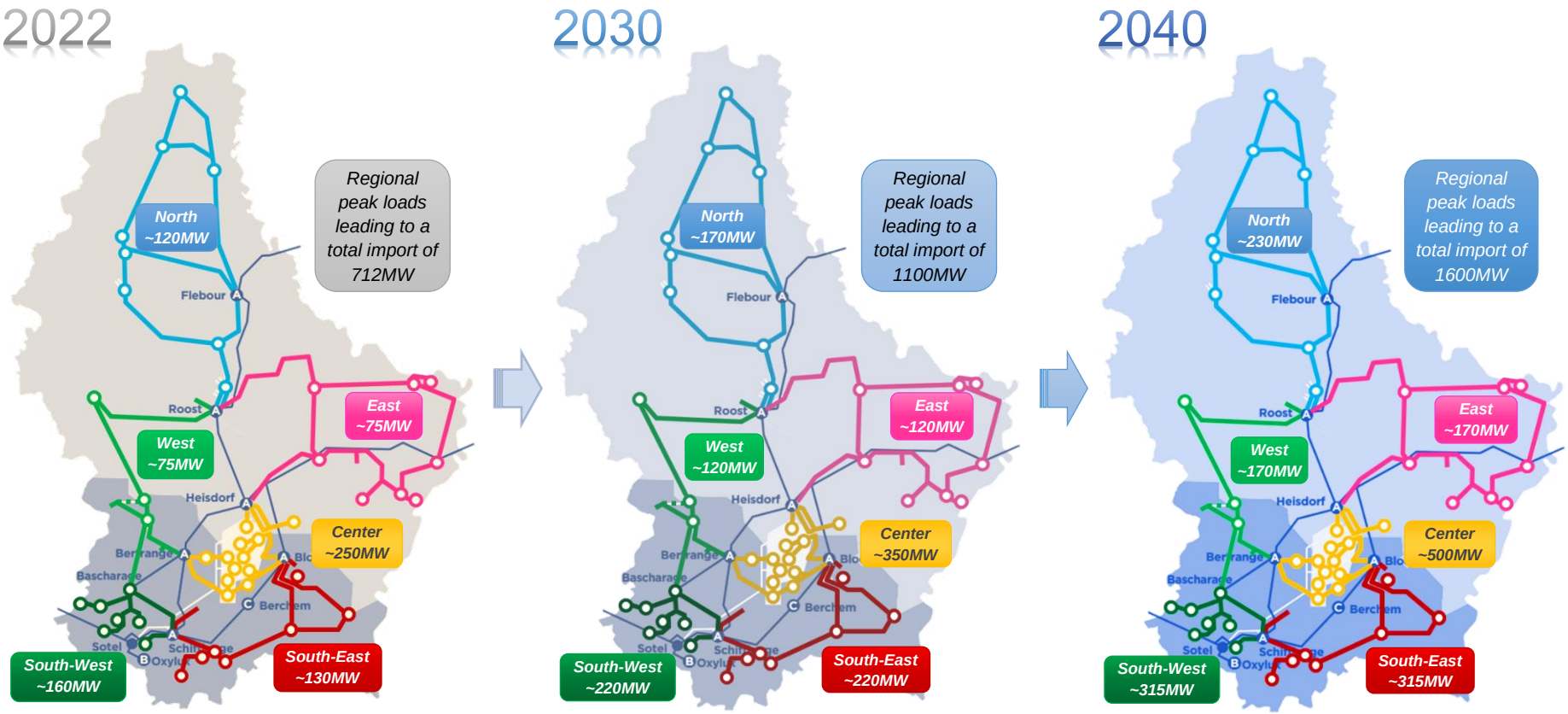
The total power demand and the related import will certainly grow in the future. Even if the growth can be somewhat reduced due to the achieved flexibilities on the demand side, the future peak import could reach about 1600MW on the high voltage transmission grid in 2040 **(target scenario)**. Even higher import needs could be possible in the future because projects involving high additional power needs on the transmission voltage level are currently under discussion. Due to the high generation capacities which are targeted in the future, the total excess generation resulting from a high power generation and a minimum power demand could reach about 1400MW. As the projected import is higher than the forecasted total excess generation, the future total import is the most relevant value to be considered for the grid development of the high voltage transmission grid.



Electricity distribution grids - Regional distribution of electricity consumption

Currently, 5% of total power demand is due to consumption needs on the 220kV high voltage transmission grid and 95% of the total power demand comes from consumptions on the subordinated distribution grids; from the 65kV high voltage distribution grids, the 20kV medium voltage and the 400V low voltage distribution grids. The 65kV high voltage distribution infrastructure, which also supplies the medium voltage and low voltage distribution infrastructures, can be subdivided in 6 distinct grid regions: **North, West, East, Centre, South-West** and **South-East**, as illustrated hereafter.

During the year 2022, peak loads as depicted here below were measured individually on the different regional 65kV grids, which generated a cumulative peak import of 712MW on the 220kV transmission grid. As future total import is forecasted to reach about 1600MW in the year 2040, this could lead to higher regional peak loads on the 65kV grids in the future. Similar to current power needs, major electricity consumptions will surely take place in the centre and south of Luxembourg in the future. Sites with high power needs resulting from decarbonisation with electricity or hydrogen have been duly considered.



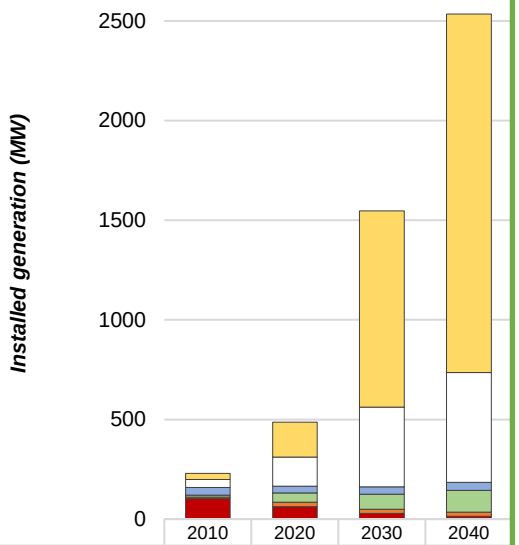
Electricity distribution grids - Regional distribution of electricity generation

To correctly assess the impact of future electricity generation and to identify the needs concerning the future generation in detail, the projected generation capacity targets must be distributed as accurately as possible on the different regional grids. In this context, only the most ambitious scenario, the 'target scenario' of the National Energy and Climate Plan, has been used for this purpose.

As it can be reasonably assumed that the regions 'North, East and West' will still be favoured for a further development of renewable energy sources in the future, the biggest part of the future RES generation capacity, about 2/3 of the total, will be allocated hereafter to the regions North, West and East.

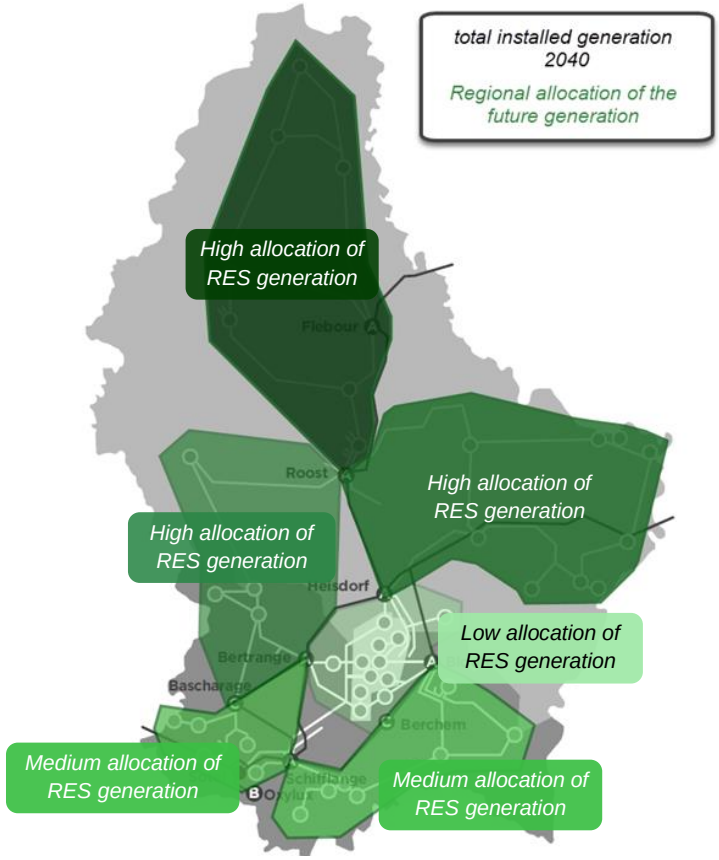
The effective excess generation per region can then be estimated with the help of the allocated capacities and the regional minimal loads.

Electricity generation capacity targets
(as assumed in NECP Target scenario)

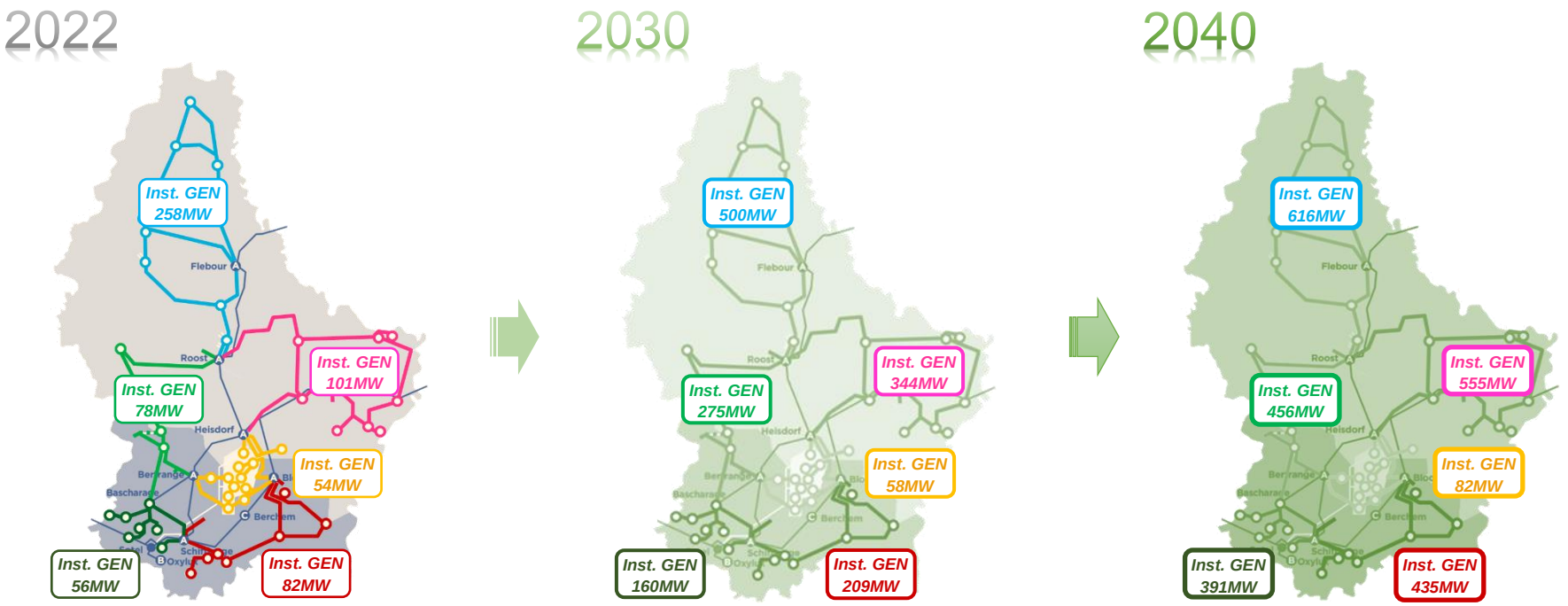


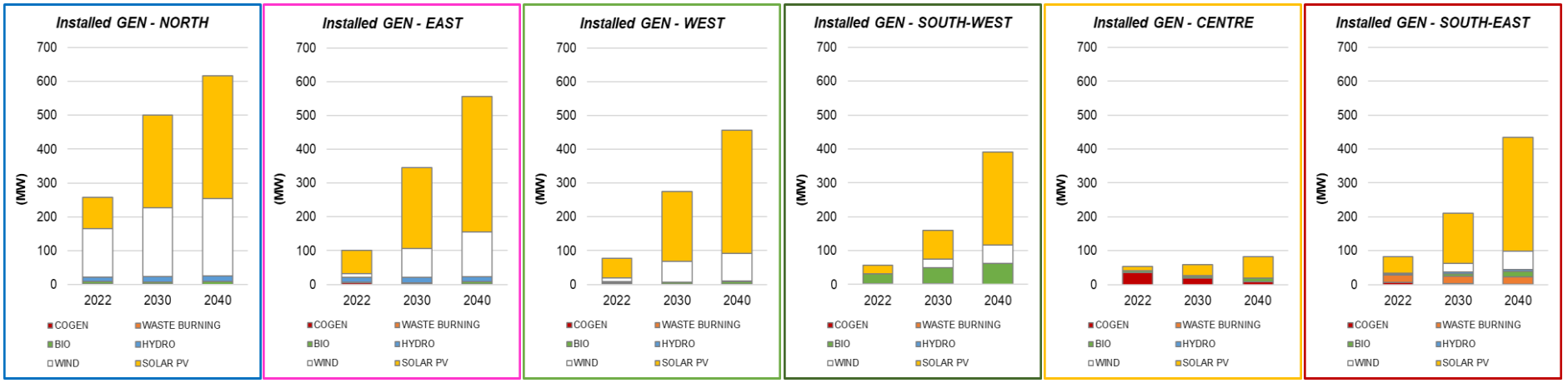
	2010	2020	2030	2040
Solar PV	30	175	984	1800
Wind	42	146	400	550
Hydro	38	34	37	40
Biogas, biomass	9	47	75	110
Waste burning	9	21	21	21
Cogeneration	102	63	29	14
Total installed Gen.	229	487	1546	2535

Total capacity targets have to be split up and allocated to a region



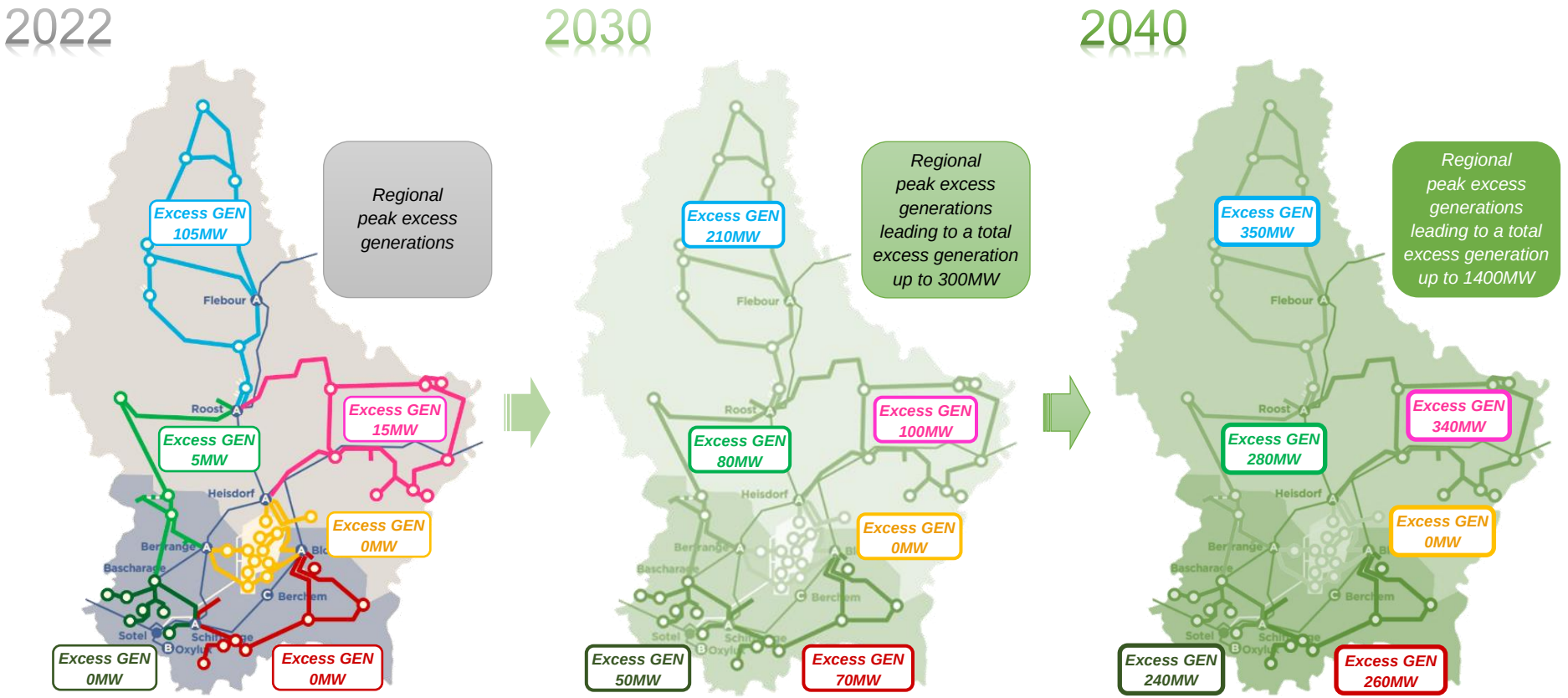
Resulting from the preceding assumptions, regional generation capacities could strongly grow in the future as illustrated here below. The specific growth of every generation type has been established in detail for each region. Most recent developments and planned projects seem to confirm the assumptions made here.





Currently, most of the electricity is consumed in the centre and south of Luxembourg and there is no indication that those circumstances will significantly change in the future. The pronounced development of electricity generation capacities in more rural areas, such as in the regions North, West and East, will then lead to high power generations in regions where consumption will be moderate or low. This will result in high excess electricity generations which have to be transported to consumption areas with the help of the high voltage grid infrastructure. The steep increase of generation capacity in the north of Luxembourg during the last decade led to a current excess generation of over 100MW during times when consumption is low. The same development will happen in other rural regions, where excess generations will arise and continue to grow with the installed generation capacities.

Except for the capital city and its surroundings, where consumption will certainly stay higher than electricity generation, effective excess generations could reach the following maximum values throughout the different regions in the future:



Network development – Electricity Transmission Grid

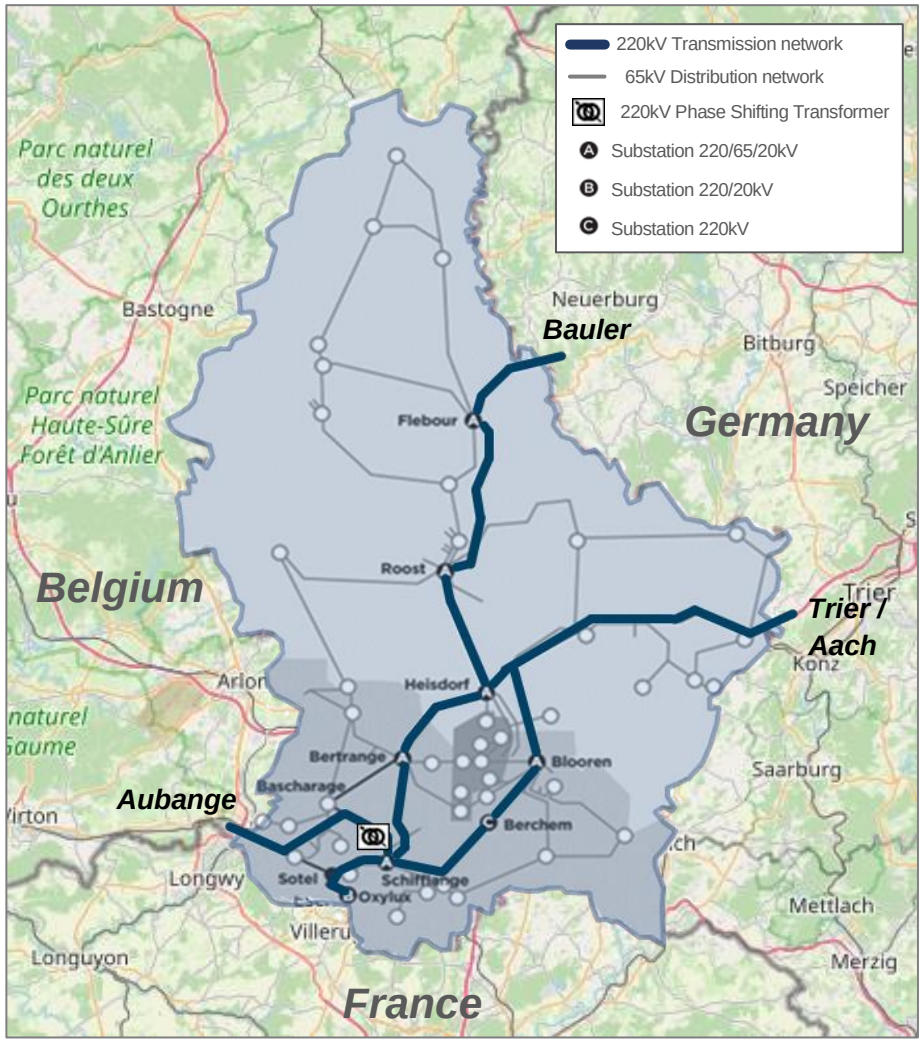
Starting point

Luxembourg's public electricity transmission grid, developed, operated and maintained by Creos Luxembourg, currently consists of a network of 220kV high voltage lines of about 160km length in total. 90% of the 220kV network has been realised using overhead lines and 10% using high voltage underground cables.

This public 220kV network in Luxembourg has presently two connections with the 220kV grid in Germany and one additional 220kV connection of reduced capacity with Belgium. A phase-shifting transformer is being used on the connection with Belgium to control the power flow in both directions.

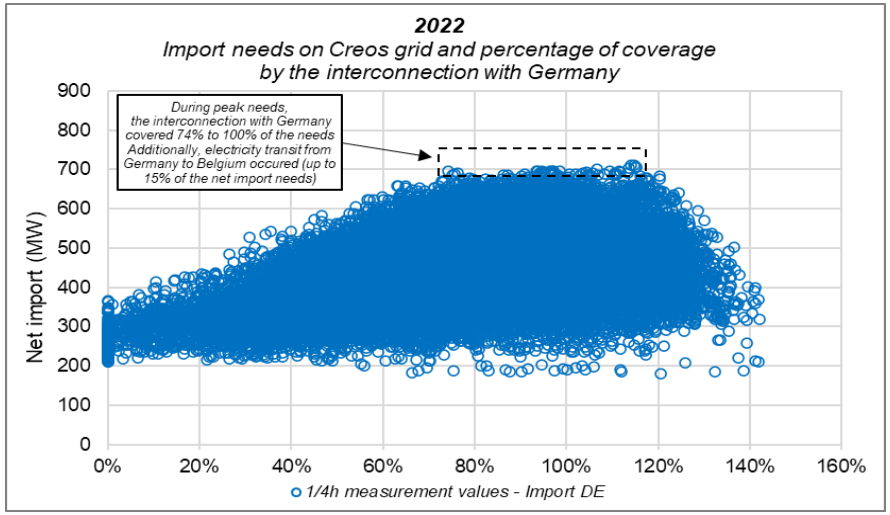
The 220kV network supplies six 220/65/20kV substations named **Flebour**, **Roost**, **Heisdorf**, **Bertrange**, **Blooren** and **Schifflange**. Those substations power the entire subordinated 65kV grids and the 20kV distribution grids among other 65/20kV stations. The 220kV grid also supplies a 220/20kV substation in Esch/Alzette at the former site '**Oxylux**' and a 220kV customer station in **Berchem**.

At present, the 220kV network only transports electricity for consumption purposes. It should be noted that Luxembourg's power system has no major power plant connected to the 220kV main grid, but centralised power generation in the form of several hydroelectric power plants, wind farms and bigger-sized solar PV parks occurs on the 65kV and 20kV distribution level. Additionally, many decentralised installations generating electricity are connected to the 20kV and 0,4kV distribution grids. At the beginning of 2023, more than 10.500 installations generating electricity were connected in total on all voltage levels and about 88% of total installed generation capacity came from renewable energy forms.



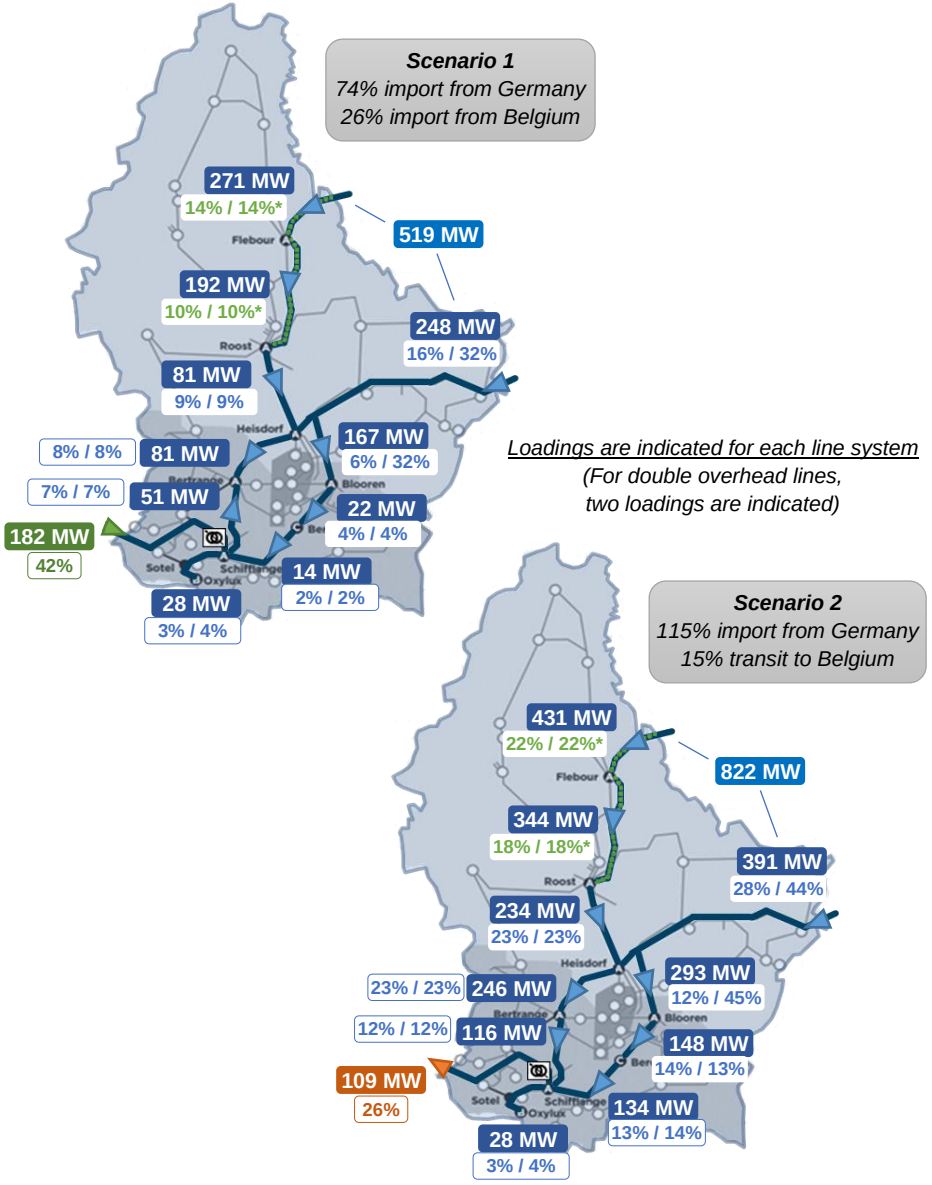
Power flow analysis

Measurements on the transmission grid show that during peak needs in 2022, the interconnection with Germany supplied between 74% and 100% of the power requirements. This implies that the interconnection with Belgium provided approximately 0% to 26% of the power then. Additionally, during certain peak periods, up to 15% more electricity was transported from Germany to Belgium via the transmission grid operated by Creos Luxembourg.



The grid illustrations on the right side indicate the power flow and loading on the current transmission grid during peak power needs in 2022 and for two import/transit situations:

- In the first scenario, 74% of the power requirements were met by the interconnection with Germany, while 26% were met by the interconnection with Belgium.
- In the second scenario, 100% of the power requirements were met by the interconnection with Germany, with an additional transit of 15% to Belgium.



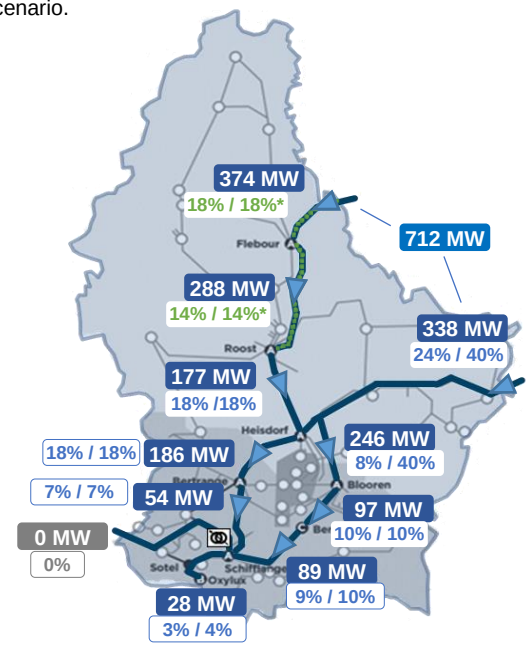
** Please note that loadings are indicated for each line system: for double overhead lines, two loadings are shown. Kindly be aware that the overhead lines between the country border near Vianden and the station Flebour, as well as between the stations Flebour and Roost, have been recently upgraded with high-performance conductors (HTLS), resulting in moderate line loadings.*

Relevant contingency cases

Scenario 3
100% import from Germany 0% import from Belgium

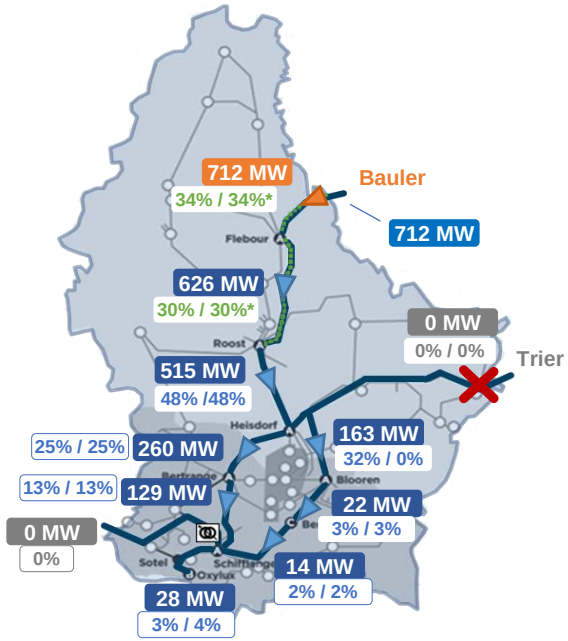
The interconnector with Belgium, being a single line connection, can become unavailable for several hours or even for several days during maintenance activities on the overhead line sections or on the phase-shifting transformer. This is a common scenario for single-line connections, as maintenance activities may require the disconnection of the interconnector to ensure safety and perform necessary repairs or upgrades.

For this reason, the calculation scenario in which the interconnector with Belgium is deactivated becomes relevant and potential grid outages must be assessed for this particular scenario.



Contingency case 1
Outage "Trier"

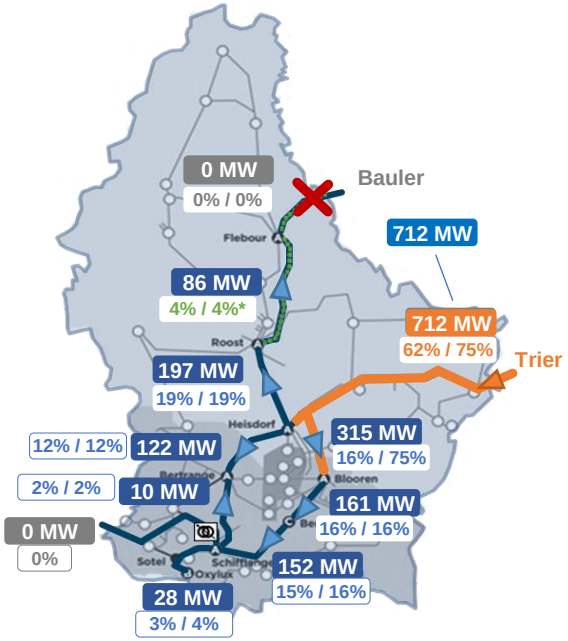
The illustration below shows the relevant grid contingency case for a high import situation in 2022 and while the interconnector with Belgium is unavailable. In this degraded grid situation, a complete outage of the double infeed from Trier / Aach is assumed and the entire load would have to be supplied by the double infeed from Bauler. While the N-1 criterion is typically applied to line systems, the specific conditions in Luxembourg led to the assessment that a pylon collapse is a risk to be considered and has been recognized as an extraordinary contingency case for the interconnection lines.



Contingency case 2
Outage "Bauler"

In a second relevant grid contingency case, it is assumed that the infeed from Bauler would suffer from a pylon collapse which implies a system failure of both lines on that pylon. In this degraded grid situation, the entire load would have to be supplied by the double infeed Trier / Aach.

As each of the two existing interconnection lines with Germany has a transmission capacity of approximately 980MW, up to 75% of the maximum capacity would already be used today during such a contingency case.



The forecasts outlined in the Scenario Report 2040 indicate that future electricity demand is expected to surpass current grid capacities. Focusing on the 'Target' scenario, it is projected that peak import on the high voltage transmission grid could potentially reach around 1600MW in 2040. Creos Luxembourg has therefore established a grid development strategy to meet the future requirements, implementing measures adapted to increase the capacities of its transmission grid.

* *Please note that loadings are indicated for each line system: for double overhead lines, two loadings are shown. Kindly be aware that the overhead lines between the country border near Vianden and the station Flebour, as well as between the stations Flebour and Roost, have been recently upgraded with high-performance conductors (HTLS), resulting in moderate line loadings.*

Network development strategy

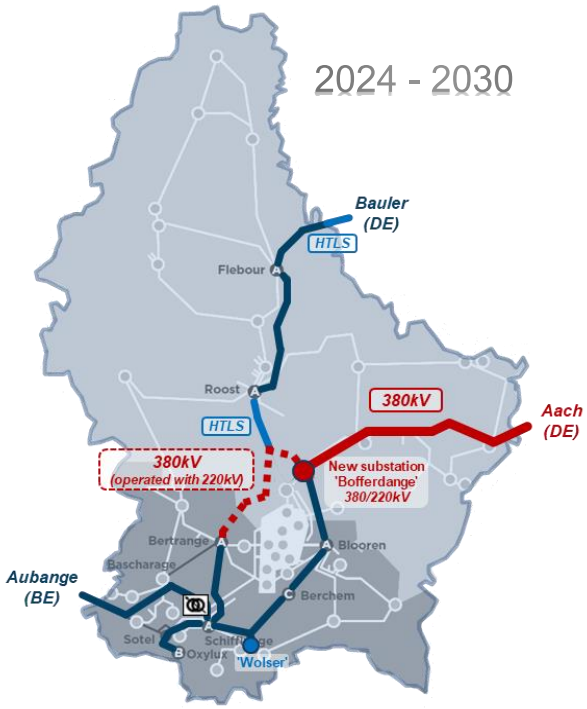
The primary objective of Creos Luxembourg's network development strategy is to substantially increase transmission capacity. Forecasts indicate a significant rise in both total power demand and resulting imports in the future, potentially leading to overloads on the current grid infrastructure. Additionally, the anticipated growth in installed electricity generation capacities could also necessitate increased grid transmission capabilities.

To do so, it is intended to create a secure connection to the 380kV electricity transmission grid in Germany with the following major milestones:

Milestone 1 : '380kV Infeed'

It is projected to create a first connection with the 380kV grid in Germany by constructing a new 380kV double line between Aach (Germany), Bofferdange and Bertrange in replacement of the existing 220kV double lines 'Trier - Heisdorf' and 'Heisdorf - Bertrange'. For this purpose, a new 380/220/110-65kV transformer substation will also be built in Bofferdange.

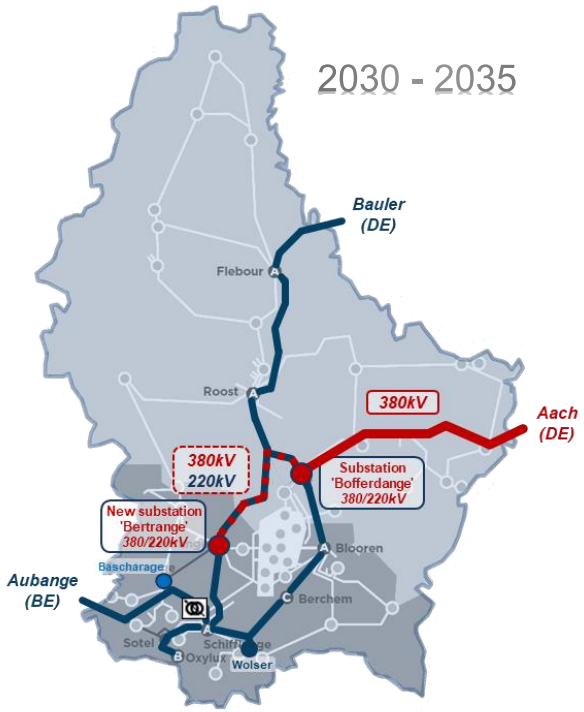
In a first step, the line section between Heisdorf and Bertrange will be operated with a voltage of 220kV.



Milestone 2 : '380kV Expansion 1'

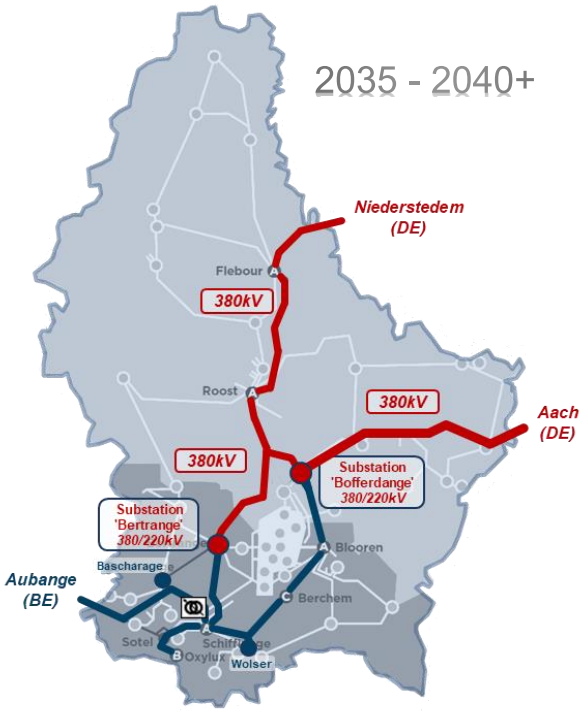
Most of the electricity is currently consumed in the south and the central part of the country. Because of the expected rising electricity demand in those regions and to guarantee the security of supply in the future, the installation of a second 380/220/110-65kV transformer substation in the south and central part of the country is planned.

The double line Heisdorf – Bertrange will then be operated with 380kV and 220kV (1 system 380kV / 1 system 220kV).



Outlook : '380kV Expansion 2'

Due to the projected increase in power demand and installed generation, it will be necessary to further strengthen the electricity grid in the long term. One of the key solutions currently being analysed is the creation of a secure double-sided connection with the German 380kV transmission grid. The projected expansion would replace the existing 220kV double line between Bofferdange, Roost, Flebour, and the country border with a 380kV infrastructure. This higher voltage level is becoming increasingly prevalent in European transmission systems and is replacing 220kV as new industry standard in many European countries.



Explanatory statement concerning the targeted grid capacities

Starting point

The secured import and transmission capacity of the existing supply lines coming from Germany is currently **980 MW**. Despite a certain degree of electrical storage capacity and even with enabled flexibilities on the demand side, peak power demand could more than double in the next 20 years.

Increased investment in renewable energies will certainly reduce the total yearly electricity import amount but will not be enough to guarantee security of supply in Luxembourg at all times, thus requiring an increase of import capacities.

Since 2017, an interconnection with limited capacity (300 MW) is in operation between Belgium and Luxembourg via a phase-shifting transformer. However, the availability of electricity supply from Belgium over this interconnection cannot be guaranteed at any time due to operational constraints: During maintenance works on this single-line interconnector or on the phase-shifting transformer, the interconnection is unavailable during several hours or even for several days.

Thus, the current interconnection with Belgium has been taken into account as part of the network development plan, but its limitations need to be acknowledged.

Milestone 1 & 2 : '380kV Infeed & Expansion 1'

The replacement of the existing 220kV overhead line between Trier, Heisdorf and Bertrange with a new cross-border 380kV high voltage overhead line leading from Aach in Germany to the new station Bofferdange and to the station Bertrange, will increase the electricity transmission capacity between Luxembourg and Germany considerably.

In case of an unavailability of the 380kV infeed, the electricity supply must be ensured via the northern 220kV connection coming from Bauler (DE), where it is planned to complete the initiated reinforcement with high performance conductors with increased transmission capacities during milestone 1. However, due to the operational limits of the line fields at the station Bauler, the import capacity via the northern 220kV connection will be limited to **1500 MW**.

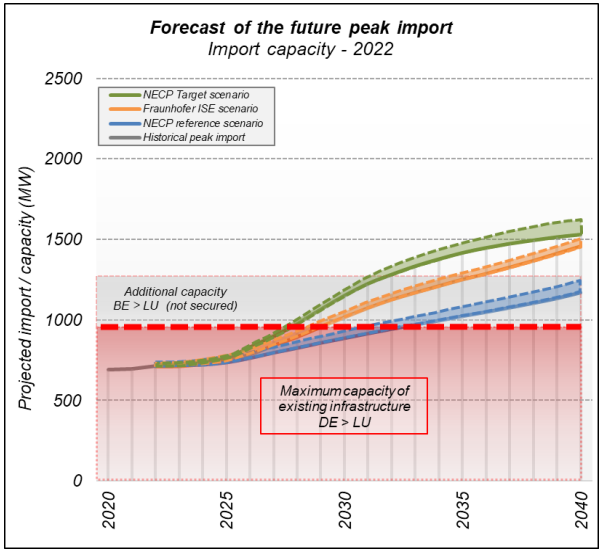
The additional import capacity from the interconnection with Belgium will be helpful but cannot be ensured at any time due to operational constraints.

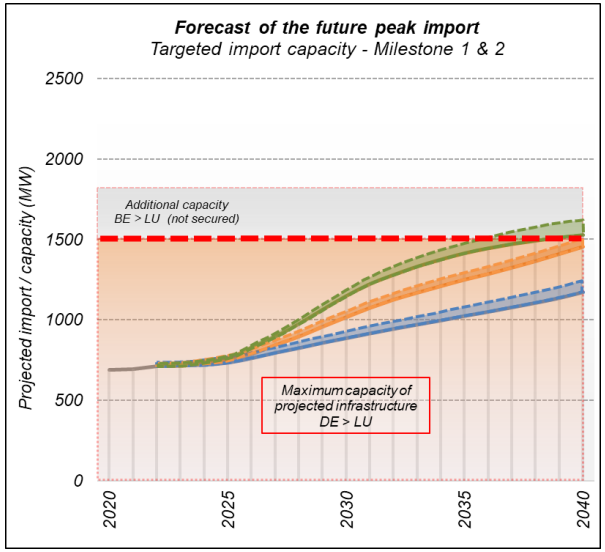
Outlook : '380kV Expansion 2'

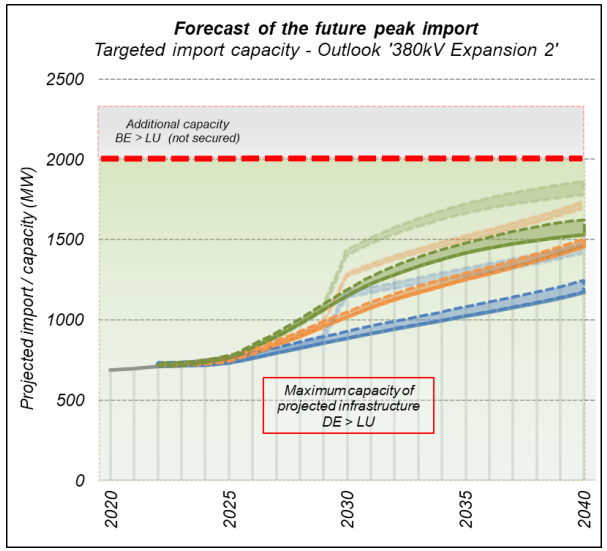
Creos Luxembourg assessed in the 'Scenario Report 2040' that peak import could reach 1600 MW in 2040 and could even get higher in particular cases (additional data centres / switch of heavy industries to the German market zone).

As the secured import capacity after the milestone 1 & 2 will be limited to 1500 MW due to the station Bauler, it is currently being considered to remove that constraint with a further expansion of the 380 kV grid, which would increase the transmission capacity between the northern country border near Vianden and the stations Bofferdange/Bertrange. The target is to achieve a secured import capacity of at least **2000 MW** and so, ensure the security of supply of Luxembourg in the long term in case of a major unavailability of the 380kV connection Aach - Bofferdange.

The network development strategy and the planning of the projects have been coordinated with the German transmission system operator Amprion and are part of the coordinated pan-European grid planning within the framework of ENTSO-E's TYNDP.







Analysed network development alternatives

The current grid development strategy of Creos Luxembourg is the product of years of continuous analysis refinement and combined know-how and expertise. During the network planning process, multiple solutions for the network development of the transmission grid were discussed, analysed and evaluated in the past. The most discussed alternatives are shown and described here below, with an evaluation regarding their applicability.

Alternative 1 – '3rd 220kV infeed from Germany

Creation of an additional 220kV interconnection with Germany

In 2004, a study about the future electricity and grid infrastructure needs of Luxembourg was conducted by Electrowatt-Ekono AG (later Pövry / today AFRY). The conclusion was that the 220kV interconnections lines with Germany would not have sufficient capacity to ensure the security of supply in the long term. Back then, the creation of an additional 220kV interconnection with Germany, possibly in the south-east of Luxembourg, was suggested for the first time.

Later on, in the position paper 'Long-Term Network Expansion Strategy' made by E-Bridge in 2011, an enhanced 220kV connection with Germany was also proposed as a variant. Building a third connection with Germany by connecting the station Berchem (LU) to the station of Ensdorf (DE) was deemed to be a useful grid development compromise.

At that time, this intended solution could however not be validated due to a lack of general consent from the authorities and due to foreseeable implementation difficulties.

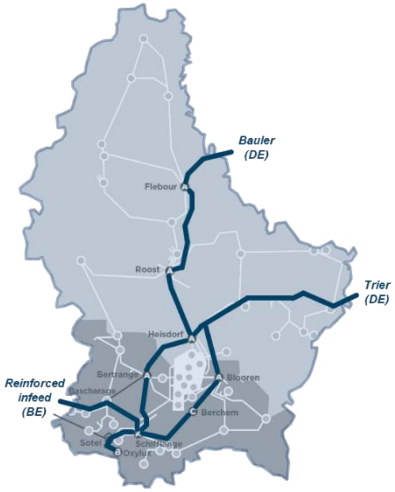
Alternative 2 – 'Reinforced 220kV infeed BE'

Reinforcement of the 220kV interconnection with Belgium

In 2011, E-Bridge recommended in the position paper 'Long-Term Network Expansion Strategy' to increase the grid capacities towards Belgium by building a double-circuit 220kV cable connection between Bascharage (LU) and Aubange (BE). The integration of the gas-fired power plant 'Twinerg' into the grid and control zone of Creos Luxembourg has been part of that intended reinforcement strategy. However, Twinerg, which had a power output of 375MW, was decommissioned in 2016.

Currently, the 220kV infrastructure at the station 'Aubange' has limited available capacity and notably cannot carry the entire load of the Creos grid. Until now, it is not planned to increase the transforming capacities at that station in the short or mid-term. It is however planned to increase the capacity of the grid connection to the station Aubange in the long term (380kV).

An interconnection between Luxembourg and Belgium at 380kV voltage level on the long term has only recently come under analysis. This option will be further evaluated.



Alternative 3 – '220kV HTLS'

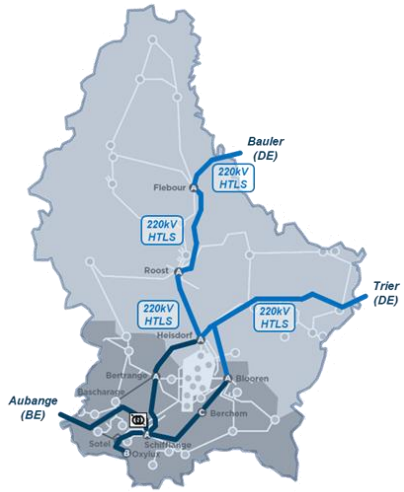
Replacement of the conductors of the two existing 220kV overhead lines LU-DE with high performance conductors

In 2017, studies were conducted by 'CTeam' to analyse different variants to increase transmission capacity on the interconnection lines between Luxembourg and Germany.

The principal conclusion was that the installation of high-performance conductors to replace the current systems would be possible with adaptation of several line pylons, but electric losses would be high during normal operation. It was recommended to use the full capacity of high-performance conductors only during extraordinary grid situations.

Also, due to the planned decommissioning of the 220kV infrastructure in Germany by Amprion, a reinforcement of the interconnections with Germany on that voltage level is not a viable long-term solution.

380kV will probably become the new industry standard for transmission lines in many European countries.

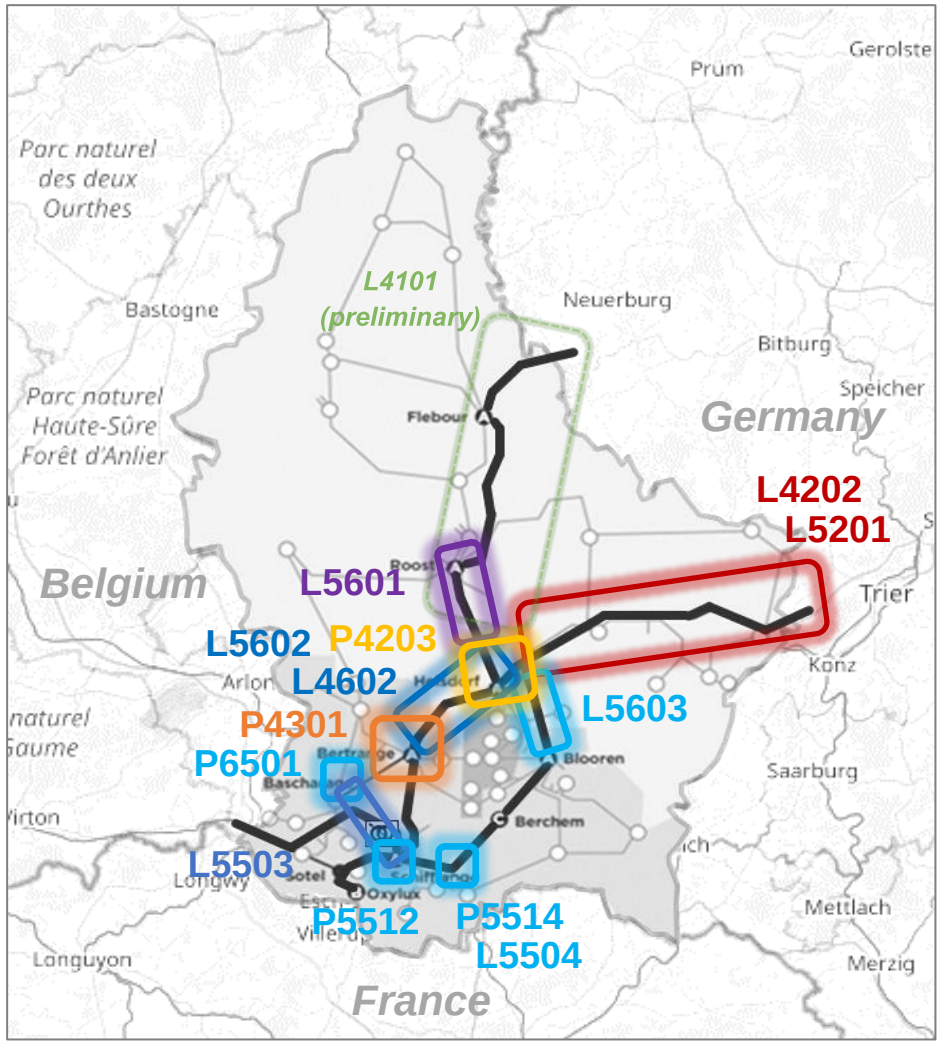


Network development projects 2024 – 2034

outlook 2040

Overview of network developments projects

To realise the different milestones of the network development, Creos Luxembourg established a series of specific projects, which can be divided into two major project groups: Network development projects relative to high voltage overhead lines or cables systems, labelled with the letter 'L' and projects relative to high voltage stations, labelled with the letter 'P'.



An overview of the major network development projects is depicted here on the left side and the different projects are listed hereafter.

Projects relative to overhead lines or cable systems

L4202	380kV overhead line BOFFERDANGE - AACH
L4602	380kV overhead line BOFFERDANGE - BERTRANGE
L5201	220kV overhead line HEISDORF - TREVES (Decommissioning of overhead line)
L5503	220kV overhead line BASCHARAGE - SCHIFFLANGE (Infeed at station Schifflange and Bascharage)
L5504	220kV overhead line SCHIFFLANGE - BERCHEM (Infeed at station Wolser)
L5601	220kV (HTLS) overhead line HEISDORF - ROOST (Infeed at station Bofferdange & Partial decommissioning of overhead line)
L5602	220kV overhead line HEISDORF - BERTRANGE (Infeed at station Bofferdange & Partial decommissioning of overhead line)
L5603	220kV overhead line HEISDORF - BLOOREN (Infeed at station Bofferdange & reserve conduits Senningerberg)
L4101 (preliminary)	*380kV overhead line BERTRANGE / BOFFERDANGE - NIEDERSTEDEM*

Projects relative to high voltage stations

P4203	380/220/110-65kV substation BOFFERDANGE
P4301	380/220/110-65kV substation BERTRANGE
P5512	220/110-65kV substation SCHIFFLANGE
P5514	220/110-65kV substation WOLSER
P5607	220/65/20kV substation HEISDORF (Decommissioning of station)
P6501	220/110-65kV substation BASCHARAGE

Additional development projects - Reactive power compensation

The increasing and variable electricity infeed from renewable energy sources, as well as a growing number of cables are causing voltage problems on Creos grids. The system stability and the quality of supply might suffer from it.

In detail, the growing number of cables in the distribution grids is generating an excessive reactive power, so increasing the operating voltage on the 220kV transmission grid which is getting close to the upper admissible limit. The upstream operator Amprion has repeatedly requested a voltage lowering on the 220kV high voltage grid, but currently Creos has no possibility to actively control voltage on that level.

As reactive power management and voltage control are amongst the obligations of all TSOs, it is necessary to install a reactive power compensation to control the reactive power flow at the borders of the grid / country and to reduce the voltage level on the 220kV transmission grid.

For this purpose, a study has been performed to find the optimal solution in terms of reactive compensation. The compensation requirements and the available / remaining space in Creos substations has been considered. Resulting from this study, a parallel shunt compensation with variable adjustment has been chosen as the most appropriated technical solution.

It is planned to install compensation equipment in various Creos stations from the year 2025 on:

Installation site(s) and projects	***Projected power of compensation equipment 2025 – 2027***	***Estimated investment costs 2025 – 2027***
Schifflange (P5512)	*150 MVAr*	*5,2 million EUR**
Bissen / Roost (P5101)	*150 MVAr*	*6,9 million EUR**

** Provisional cost assessment, may be subject to revision*

Additional installation site(s)	***Power of additional comp. equipment after comm. of 380kV infeed***
to be defined	*300 MVAr***

*** Those figures should be considered as preliminary results from the study on reactive compensation. Changes might be necessary during the specific implementation of the project.*

The projected compensation also aims to fulfil the following requirements in the end phase of the deployment:

- Prevention of cross-border reactive power flows with Germany by installing compensations at the stations Roost/Bissen and Flebour
- Reactive power flows to all neighbouring countries should tend to 0 MVAr
- Full use of the total compensation capacities from 2030 on

Preliminary schedule of planned projects and outlook for 2040

The following table shows the intended implementation timelines of the major network development steps of the electricity transmission grid. A more detailed view of all the specific projects and investment amounts is documented in the 10-year investment inventory of Creos Luxembourg.

The projects relative to milestone 1, focusing on the '380kV infeed,' are fully planned with precise investment requirements. However, detailed plans for milestone 2 and beyond to 2040 are not yet finalized, with investment needs and timelines only roughly estimated.

			Milestone 1 & Milestone 2												*Outlook*					
			before 2023	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Milestone 1	**L4202**	380kV overhead line BOFFERDANGE - AACH																		
	L4602	380kV overhead line BOFFERDANGE - BERTRANGE																		
	P4203	380/220/110-65kV substation BOFFERDANGE																		
	L5601	220kV (HTLS) overhead line HEISDORF - ROOST (Infeed at station Bofferdange & Roost/Bissen & Partial decommissioning of overhead line)																		
	L5602	220kV overhead line HEISDORF - BERTRANGE (Infeed at station Bofferdange & Decommissioning of overhead line)																		
	L5603	220kV overhead line HEISDORF - BLOOREN (Infeed at station Bofferdange & reserve conduits Senningerberg)																		
	L5201	220kV overhead line HEISDORF - TREVES (Decommissioning of overhead line)																		
	P5607	220/65/20kV substation HEISDORF (Decommissioning of station)																		
	P5514	220/110-65kV substation WOLSER																		
	L5504	220kV overhead line SCHIFFLANGE - BERCHEM / BLOOREN (Infeed at station Wolser)																		
	P6501	220/110-65kV substation BASCHARAGE																		
	P5512	220/110-65kV substation SCHIFFLANGE																		
	L5503	220kV overhead line BASCHARAGE - SCHIFFLANGE (Infeed at station Schifflange and Bascharage)																		
M2	**P4301**	380/220/110-65kV substation BERTRANGE																		
O1	*L4101* (preliminary)	*380kV overhead line BERTRANGE / BOFFERDANGE - NIEDERSTEDEM*																		
Compensation	**I.P.** **P5101**	220kV reactive power compensation - BISSEN (ROOST)																		
	I.P. **P5512**	220kV reactive power compensation - SCHIFFLANGE																		
	I.P.	220kV reactive power compensation - (installation site(s) not yet defined)																		

Project under reassessement **Preliminary studies and works** **Planned investments / implementation**

Timeline for milestone 1:

It is intended to construct and commission the 380kV line 'Aach – Bofferdange – Bertrange' and the new transformer station Bofferdange before 2030 with the realisation of the projects L4202, L4602 and P4203. The connection of the 220kV grid to the station Bofferdange is planned within the same timeframe, with the projects L5602, L5603 and partially L5601.

Until 2030, it is also intended to reinforce the 220kV overhead line between Heisdorf and Roost by installing high temperature conductors (Project L5601). However, this part of the project is currently under reassessment as an earlier and partly realised project L4101 might replace this intended reinforcement.

The completion of all these projects will enable the decommissioning and dismantling of the 220kV overhead line Heisdorf – Treves and of the 220kV station Heisdorf (Projects L5201 and P5607).

With the projects P5514 and P6501, it is intended to prepare the grids for future consumption and generation. It is planned to construct and commission additional 220kV stations in Dudelange/Bettembourg (Wolser) and in Bascharage to achieve a discharge of the subordinated 65/110kV distribution grids and a better load distribution. However, due to the rapidly increasing costs of 220kV transformers and equipment, some of these planned modifications and intended reinforcements are currently under reassessment.

Timeline for milestones 2:

Between 2030 and 2035, it is planned to construct the 380kV extension of the station Bertrange with the project P4301.

Long-term outlook:

In the timeframe 2033 to 2037/2038, it is currently being considered to build a 380kV overhead line as a replacement of the 220kV overhead line between Bofferdange – Roost – Flebour and the country border near Vianden (preliminary project L4101).

The German transmission system operator Amprion acknowledged the future grid capacity needs of Luxembourg and intends to replace the 220kV infrastructure between Niederstedem and Luxembourg with a 380kV / 220kV infrastructure in the long term. The corresponding project / measure is disclosed in the German Network Development Plan NEP 2037/2045 with an estimated commissioning in the year 2037. (NEP: Netzentwicklungsplan Strom 2037/2045, Version 2023 Project P601: M903)

Project L4202: 380kV overhead line Bofferdange – Aach

Location

Objective(s)

The primary objectives are to increase the electricity transmission capacity between Luxembourg and Germany to ensure the supply of future electrical energy and to modernise the electrical grid infrastructure between the eastern country border near Moersdorf and the stations Heisdorf and Bertrange.

The target is to connect Luxembourg to the European 380kV transmission grid which is a highly resilient interconnected grid and a future-proof infrastructure. The connection to the European 380kV transmission grid represents an important element to enable the Energy Transition and the European and national energy policy objectives.

Costs

€

~ 63 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

It is planned to construct a new cross-border 380kV high voltage overhead line leading from Aach in Germany to the new station Bofferdange and to the station Bertrange, to replace the existing 220kV overhead line between Trier, Heisdorf and Bertrange which was originally set up in the 1960's. This replacement construction project consists of subsection Aach – Bofferdange (project L4202) and subsection Bofferdange – Bertrange (project L4602). The project L4202 is however limited to the infrastructure on national territory, starting from the country border near Moersdorf.

The projected 380kV overhead line in subsection Aach – Bofferdange has a length about 30km and comprises approximately 100 line pylons. Concerning tower design, it is planned to use steel lattice towers of 'Danube' design which have the advantage of a lean appearance and a reduced tower height. It is intended to equip the pylons with 2 AC circuits (1 circuit per side) isolated for a voltage level of 380kV. One AC circuit will be composed of 3 phases and each phase will consist of 4 conductors. It is planned to use aluminium-steel composite conductors with a section of 550mm^2 and a maximum operating temperature of 80°C (norm designation: 550-AL1/71-ST1A). The preliminary line route(s) are described more in detail on the following page(s).

Timeline

2024 – 2028

Project L4202 - Background information and project details

Since the beginning of the 380kV network development project(s), Creos Luxembourg communicated in a proactive and transparent manner, wanting to inform authorities and public about the intended works. Numerous bi- and multilateral discussions and meetings with the concerned national and local authorities were conducted and public information sessions were held with the purpose to provide information about the backgrounds, planned actions and the process of the project(s).

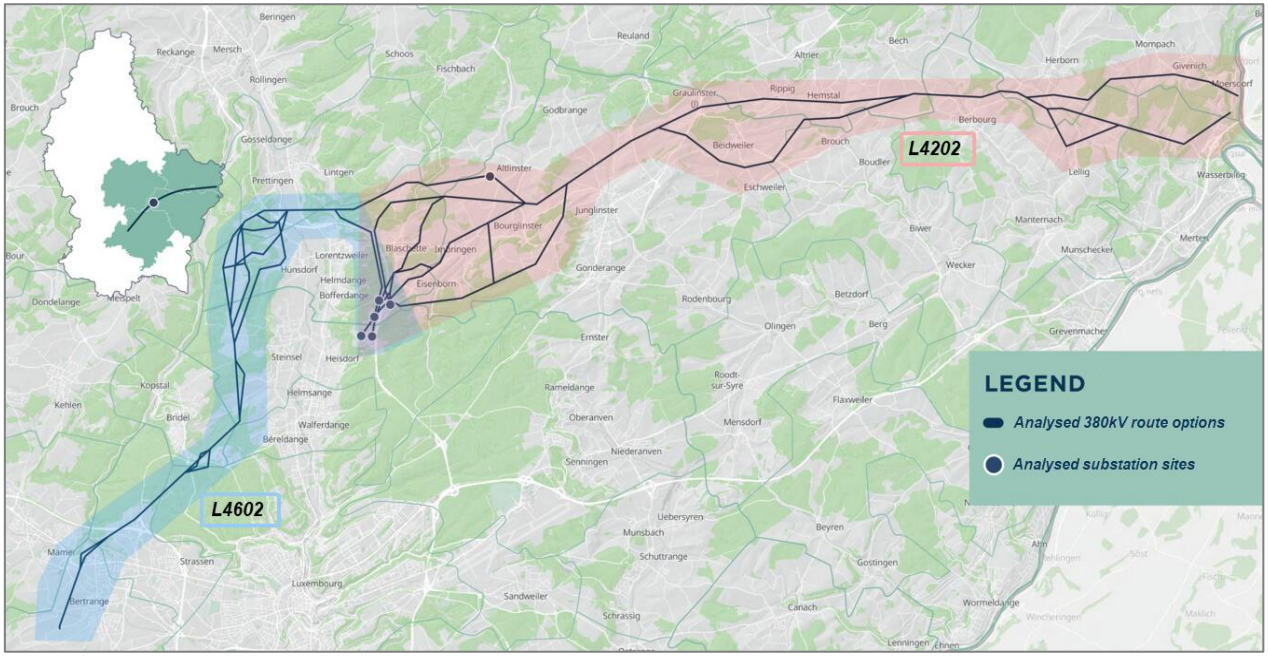
The planned 380kV network developments project(s) must abide by the legal requirements stipulated in the law of 15 May 2018 relative to the evaluation of incidences on the environment (EIE) and in the related Grand-Ducal Regulation of 15 May 2018. The impact on the environment must be assessed in detail and documented in the form of a study report (UVP - Environmental Impact Assessment) which must fulfil the criteria of the mentioned law and regulation. The UVP studies relative to the planned 380kV projects were delivered to the relevant authorities at the end of October 2022.

Within the UVP studies of the 380kV project(s), the environmental impact resulting from the installation and operation of underground cable systems and from the construction and operation of overhead lines was analysed and compared, including the comparison of several types of overhead lines towers. The conclusion of this analysis was that, for this voltage level in general, the construction of overhead lines, with an appropriate choice of line towers, has the least impact on the environment considering the substantial excavation works necessary to install underground cables. Therefore, it is planned to realise the project subsections L4202 Bofferdange – Aach and L4602 Bofferdange – Bertrange using overhead lines, due to a lesser impact on nature and due to a better socio-economic value.

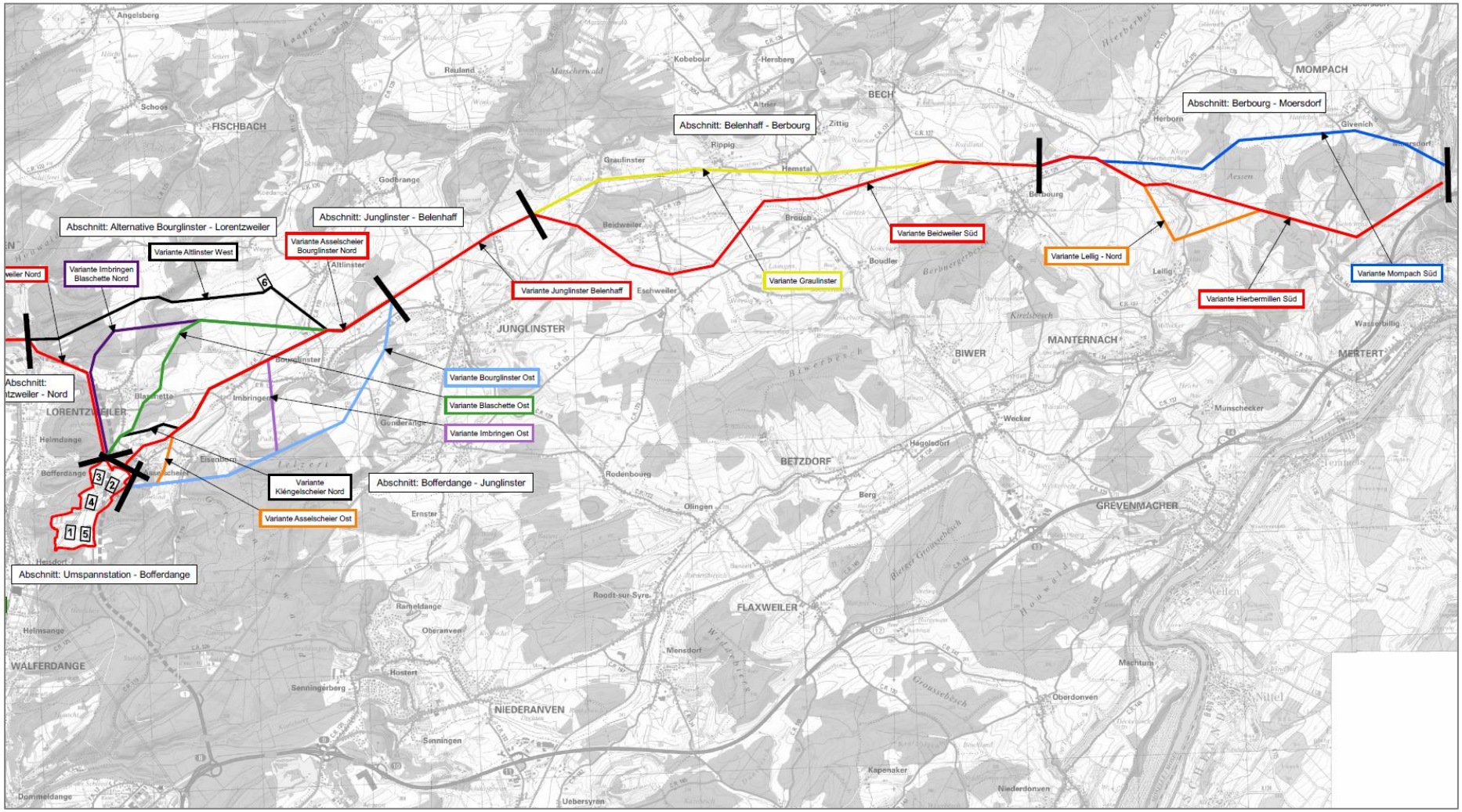
As shown here on the right side, several route options for the planned 380kV overhead line(s) between the country border near Moersdorf, Bofferdange and Bertrange are still under discussion. Also, different sites for the installation of the station ‘Bofferdange’ are being studied.

The projected 380kV overhead line in subsection L4202 Bofferdange – Aach with a length of 30km and about 100 line pylons, is intended as a replacement construction of the existing 220kV overhead line between Treves – Heisdorf.

The decommissioning and dismantlement of the existing 220kV line will be made after the commissioning of the overhead line subsection L4202 and of the station Bofferdange (P4203).



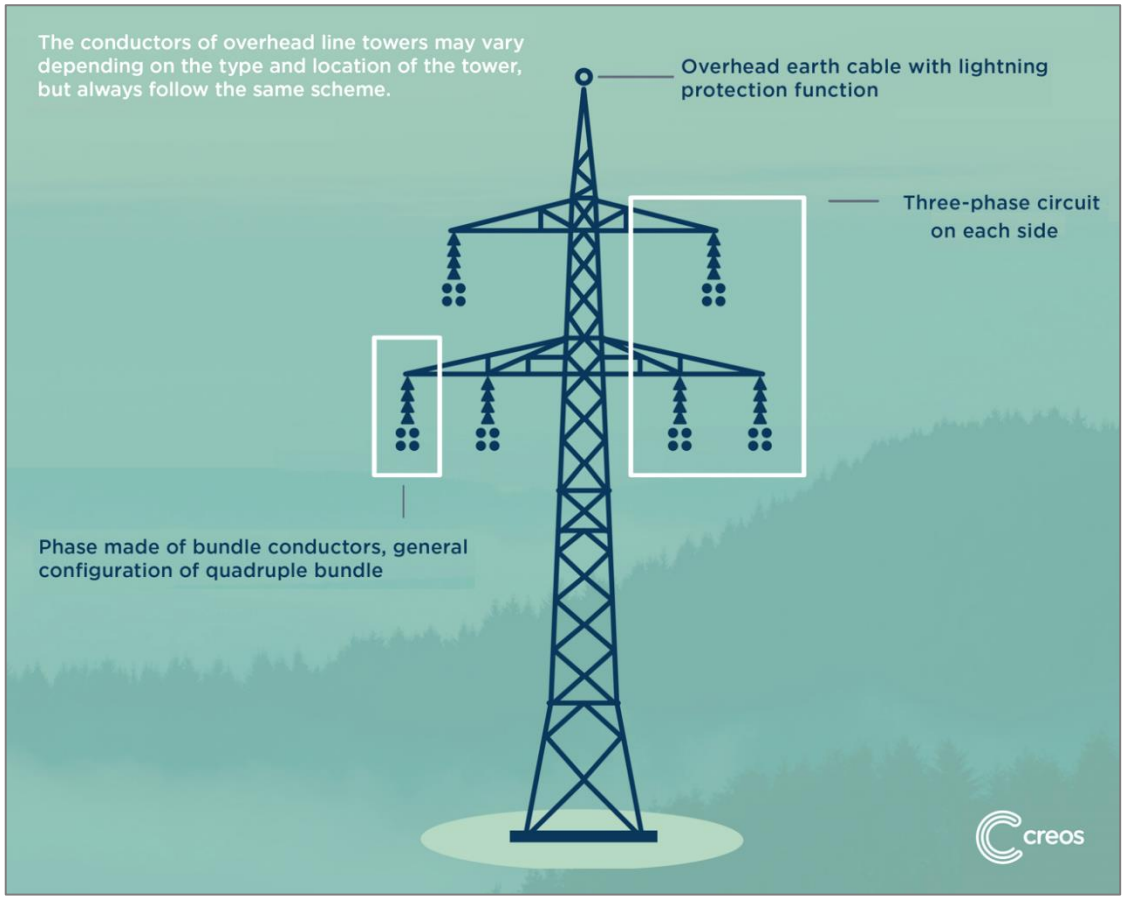
A more detailed view of the different route options of the intended 380kV overhead line project L4202 Bofferdange – Aach is shown below. The final choice of route has not yet been taken as authorisation procedures are still on-going and construction permit(s) have not yet been issued.



Concerning the type of overhead line towers, it is planned to use steel lattice towers of 'Danube' design for project L4202, which offer a lean appearance and reduced tower heights compared to other tower design alternatives (please see representation below).

Although several tower types can be used for the construction of high-voltage and extra high voltage overhead lines, steel lattice towers are most commonly used. Lattice towers have the advantage that they are composed of light and not bulky individual parts which can be better transported and mounted on site. This type of tower also requires smaller foundations with less steel reinforcements.

The planned line towers of project L4202 will be equipped with two separate electrical circuits (one circuit per tower side) isolated for a voltage level of 380kV. Each circuit will be composed of three phases and each phase will consist of four conductors (quadruple bundle configuration). It is planned to use aluminium-steel composite conductors with a section of 550mm^2 and a maximum operating temperature of 80°C (norm designation: 550AL1 / 71ST1A).



Project L4602: 380kV overhead line Bofferdange – Bertrange

Location

Objective(s)

The objectives of this project are to create the necessary grid capacity and infrastructure to ensure the future electrical energy supply of the projected 380kV station Bertrange and to modernise the existing electrical grid infrastructure between the stations Heisdorf and Bertrange.

It is planned to install a 380kV station in Bertrange to prepare for the expected rising electricity demand in the south and central part of Luxembourg. To supply the future 380kV station in Bertrange and to guarantee the security of supply, it is necessary to expand the 380kV grid connection 'Aach – Bofferdange' to Bertrange.

Costs

€

~ 48 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

It is planned to construct a new cross-border 380kV high voltage overhead line leading from Aach in Germany to the new station Bofferdange and to the station Bertrange, to replace the existing 220kV overhead line between Trier, Heisdorf and Bertrange which was originally set up in the 1960's. This replacement construction project consists of the subsection Aach – Bofferdange (project L4202) and the subsection Bofferdange – Bertrange (project L4602).

The projected 380kV overhead line in subsection Bofferdange – Bertrange has a length of about 20km and comprises approximately 70 line pylons. Concerning tower design, it is planned to use lattice steel pylons of 'Danube' design which have the advantage of a lean appearance and a reduced tower height. It is intended to equip the pylons with 2 AC circuits (1 circuit per side) isolated for a voltage level of 380kV. One AC circuit will be composed of 3 phases and each phase will consist of 4 conductors. It is planned to use aluminium-steel composite conductors with a section of 550mm^2 and a maximum operating temperature of 80°C (norm designation: 550-AL1/71-ST1A). The preliminary line route(s) are described more in detail on the following page(s).

Timeline

2027 – 2029

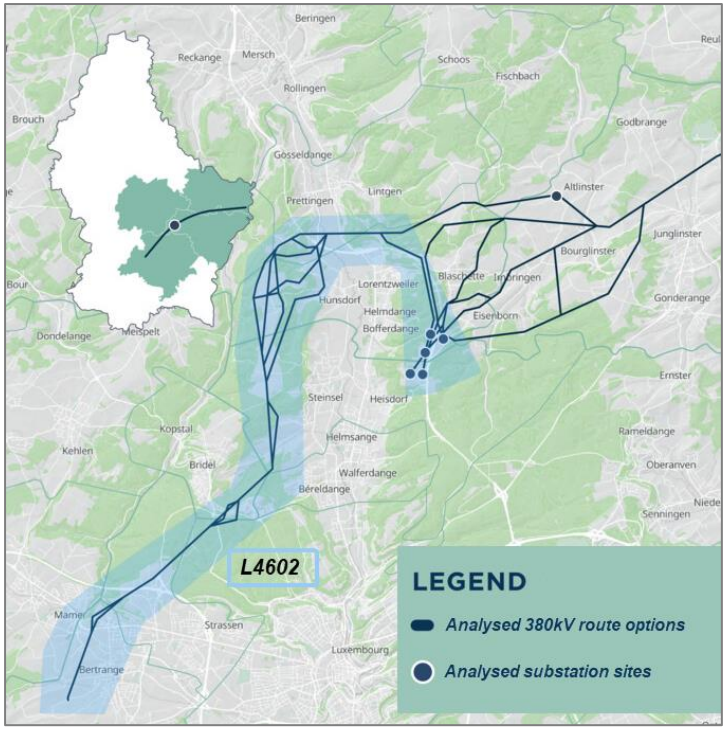
Project L4602 - Background information and project details

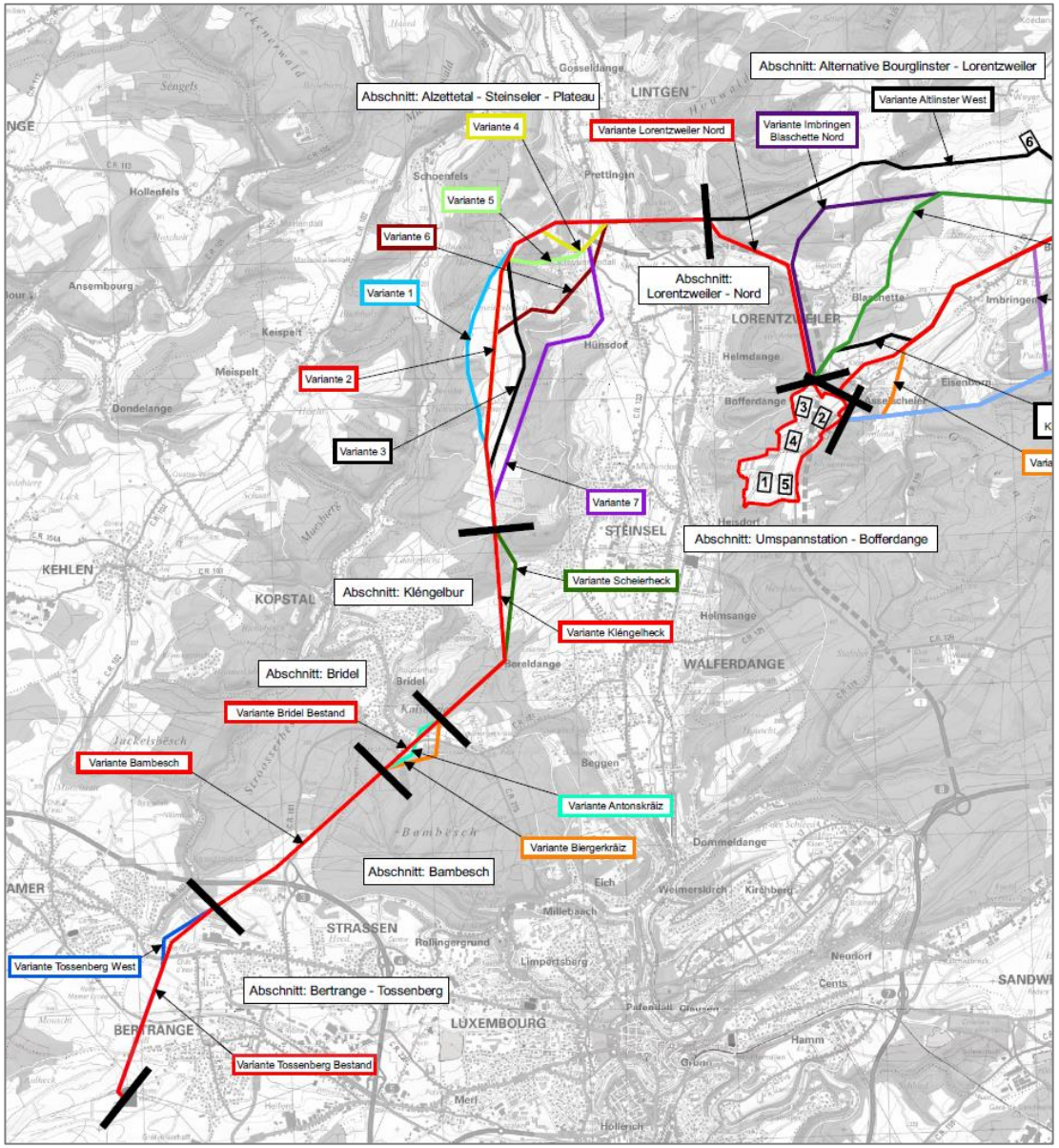
The projected 380kV overhead line in subsection L4602 Bofferdange – Bertrange, which will replace the existing 220kV overhead line between Heisdorf and Bertrange, has a length of 20km. About 70 line pylons must be built for this project.

For the moment, there are still several possible routes for the planned 380kV overhead line(s) Bofferdange – Bertrange, as is shown here below.

The final choice of route has not yet been taken as authorisation procedures are still on-going and construction permit(s) have not yet been issued.

A more detailed view on the different route options of the intended 380kV overhead line project is shown here at the right side.

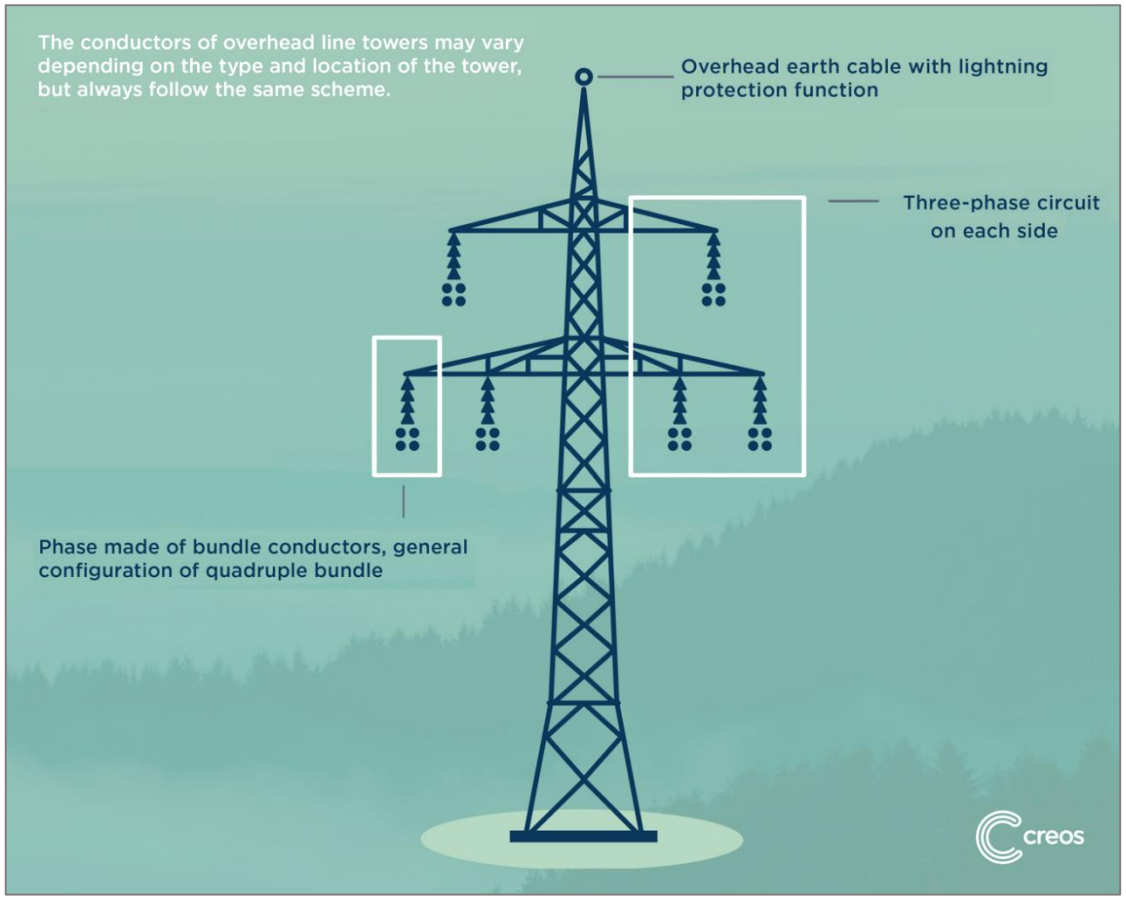




Concerning the type of overhead line towers of the project L4602, it is planned to use steel lattice towers of 'Danube' design, which offer a lean appearance and reduced tower heights compared to other tower design alternatives (please see representation here below).

Although several tower types can be used for the construction of high-voltage and extra high voltage overhead lines, steel lattice towers are most commonly used. Lattice towers have the advantage that they are composed of light and not bulky individual parts which can be better transported and mounted on site. This type of tower also requires smaller foundations with less steel reinforcements.

The planned line towers of project L4602 will be equipped with two separate electrical circuits (one circuit per tower side) isolated for a voltage level of 380kV. Each circuit will be composed of three phases and each phase will consist of four conductors (quadruple bundle configuration). It is planned to use aluminium-steel composite conductors with a section of 550mm^2 and a maximum operating temperature of 80°C (norm designation: 550AL1 / 71ST1A).



Project P4203: 380/220/110-65kV substation Bofferdange

Location

Objective(s)

The objective of project P4203 is to build a substation which will be able and adapted to transform, distribute and ensure the supply of future electrical energy. The electricity transmitted with the future 380kV grid connection Aach – Bofferdange needs to be transformed to the voltage levels 220kV and 110/65kV so that the existing grid infrastructures on those voltage levels can be used effectively to distribute the future electrical energy.

At the same time, the realisation of this project aims to replace a part of the existing station Heisdorf.

Costs

~ 63 million EUR*
(380kV - 220kV)

~ 24 million EUR*
(110-65kV - 20kV)

** Provisional cost assessment, may be subject to revision*

Description

It is planned to build a new 380 / 220 / 110-65kV transformer substation on a plateau near the locality of Bofferdange, which will connect the 380kV transmission grid to the 220kV grid infrastructure and the 65/110kV regional meshed grids.

It is projected to equip the new substation with 380kV gas-insulated tubular lines and switchgear, and 4 high voltage transformers in total (2x 380/220kV transformers and 2x 380/110-65kV transformers). The 220kV and the 110kV part will consist of gas-insulated equipment and will be housed in several separate buildings. The indicated costs 380kV - 220kV include the 380kV and 220kV parts and the related transformers of the station Bofferdange. A preliminary plan of the substation can be found on the following page(s).

With the new station Bofferdange, it will be possible to remove the existing 220 / 65kV station Heisdorf from the town centre. The new station Bofferdange will completely replace the existing 220kV part of the station Heisdorf. The remaining 65/20kV part of the station Heisdorf will be replaced by the projected 110-65kV substation Steinsel.

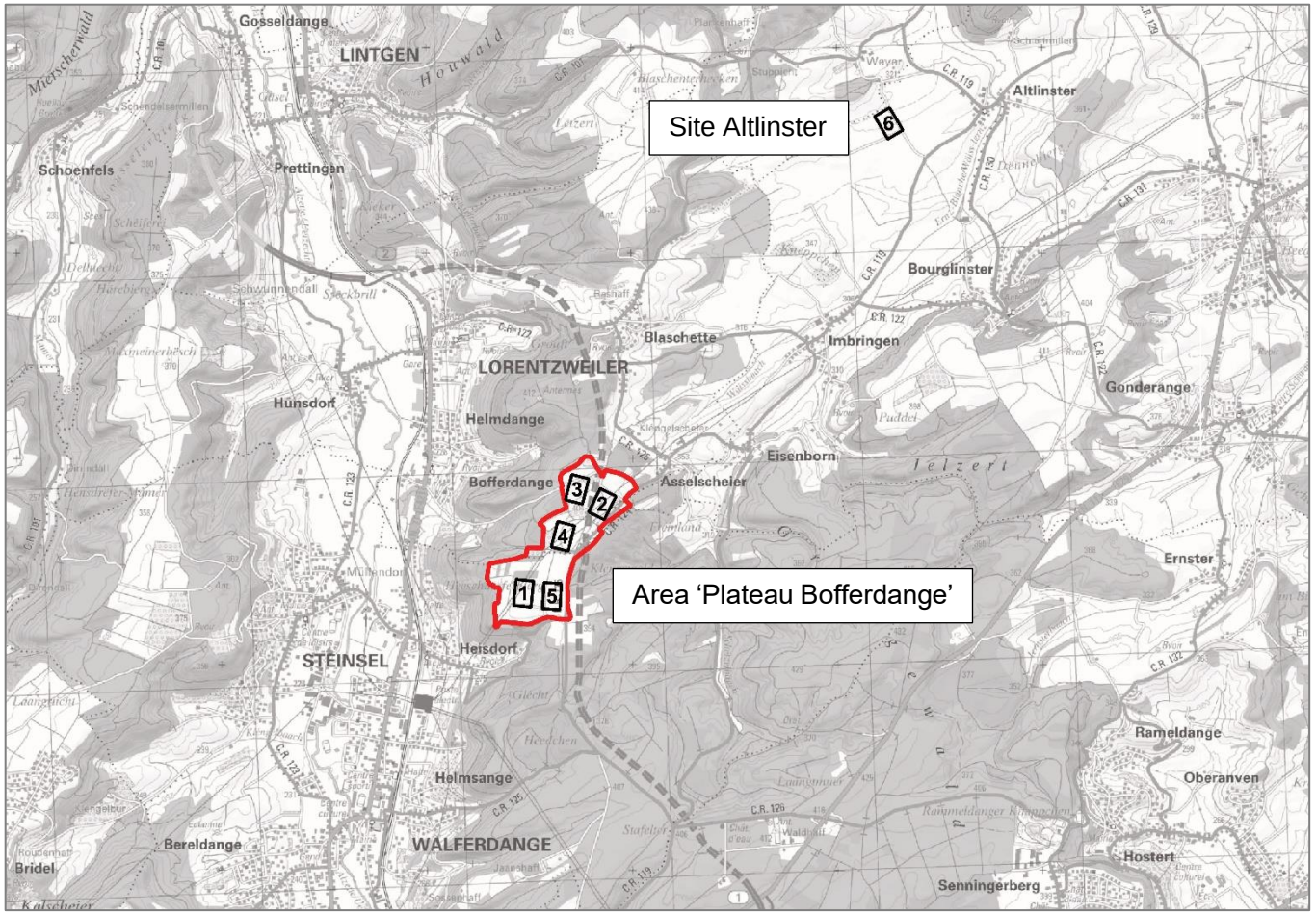
Timeline

2024 – 2027

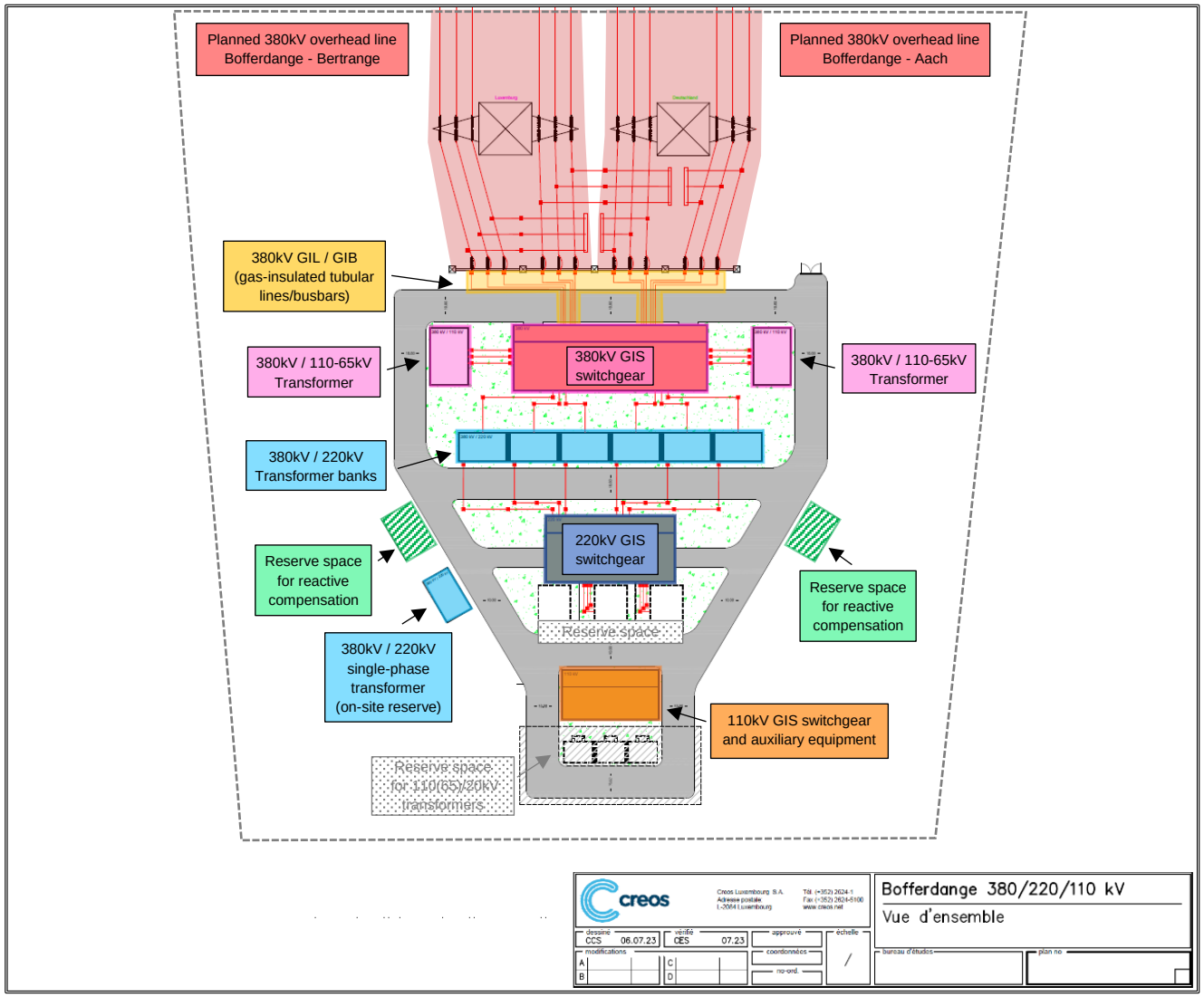
Project P4203 - Background information and project details

In the frame of the 'Environmental Impact Assessment' study, several locations have been analysed as possible sites for the construction of the planned substation Bofferdange.

In total, 6 potential locations, 5 near Bofferdange and 1 site near Altlinster, have been identified and the environmental impact and the repercussions on nature and human-beings have been studied. The 5 possible locations near Bofferdange and the site near Altlinster are shown below. Recent discussions and developments indicate that, among the 6 possible sites, site number 2 and number 4 might be suitable for the realisation of the intended project P4203. A more detailed analysis is however necessary.



Depicted below, is a preliminary plan of the substation Bofferdange (P4203), which can be divided into several voltage level related sections. 380kV gas-insulated tubular lines / conductors (GIL) or gas-insulated busbars (GIB) will be used to transmit the electrical energy from the planned 380kV overhead lines to the 380kV gas-insulated switchgear (GIS) and then to 380kV/220kV and 380kV/110-65kV transformers. It is also planned to use gas-insulated switchgear and busbars on the 220kV voltage level. The 110kV GIS switchgear and auxiliary equipment will be housed in a separate building. In a first step, it is not planned to install 110-65kV/20kV transformers, but appropriate reserve spaces have been projected, allowing a future installation.



Project L5601: 220kV (HTLS) overhead line Heisdorf – Roost

Location

Objective(s)

The goal of this replacement project is to increase the transmission capacity of the overhead lines between Roost and the future station Bofferdange (replacing the existing station Heisdorf), in order to guarantee the security of supply in the short and mid-term in case of an unavailability of the 380kV infeed.

As the conductors of the overhead lines between the country border near Vianden, the station Flebour and the station Roost, representing the northern 220kV connection with Germany, have already been replaced by high performance conductors with increased transmission capacities, the project L5601 aims to complete the initiated reinforcement with high performance conductors on this northern 220kV connection.

Costs

~ 8,9 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

It is planned to replace the existing conductors of the two circuits of the 220kV overhead line Roost – Heisdorf with high performance conductors. Per circuit, it is intended to use a double bundle of 220kV ACCC (Aluminium Conductor Composite Core) high performance conductors which have a nominal section of 330mm^2 and a maximum operating temperature of 150°C.

The replacement of the conductors is planned on a route length of about 8,5 to 9km, from the station Roost to the intersection point with the planned 380kV overhead line project L4602 Bofferdange – Bertrange, near the locality of Prettingen. A more detailed view on the line route where the conductor replacement is projected, is shown and described on the following page.

This project also includes cable connections at the new station Bofferdange and the station Roost/Bissen, and the decommissioning and dismantlement of 220kV overhead line section between Heisdorf and Lorentzweiler (5km route length; ~15 pylons) after the completion of the replacement project L4602.

This project is currently under reassessment. An earlier and partly realised project L4101 might be a substitute for the intended conductor replacement.

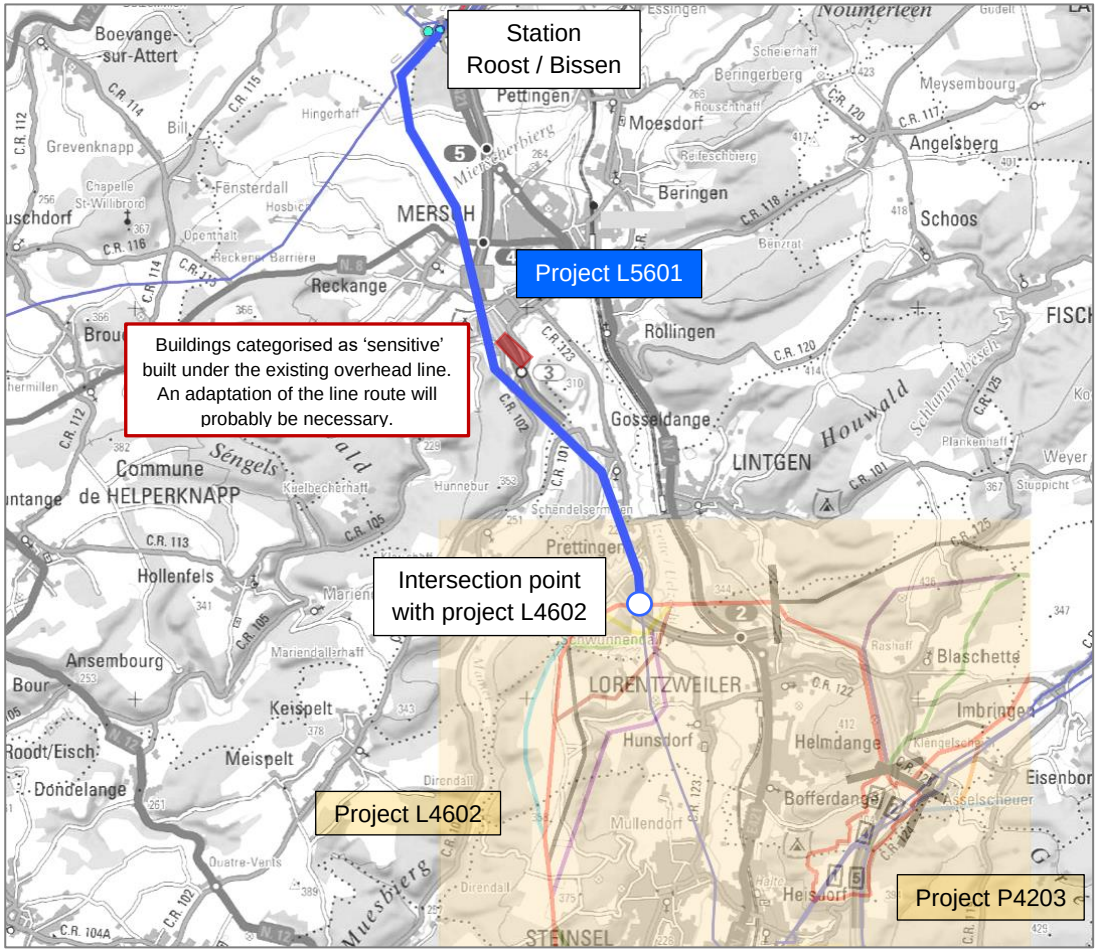
Timeline

2023 (infeed at station Roost/Bissen) & 2026 – 2027 (Conductor replacement and infeed at station Bofferdange)
2029 (Decommissioning)

Project L5601 - Background information and project details

Here below is a more detailed view on the section of the project L5601, where the replacement of the conductors of the existing 220kV overhead line between Heisdorf and Roost is planned. The replacement with high performance conductors is planned from the 220/65kV station Roost to the intersection point with the projected 380kV overhead line L4602 Bofferdange – Bertrange.

The project L5601 is however being reassessed because it is intended to realise a 380kV overhead line with two circuits between the depicted intersection point and the station Roost in a later phase. An earlier and partly realised project L4101 might replace the intended conductor replacement.



Project L5602: 220kV overhead line Heisdorf – Bertrange

Location

Objective(s)

The primary objective of the project L5602 is to connect the projected 380kV overhead line Bofferdange – Bertrange to the projected 380/220/110-65kV substation Bofferdange on the 220kV voltage level.

This project also serves the purpose to decommission and dismantle the existing 220kV overhead line Heisdorf – Bertrange, after the completion of the replacement project L4602 – 380kV overhead line Bofferdange – Bertrange.

Costs

~ 5,4 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

It is planned to connect the projected 380kV overhead line Bofferdange – Bertrange to the 220kV switchgear and busbars of the substation Bofferdange using 220kV underground cables of appropriate sections. At this stage of the project, it is planned to use 220kV high voltage cables made of aluminium and of a section of 2500mm^2.

After the construction and commissioning of the overhead line Bofferdange – Aach (L4202), the overhead line Bofferdange – Bertrange (L4602) and the substation Bofferdange (P4203), the existing 220kV overhead line between Heisdorf and Bertrange will be decommissioned and dismantled. In total, overhead line sections on a route length of about 12km and approximatively 34 line pylons will be dismantled between Heisdorf and Bertrange.

Timeline

2028 – 2029 (Infeed at station Bofferdange)
2030 (Decommissioning)

Project L5603: 220kV overhead line Heisdorf – Blooren

Location

Objective(s)

The objective of project L5603 is to connect the existing 220kV overhead line Heisdorf – Blooren to the projected 380/220/110-65kV substation Bofferdange on the 220kV voltage level.

Costs

€

~ 8,5 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

It is planned to connect the existing 220kV overhead line Heisdorf – Blooren to the 220kV switchgear and busbars of the substation Bofferdange using 220kV underground cables of appropriate sections. At this stage of the project, it is planned to use 220kV high voltage cables made of aluminium and of a section of 2500mm^2.

This project also includes the modifications works and reserve conduits which are necessary to connect the future 110-65/20kV Senningerberg to the new station Bofferdange.

Timeline

2023 – 2024 (Reserve conduits Senningerberg)
2026 – 2027 (Infeed at station Bofferdange)

Project L5201: 220kV overhead line Heisdorf – Treves (Decommissioning)

Location

Objective(s)

The objective of the project L5201 is the decommissioning and dismantling of the 220kV overhead line Treves – Heisdorf to prevent a double grid infrastructure between Treves and Heisdorf/Bofferdange. With the realisation of the 380kV overhead line project L4202 and of the 380kV substation Bofferdange, there is no longer a need to operate the existing 220kV overhead line Treves – Heisdorf.

The decommissioning and dismantling of the 220kV overhead line Treves – Heisdorf will allow a renaturation of the involved line route.

Costs

~ 2,6 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

After the construction and the commissioning of the overhead line Bofferdange – Aach (L4202) and the substation Bofferdange (P4203), the existing 220kV overhead line between Treves and Heisdorf will be decommissioned and dismantled.

In total, overhead line sections on a route length of about 30km and approximately 85 line pylons will be dismantled between the eastern country border near Moersdorf and Bofferdange.

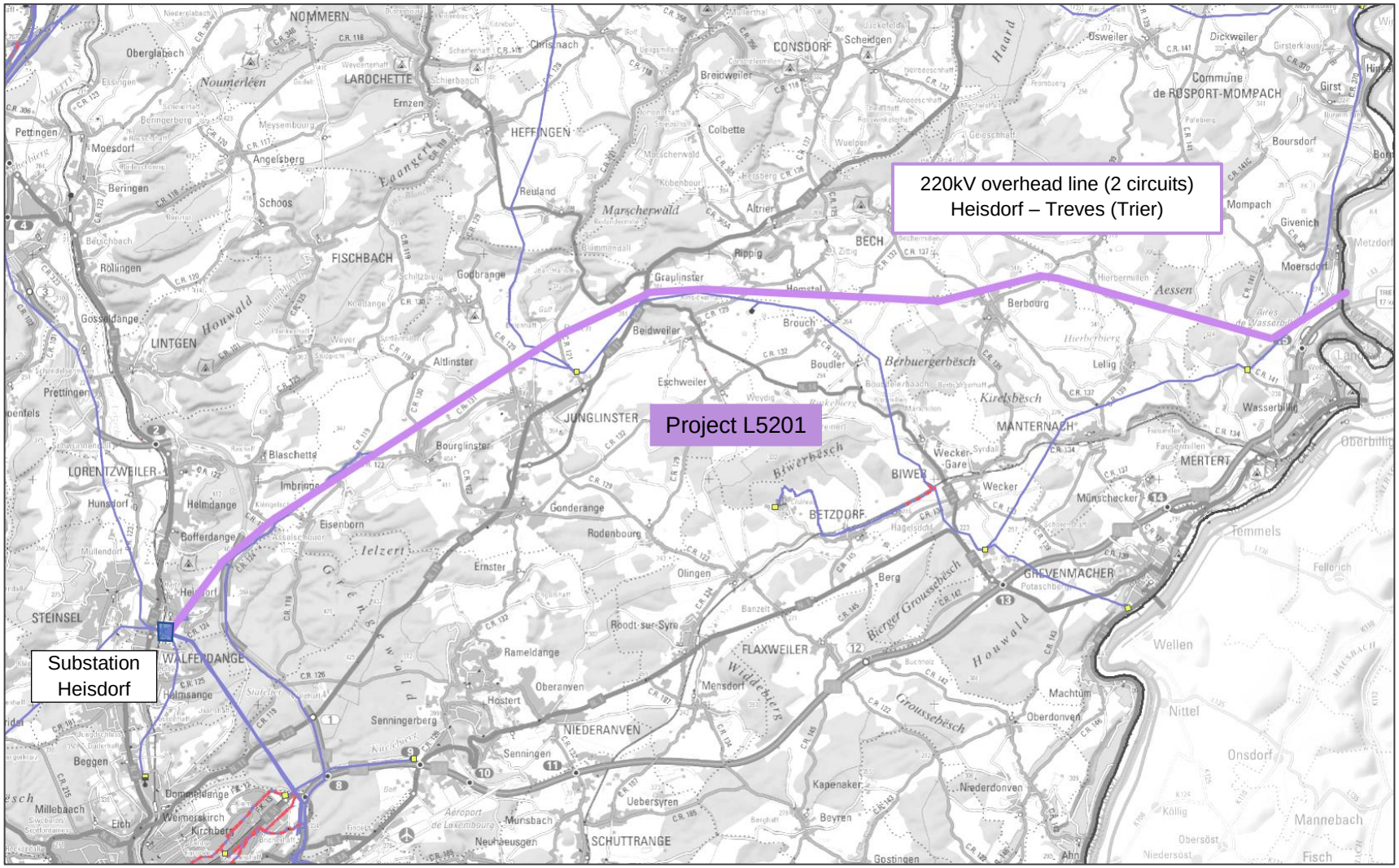
Timeline

2028

Project L5201 - Background information and project details

The 220kV overhead line 'Heisdorf – Treves' can be decommissioned and dismantled between the country border near Moersdorf and the substation Heisdorf, after the realisation of the project L4202 (380kV Aach – Bofferdange).

In total, overhead line sections on a route length of about 30km and approximately 85 line pylons will be dismantled with this project.



Project P5607: 220/65/20kV substation Heisdorf (Decommissioning)

Location

Objective(s)

The purpose of project P5607 is the decommissioning and dismantling of the existing 220/65kV station Heisdorf, after the construction and commissioning of the projected 380/220/110-65kV substation Bofferdange.

The realisation of the project P4203 (substation Bofferdange) will enable the possibility to decommission and dismantle the 220kV part of the station Heisdorf. The costs of the project P5607 also include the dismantling of the 65/20kV part of the station Heisdorf, which will be enabled by the commissioning of the projected 110-65kV substation Steinsel.

Costs

~ 0,7 million EUR*
(380kV - 220kV)

~ 0,7 million EUR*
(110-65kV - 20kV)

** Provisional cost assessment, may be subject to revision*

Description

It is planned to dismantle the entire substation Heisdorf after prerequisite conditions are met:

The 220kV part of the station Heisdorf can be decommissioned and dismantled after the commissioning of the project L4202 (380kV Aach – Bofferdange), the project L4602 (380kV Bofferdange - Bertrange) and the project P4203 (substation Bofferdange).

The 65/20kV part of the station Heisdorf can be decommissioned and dismantled after the commissioning of the projected 110-65/20kV station Steinsel and the projected 110(65)kV grid connection Bofferdange – Junglinster.

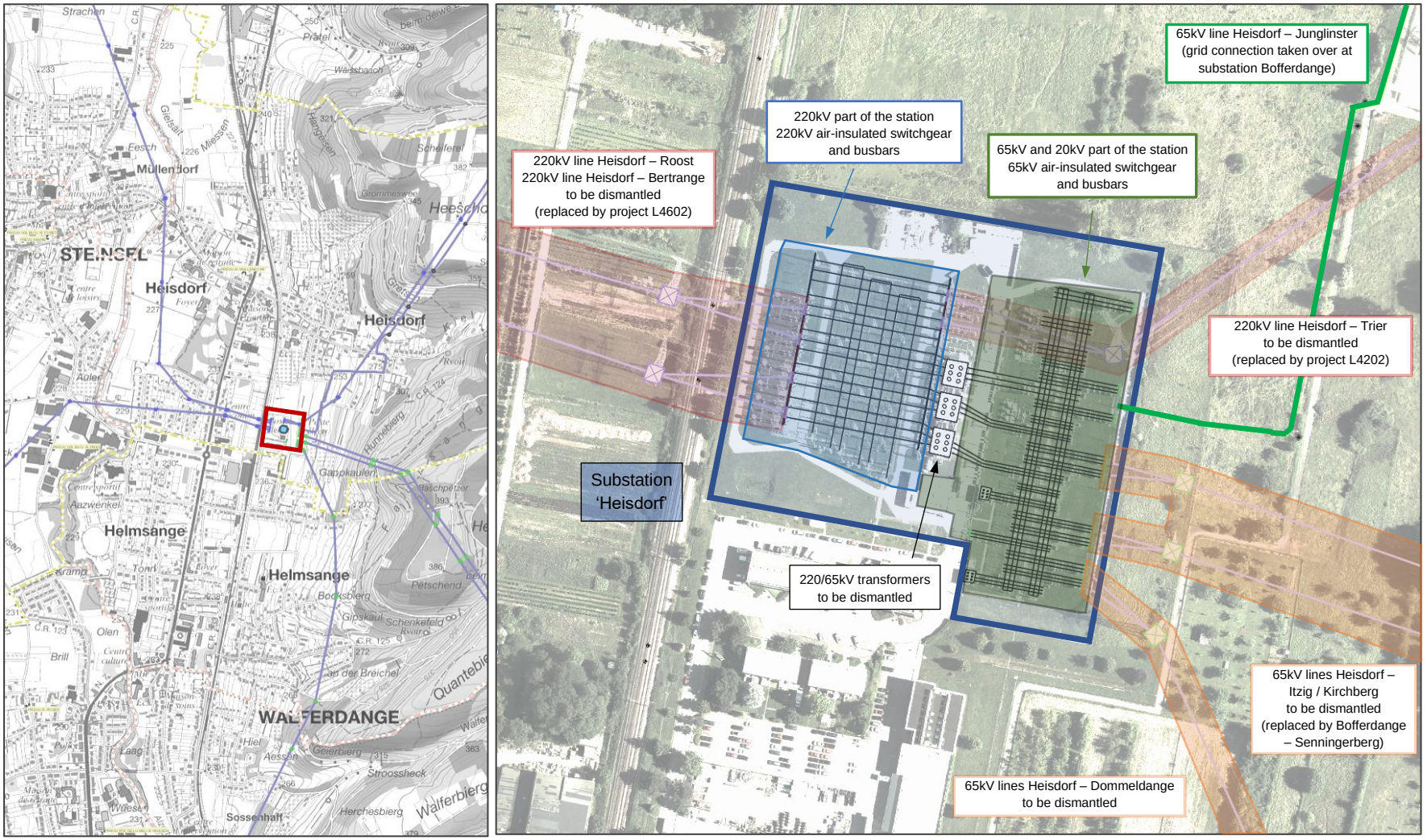
Moreover, it is planned to create a new 110(65)kV grid connection Bofferdange – Senningerberg to replace the existing 65kV connection Heisdorf – Itzig – Kirchberg. The 65kV station Dommeldange and its infeed from Heisdorf will be completely dismantled; the load taken over by the subordinated 20kV grid infrastructure.

Timeline

2029 – 2030

Project P5607 - Background information and project details

Please find here below a sketch of the existing substation Heisdorf with a few clarifying notes.



Project P5514: 220/110-65kV substation Wolser

Location

Objective(s)

The objective of project P5514 is to increase grid capacity in the region South-East to ensure the supply of future electrical energy. It is expected that future electricity needs will increase significantly in this area.

A 220kV transformation at the station Wolser represents the most effective and cost-efficient way to increase grid capacity in the region South-East. The created grid capacity will facilitate the energy transition.

At the same time, this project is intended as replacement of existing 65/20kV substation Dudelange and its realisation will enable the dismantling of the station Dudelange.

Costs

~ 0,7 million EUR*
(220kV)

~ 25,6 million EUR*
(110-65kV - 20kV)

** Provisional cost assessment, may be subject to revision*

Description

To replace the existing 65/20kV substation Dudelange, it is planned to build a new 220/110-65kV transformer substation right next to the existing station Galvalange at Dudelange, which will connect the 220kV grid infrastructure to the 65kV regional grids. The 65kV station Galvalange will be connected separately to the new 220/110-65kV transformer substation.

It is projected to equip the new substation with air-insulated 220kV and gas-insulated 110kV switchgear and 3 high voltage transformers (1x 220/110-65kV transformer and 2x 110-65/20kV transformers). The 110kV gas-insulated equipment will be housed in a separate building together with auxiliary equipment. A preliminary plan can be found on the following page(s).

With the realisation of the new station Wolser, it will be possible to remove the existing 65/20kV station Dudelange, which is aged and poorly situated.

Timeline

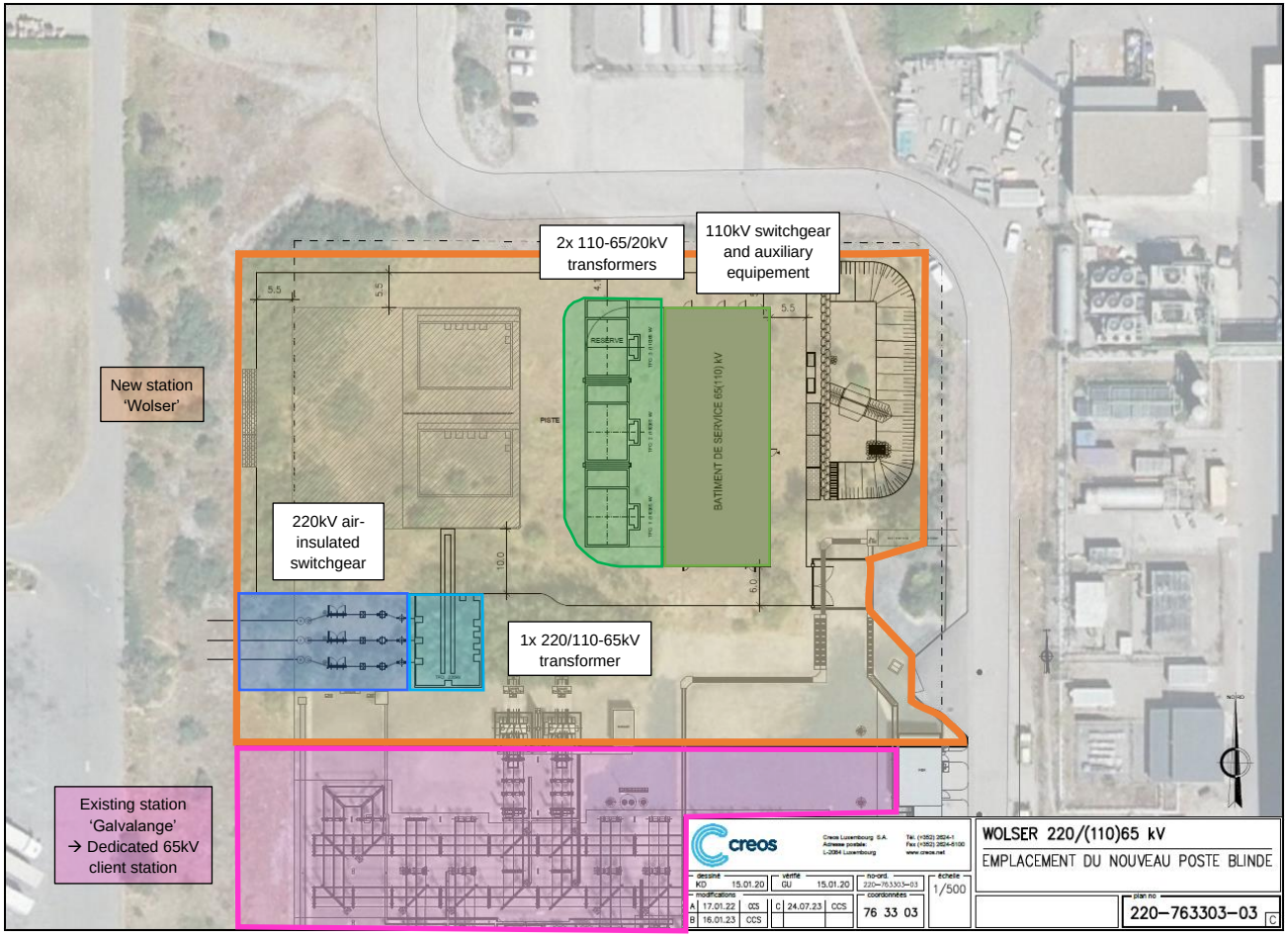
2023 – 2028

Project P5514 - Background information and project details

The basic design of the projected substation Wolser (P5514) is shown hereafter with the help of a preliminary plan.

It is planned to build the new substation Wolser right next to the existing substation Galvalange, which will be connected separately with 110(65)kV underground cables and will function as a 65kV dedicated client station after the projected works.

It is intended to use 220kV and 110kV gas-insulated switchgear. As best cost-benefit solution, it has been determined to equip this station with only one 220/110-65kV transformer. Grid calculations have shown that the existing and planned 65/110kV grid infrastructure will be sufficient to guarantee the security of supply in case of a major failure of that transformer or during maintenance.



Project L5504: 220kV overhead line Schifflange – Berchem / Blooren

Location

Objective(s)

The objective of project L5504 is to connect the existing 220kV overhead line Schifflange – Berchem/Blooren to the projected 220/110-65kV substation Wolser (P5514) on the 220kV voltage level.

The overall aim is to increase grid capacity in the region South-East to ensure the supply of future electrical energy. It is expected that future electricity needs will increase significantly in this area.

Costs

~ 7,1 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

It is planned to connect the existing 220kV overhead line Schifflange – Berchem / Blooren to the 220kV switchgear and busbars of the substation Wolser using 220kV underground cables of appropriate sections on an approximative trench length of 1,8km.

At this stage of the project, it is planned to use 220kV high voltage cables made of aluminium and of a section of 2500mm^2. A concept drawing and a preliminary plan of the intended connection project can be found on the following page.

Timeline

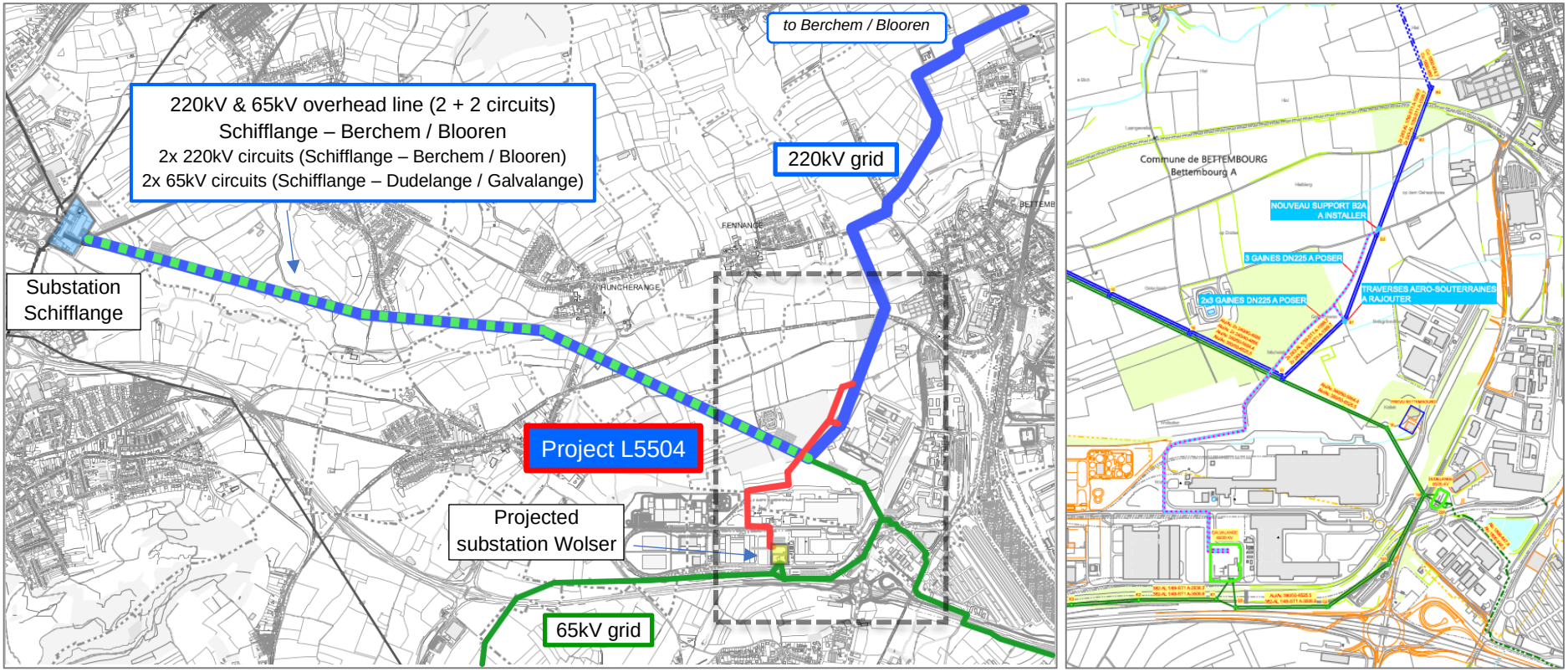
2026 – 2027

Project L5504 - Background information and project details

The existing overhead line Schifflange – Berchem / Blooren is equipped with two 220kV line circuits and two 65kV line circuits. It is planned to use one 220kV circuit of this overhead line to connect and supply the projected substation Wolser with 220kV.

For this purpose, it is projected to install a new line pylon and modify another pylon to connect 220kV underground cables, which will be installed on a length of about 1,8km between the relevant line pylons and the projected substation Wolser.

As a variant, a reduced 220kV connection is currently being analysed. It is examined if a stub line connection would be technically feasible and would not lead to inadmissible violations of the N-1 criterion. This alternative implementation would reduce the project costs.



Project P6501: 220/110-65kV substation Bascharage

Location

Objective(s)

The objective of project P6501 is to increase grid capacity in that region in order to ensure the supply of future electrical energy. It is expected that future electricity needs will rise significantly in this area.

Adding a 220kV transformation at the station Bascharage represents the most effective and cost-efficient way to increase grid capacity in the region South-West. The created grid capacity will facilitate the energy transition.

Costs

~ 4,6 million EUR*
(220kV)

~ 22,2 million EUR*
(110-65kV - 20kV)

** Provisional cost assessment, may be subject to revision*

Description

With project P6501 it is intended to extend the existing 65/20kV substation Bascharage with a 220kV section and a 220/110-65kV transformation. The indicated costs 220kV only include the 220kV part of the station.

It is projected to equip the substation with 1 new 220/110-65kV transformer and to supply it with the help of a 220kV stub line. For this purpose, it is intended to use the existing overhead line Bascharage - Schifflange which is equipped with two line circuits and already prepared to use with a voltage of 220kV. Currently one circuit of this line is operated with a voltage of 65kV and one circuit is operated with 220kV for the 220kV connection with Belgium.

As the realisation of project P6501 is intended only after 2030, it has not yet been planned in detail nor has a preliminary plan of the modification/extension at the substation Bascharage been made.

The project of the 220kV extension might be revaluated / modified at a later time due to future developments.

Timeline

2031 – 2034 (220kV)

Project P5512: 220/110-65kV substation Schifflange

Location

Objective(s)

The objective of project P5512 is extend / modify the 220kV section of the substation Schifflange to enable the 220kV connection of the overhead line Bascharage - Schifflange and to supply the projected substation Bascharage (P6501).

Adding a 220kV transformation at the station Bascharage represents the most effective and cost-efficient way to increase grid capacity in the region South-West. The created grid capacity will facilitate the energy transition.

Costs

~ 0,8 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

With project P5512, it is intended to extend and modify the existing 220kV section of the substation Schifflange.

It is planned to install additional 220kV switchgear and equipment at the substation Schifflange to connect one circuit of the overhead line Bascharage - Schifflange on the 220kV voltage level (please refer to project L5503: 220kV overhead line Bascharage – Schifflange).

As the project of the 220kV extension of the substation Bascharage (P6501) might be revaluated / modified at a later time due to future developments, this project might also be reassessed later. A preliminary plan of the 220kV switchgear modification/extension at the substation Schifflange has not yet been made.

Timeline

2026 – 2027

Project L5503: 220kV overhead line Bascharage – Schifflange

Location

Objective(s)

The objective of project L5503 is to prepare the connection of the existing 220kV overhead line Bascharage – Schifflange to the projected 220/110-65kV substation Bascharage (P6501) on the 220kV voltage level.

The overall aim is to increase grid capacity in the region South-West to ensure the supply of future electrical energy. It is expected that future electricity needs will increase significantly in this area.

Costs

~ 2,6 million EUR*

** Provisional cost assessment, may be subject to revision*

Description

With project L5503 it is intended to create the 220kV connections between the existing overhead line Bascharage – Schifflange, the substation Schifflange and the substation Bascharage. It is planned to connect the overhead line Bascharage – Schifflange to the 220kV switchgear and busbars of the substations Schifflange and Bascharage using 220kV underground cables of appropriate sections.

The overhead line Bascharage – Schifflange is equipped with two line circuits and already prepared for an operation with a voltage of 220kV. Currently one circuit of this line is operated with a voltage of 65kV and one circuit is operated with 220kV for the 220kV connection with Belgium.

As the project of the 220kV extension of the substation Bascharage (P6501) might be revaluated / modified at a later time due to future developments, this project might also be reassessed later.

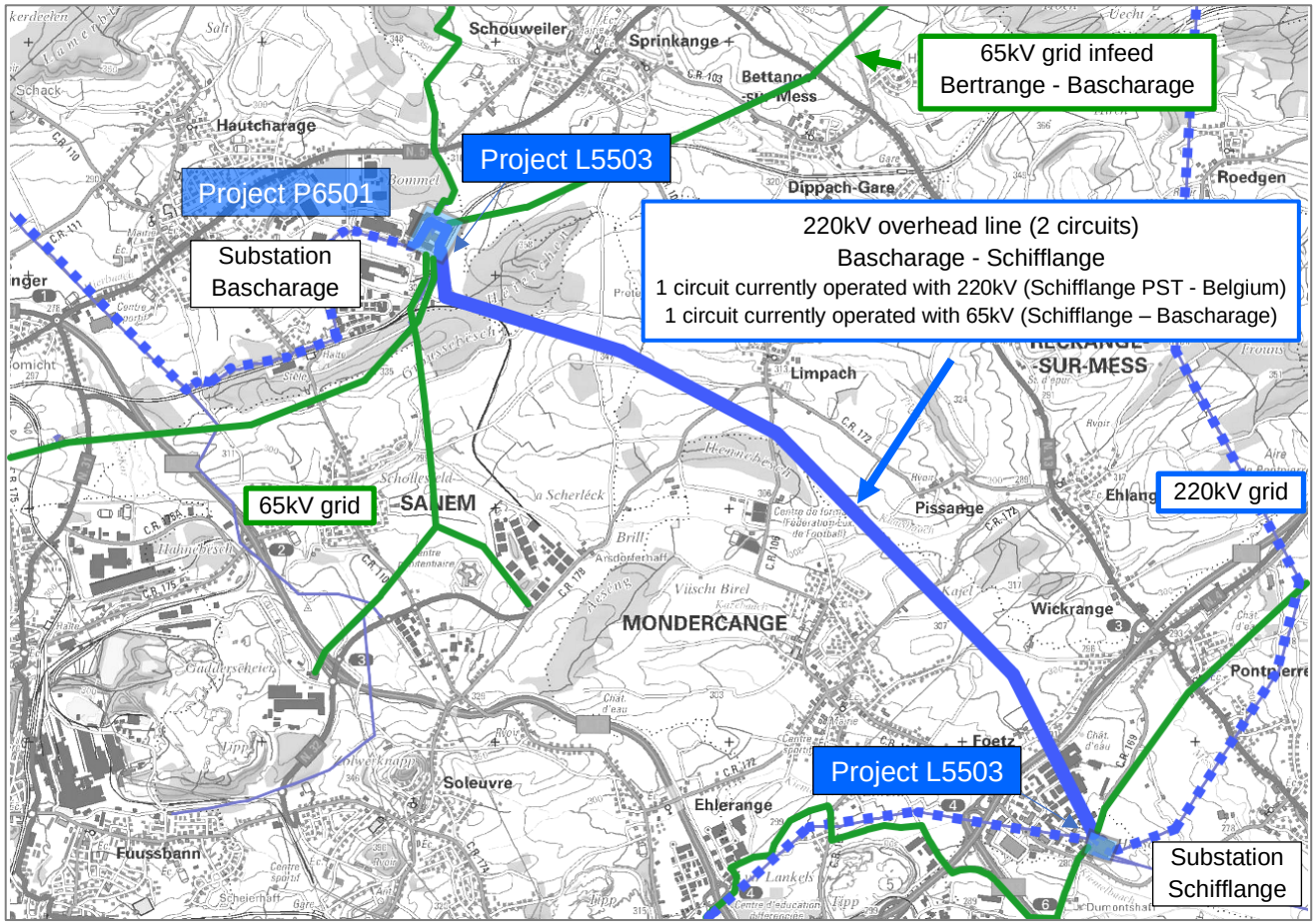
Timeline

2028 – 2029

Project L5503 - Background information and project details

It Is intended to use one circuit of the existing overhead line Bascharage – Schifflange already built for a voltage level of 220kV – to supply the substation Bascharage with 220kV in the future. This overhead line is equipped with two line circuits; one circuit is currently operated with 220kV and used for the 220kV connection with Belgium, the other circuit is operated with 65kV and used to partly supply the substation Bascharage (currently 65/20kV).

For a future operation with 220kV, the circuit currently operated with 65kV has to be connected to 220kV switchgear at the substation Schifflange and to the projected 220kV section at the station Bascharage. It is planned to use this circuit as a stub line connection with only one 220/110-65kV transformer. Grid calculations have shown that the existing and planned 65/110kV grid infrastructure will be sufficient to guarantee the security of supply in case of a major failure of that stub line and of the transformer or during maintenance.



Project P4301: 380/220/110-65kV substation Bertrange

Location

Objective(s)

The objective of project P4301 is to build an additional 380kV substation in the south of Luxembourg (extension of current station Bertrange, if possible) to ensure the supply of future electrical energy in that region and to guarantee the security of supply. It is expected that future electricity needs will rise significantly in the south and central part of the country. The created grid capacity will also facilitate the energy transition.

A transformation to the voltage levels 220kV and 110-65kV is necessary so that the existing grid infrastructures on those voltage levels can be used as effectively as possible to distribute the future electrical energy and to integrate the projected electricity generation.

Costs

~ 61 million EUR*
(380kV - 220kV)

~ 37 million EUR*
(110-65kV - 20kV)

** Provisional cost assessment, may be subject to revision*

Description

It is planned to extend and modify the existing 220/65/20kV substation Bertrange to connect the 380kV transmission grid to the 220kV grid infrastructure and the 65kV (later 110kV) regional meshed grids.

It is projected to build the extension of the substation Bertrange with 380kV air-insulated busbars and switchgear, and 4 high voltage transformers in total (2x 380/220kV transformers and 2x 380/110-65kV transformers). If possible, it is also intended to use air-insulated equipment for the 220kV and the 110kV switchgear. This project also includes the works on 380kV and 220kV voltage level to correctly connect 2 circuits of the 380kV overhead line Bofferdange – Bertrange and 2 circuits of the 220kV overhead line Bertrange – Schifflange to the substation.

The indicated costs 380kV – 220kV include the 380kV and 220kV equipment, the related transformers and the 220kV / 380kV grid connections of the substation Bertrange. A detailed plan of the modification/extension and modernization of the substation Bertrange has not yet been drawn up.

Timeline

2030 – 2035

Preliminary project L4101: 380kV overhead line Bofferdange / Bertrange - Niederstedem

Location

Objective(s)

The primary objective of this project would be to increase the transmission capacity of the overhead lines between the northern country border near Vianden and the stations Bofferdange/Bertrange, to ensure the security of supply of Luxembourg in the long term in case of a major unavailability of the 380kV connection Aach - Bofferdange.

The target is to create a fail-safe grid connection of high capacity, a resilient and future-proof grid connection of Luxembourg to the 380kV European grid infrastructure. The connection to the European 380kV transmission grid represents an important element to enable the Energy Transition and the European energy policy objectives.

Costs

N / A

Description

The overall concept would be to build a new cross-border 380kV high voltage infrastructure leading from the station Niederstedem in Germany to the stations Bofferdange and Bertrange, to replace the existing 220kV overhead line between Bauler (DE) and Heisdorf, which was originally set up in the 1970's and 1980's. The preliminary project L4101 would be limited to the infrastructure on national territory and would start from the country border near Vianden up to the intersection point with the planned 380kV overhead line project L4602 Bofferdange – Bertrange, near the locality of Prettingen.

While the preliminary project L4101 has not yet undergone detailed planning, an estimated length of approximately 35km for the projected overhead line within potential line corridors can be anticipated. It is likely that lattice steel pylons of the 'Danube' design will be used. It is intended to equip the pylons with 2 AC circuits (1 circuit per side) isolated for a voltage level of 380kV. One AC circuit will be composed of 3 phases and each phase will consist of 4 conductors. It is projected to use aluminium-steel composite conductors with a section of 550mm^2 and a maximum operating temperature of 80°C (norm designation: 550-AL1/71-ST1A). Project commissioning is anticipated for the year 2037.

Preliminary timeline

2033 – 2037/38

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