Strategic Grid 2040

Grid planning at Swissgrid

swissgrid

Contents

1 Executive summary

1 Executive summary

The continuous further development of the Swiss transmission grid and coordination with other grid operators are key statutory tasks for Swissgrid[1]. They will allow Swissgrid to continue to help implement the energy strategy and to ensure a secure, high-performance and efficient supply of electricity in the coming decades.

As part of the Strategic Grid 2040 project, by 2024 Swissgrid will prepare and publish long-term grid planning for the target year 2040. The legal basis was set out in the new Federal Act on the Renovation and Expansion of the Grids (Electricity Network Strategy) and established in Art. 9a–d of the Electricity Supply Act (StromVG; SR 734.7).

It is intended that the Federal Council will approve the Scenario Framework Switzerland (SZR CH) prepared by the Swiss Federal Office of Energy (SFOE) in autumn 2022 following a public consultation.

Swissgrid and the distribution system operators on the transmission grid (extra-high-voltage distribution grid, grid level 3) regionalise the national requirements set out in the SZR CH on the grid nodes of their grids. Following the approval of the SZR CH by the Federal Council, Swissgrid has nine months, in accordance with Art. 9d, para. 1 of the Electricity Supply Act, to determine the grid expansion requirements for the transmission grid, i.e. the Strategic Grid, and to submit these to Federal Electricity Commission (ElCom) for review. The ElCom must notify Swissgrid in writing of the result of the review within nine months of submission (Art. 22 Para. 2bis StromVG). Swissgrid then publishes its Strategic Grid.

This process is repeated every four years.

This document defines how Swissgrid approaches long-term grid planning. It sets out the objectives of grid planning, the framework conditions and the main principles of grid planning. These form the guardrails for the planning process, both now and in the future.

Sustainable, resource-saving, environmentally friendly and economically efficient grid planning is important to Swissgrid. The grid of the future should be stable and secure to operate. Grid expansion is not carried out to create advance capacity, but on the basis of comprehensible and transparent considerations. Swissgrid involves all affected stakeholders in its grid planning and communicates transparently and comprehensibly. This ensures coordinated expansion planning whilst avoiding parallel investments and blind spots. This document («Grid planning at Swissgrid») is published on the Swissgrid website and updated as necessary.

1.1 Structure of the document

This document is divided into the following sections.

Section 2 serves as an **introduction**. It outlines the objectives of this document, summarises the history of long-term grid planning in Switzerland, and describes the regulatory framework in Switzerland and Europe.

Section 3 provides an overview of the **grid planning process**.

Section 4 contains the **objectives for the grid planning process**, the relevant **framework conditions** and the **planning principles**.

Section 5 provides an overview of the **process for establishing the Strategic Grid.** The individual steps are described in the following sections.

Section 6 describes the **scenarios** that form the basis for long-term grid planning and the regionalisation process used to distribute the values set for Switzerland to the individual grid nodes of the transmission grid.

Section 7 describes the **start grid**, which forms the starting point for Swissgrid's grid planning.

Section 8 describes the process for forming the **reference grid**, in which future grid congestion is avoided by adding grid projects to the start grid. Potential congestion is identified by applying scenarios or carrying out stress tests.

Section 9 describes the process of **target grid formation**. A multi-criteria cost-benefit analysis is used to examine whether each additional grid project is really necessary. The target grid may therefore not include all additional grid projects from the reference grid. Swissgrid refers to the sum of the additional grid projects of the target grid as the «Strategic Grid 2040».

Section 10 contains the glossary and a list of abbreviations.

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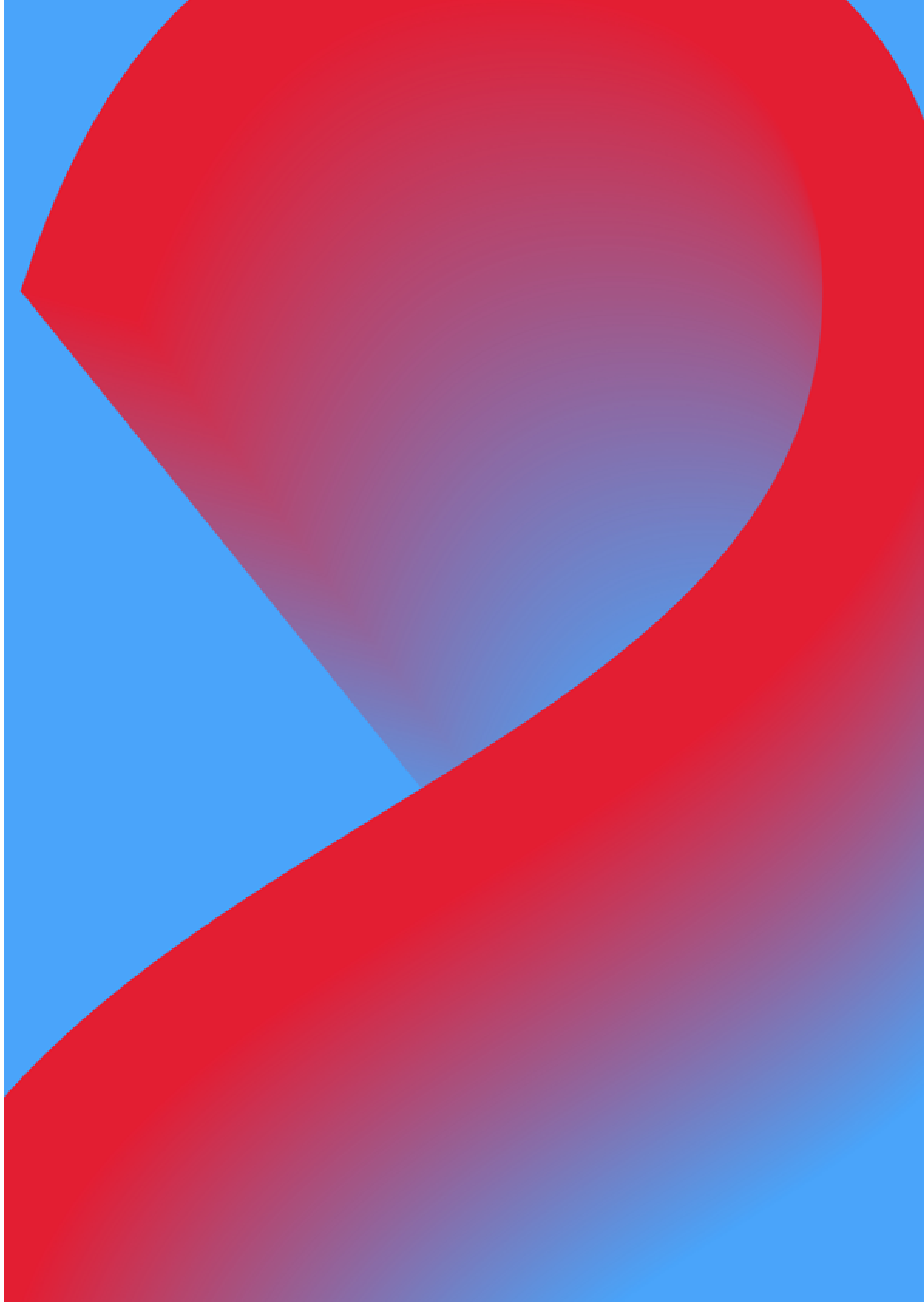
[1] Cf. Electricity Supply Act art. 8, para. 1 and art. 9a–d.

2 Introduction



2.1 History of strategic grid planning in Switzerland

The Strategic Grid 2040 is the third coordinated process for the further development of the Swiss transmission grid. For the first time, it takes into account the legal basis established in the «Electricity Network Strategy», according to which the planning process must be repeated in a comparable manner every four years.

The first two projects to determine the Strategic Grids 2015 and 2025 differed significantly from the current solution.

- In 2008, the planning process for the Strategic Grid 2015 was carried out separately by the eight former owners of the transmission grid[2].
- 2015 was the first year that Swissgrid planned the Strategic Grid 2025 on its own. At the time, Swissgrid created the scenarios itself. This will be a task for the SFOE for the first time in the Strategic Grid 2040[3].

Figure 1 summarises the development of the transmission grid planning processes in Switzerland.

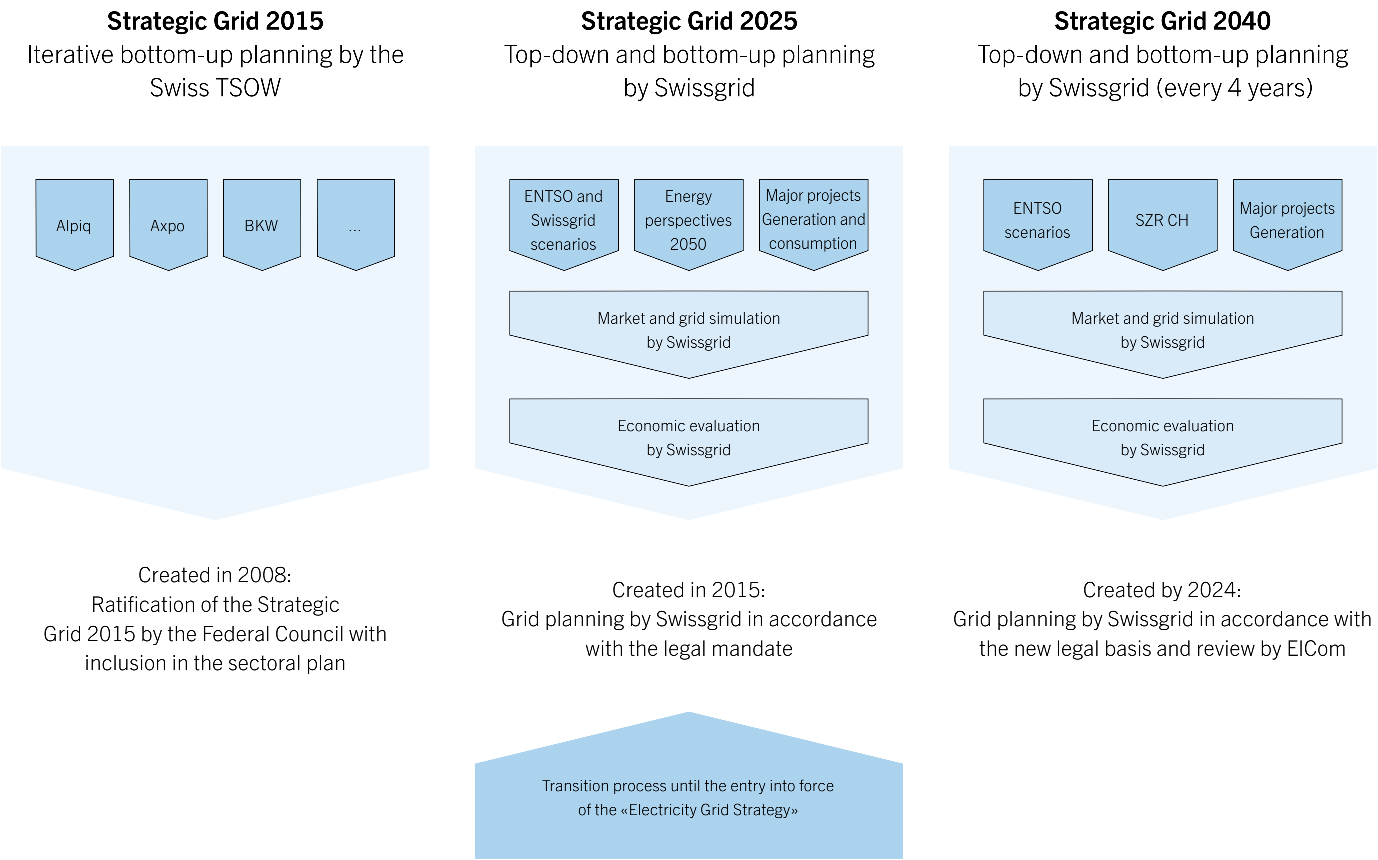


Figure 1 – The transmission grid development process in transition

2.2 Regulatory framework

2.2.1 Regulatory requirements in Switzerland

According to Art. 8, para. 1 of the Electricty Supply Act, the grid operators are responsible for ensuring a secure, high-performance and efficient grid.

With the gradual entry into force (2019–2021) of the provisions of the Federal Act on the Renovation and Expansion of the Grids («Electricity Network Strategy»), the grid planning process is now additionally regulated by law (Art. 9a–d of the Electricity Supply Act).

The Scenario Framework Switzerland (SZR CH) is merely a basis for the grid planning of grid levels 1 to 3. Swissgrid and the distribution system operators on the transmission system (DSOs on the TS) make numerous assumptions for the regional implementation of the requirements of the SZR CH as part of the regionalisation process. Swissgrid makes further assumptions when modelling the use of power plants/storage systems and flexibility (demand-side management, demand-side response). For the purpose of grid planning, Swissgrid relies on the assumption that the future regulatory framework conditions will ensure that generation and consumption develop within the framework established by the SZR CH.

Swissgrid is obliged to cooperate with foreign transmission system operators (TSOs). It must also represent Switzerland in the relevant bodies (Art. 20, para. 2e of the Electricity Supply Act). Grid planning and the Strategic Grid must be coordinated internationally. This coordination is ensured by Swissgrid's membership of European Network of Transmission System Operators for Electricity (ENTSO-E) and via bilateral coordination and joint grid studies with directly neighbouring TSOs.

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[2] Report by the Transmission Lines and Security of Supply working group of 28.02.2007: https://bhlaw.ch/wp-content/uploads/2018/08/Schlussbericht_AG_LVS_BFE_2007_Merker_d.pdf

[3] Swissgrid report on the Strategic Grid 2025: https://www.swissgrid.ch/dam/swissgrid/projects/strategic-grid/sg2025-brochure-en.pdf

2.2.2 Regulatory requirements in Europe

The EU Regulation 943/2019 on the internal market[4] in electricity mandates ENTSO-E in Art. 30 (1) lit (b) to «adopt and publish a non-binding Union-wide ten-year network development plan biennially»: this is the TYNDP (ten-year network development plan).

The TYNDP process is divided into eight steps. These are shown in Figure 2 below.

Framework conditions
- Production development per technology
- Consumption trend per sector
- Climate targets

Scenario preparation
- Prepared by ENTSO-E and ENTSOG
- Review of future electricity and gas infrastructure needs
- Different stakeholders are involved

Market study
- Use of the ENTSO scenarios
- Use of production and cross-border capacities for load supply

Identification of System Needs (IoSN)
- Pan-European study analyses price differences between bidding zones
- Deduction of grid expansion requirements per border

Project list
- Projects submitted by TSOs and third parties (grid, storage systems, power plants)
- Additional projects based on the IoSN study

Formation of the reference grid
- Collection of projects to enhance the European transmission grid

Cost-benefit analysis
- Implementation for one or more scenarios
- Application of the TOOT method for reference grid projects

Publication
- Reporting and consultation
- Publication of the report
  - System requirements and list of grid projects with evaluation
  - Contribution towards achieving the energy targets

Figure 2 – Overview of the TYNDP process

> **The transmission grid is an important pillar of the Energy Strategy 2050. It is developed and optimised on a regular basis as part of a coordinated process.**

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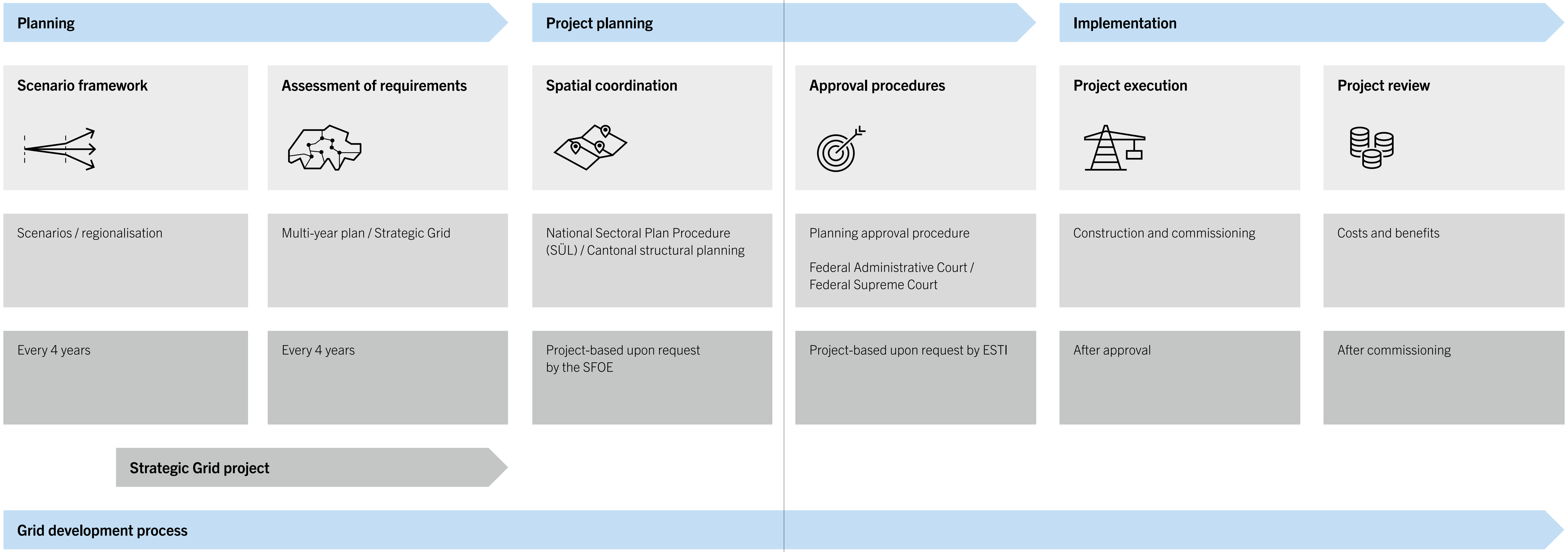
[4] This regulation from the Clean Energy Package is a further development of the EU regulation 2009/714.

3 Overview of the grid development process



Planning		Project planning		Implementation	
Scenario framework	**Assessment of requirements**	**Spatial coordination**	**Approval procedures**	**Project execution**	**Project review**
Scenarios / regionalisation	Multi-year plan / Strategic Grid	National Sectoral Plan Procedure (SÜL) / Cantonal structural planning	Planning approval procedure Federal Administrative Court / Federal Supreme Court	Construction and commissioning	Costs and benefits
Every 4 years	Every 4 years	Project-based upon request by the SFOE	Project-based upon request by ESTI	After approval	After commissioning

Figure 3 – Grid development process

Figure 3 shows the grid development processall the way from the planning to the realisation of grid expansion projects. In the planning phase, the Strategic Grid project determines the grid expansion requirements on the basis of the SZR CH approved by the Federal Council and the data on the local development of generation and consumption regionalised by the distribution system operators on the transmission system.

The «**project planning**» and «**realisation**» phases, in which grid projects are specifically planned, approved and built, are not part of the Strategic Grid project and are therefore not described in this document.

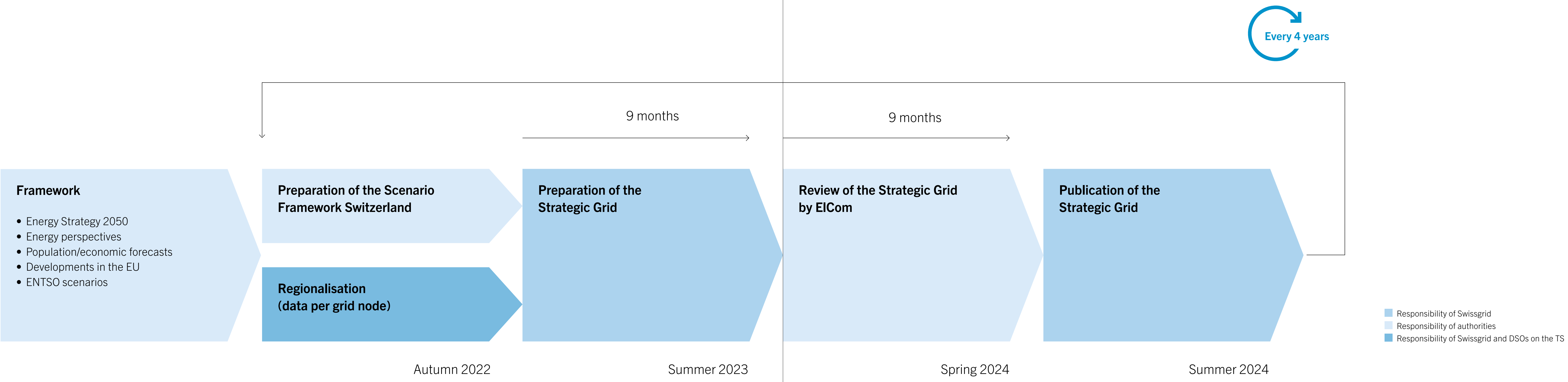


Figure 4 – Periodic preparation of the SZR CH and the Strategic Grid

Figure 4 illustrates the process for creating the Strategic Grid, which is repeated every four years

The SFOE prepares an **SZR CH** as the basis for grid planning of the transmission grid and of the extra-high-voltage distribution grids (NE1–3). The SZR CH is based on the energy policy objectives of the Federal Government and macroeconomic framework data, and takes into account the international environment (in particular the ENTSO scenarios). The SZR CH is approved by the Federal Council and represents a binding basis for the authorities (incl. ElCom) and Swissgrid as far as grid planning is concerned (cf. section 6).

The national targets set out in the SZR CH for the development of generation and consumption, separated according to technologies or consumer groups, are then regionalised by means of a **regionalisation process** developed by an industry working group.

The regionalisation process describes how the national key figures per parameter are distributed to the grid areas (supply regions) of the grid operators of grid level 3 (NE3) and subsequently to the grid nodes (NE1 and NE3), thus creating a usable (i.e. node-specific) data base for grid planning.

The grid operators at all grid levels coordinate their grid planning and make the necessary information available to each other free of charge. This includes, in particular, information on the existing grid, planned grid projects and forecasts regarding production and consumption. Swissgrid must above all take grid development at NE3 into account when planning the Strategic Grid.

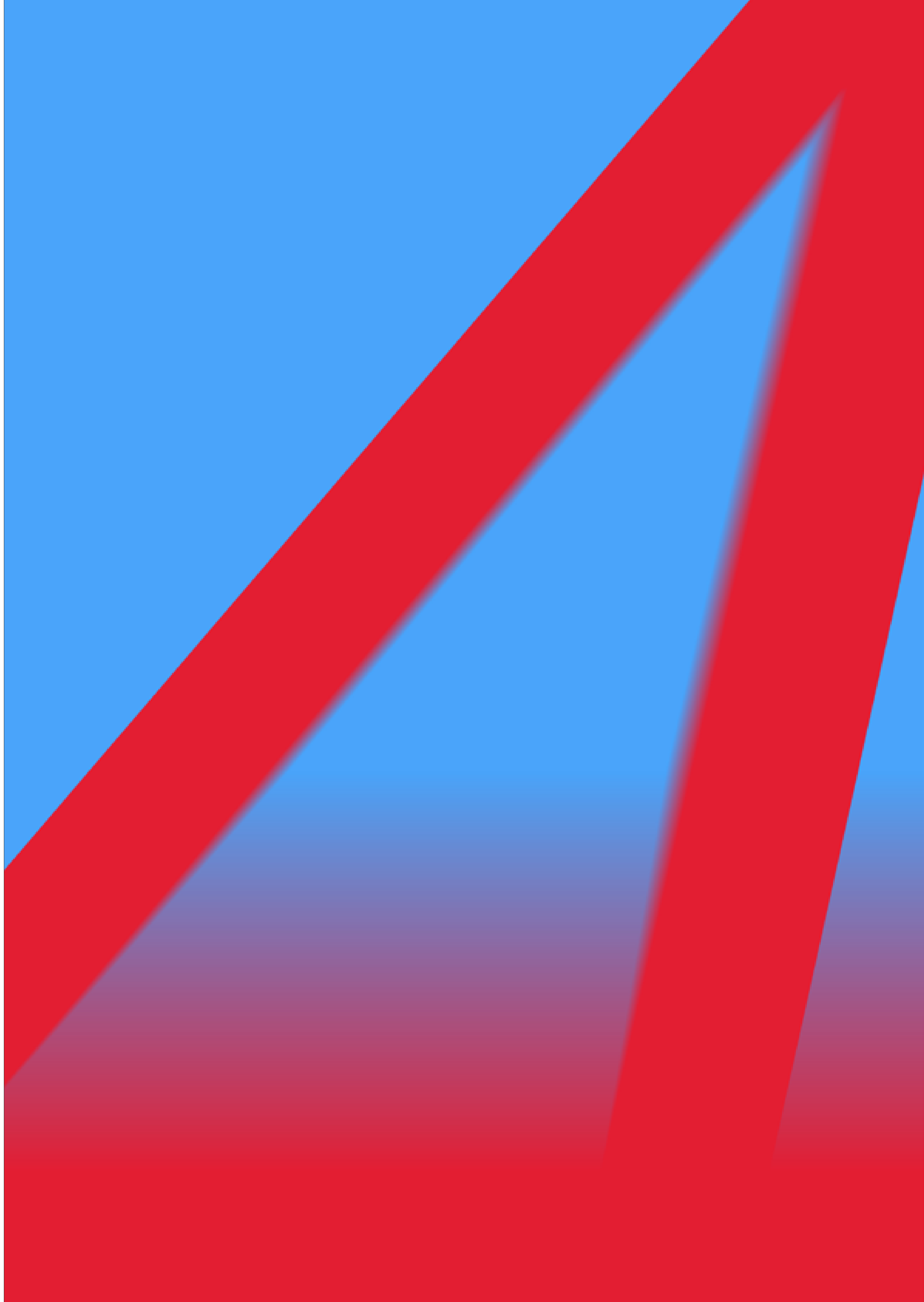
Based on the SZR CH and on the regionalised data derived from it, Swissgrid draws up the **Strategic Grid**. The Strategic Grid describes and provides the rationale for the planned grid projects for the period under review. The multi-year plan or the report on the Strategic Grid must be submitted to ElCom within nine months of approval of the SZR CH by the Federal Council.

ElCom reviews the Strategic Grid within the next nine months to determine whether the grid projects contained in it are effective and appropriate from a technical and economic perspective. If ElCom has any objections, adjustments are made to the Strategic Grid.

The reviewed Strategic Grid 2040 is subsequently **published** by Swissgrid by means of appropriate communication measures.

Every four years, this process begins again with an update of the SZR CH.

4 Objectives, framework conditions and planning principles for the Strategic Grid



4 Objectives, framework conditions and planning principles for the Strategic Grid

Figure 5 provides an overview of the main objectives, the framework conditions to be observed and the planning principles for the Strategic Grid project.

Goals of long-term grid planning

A robust, economically optimised grid ensures security of supply for different scenarios and forms the basis for the energy transition. During planning, attention is paid to resource conservation and minimal environmental impact.

Framework conditions for grid planning

Developments in generation and consumption in Europe and Switzerland are specified in the SZR CH.	The unclear relationship with the EU is leading to uncertainty regarding Switzerland's cross-border capacity and import possibilities.	The further development of grid operation and of operating facilities for load control increases the robustness of the future transmission grid.

Planning principles for the SN2040

Environmental impacts are minimised by the NOVA principle, infrastructure bundling, technology neutrality (cables, overhead lines) and the reduction of the number of substations.

Future grid congestion and voltage violations are avoided.	The flexibility of storage systems, generators and consumers will only be considered if it can be utilised.	Relevant stakeholders are involved in the grid planning process.
Dynamic grid stability must be ensured.	Grid projects will be implemented if they have a positive cost-benefit ratio.	The results are communicated in a transparent and comprehensible manner.

Figure 5 – Objectives, framework conditions and planning principles for the Strategic Grid

In order to achieve the objectives, knowledge of and compliance with the framework conditions are just as important as clearly defined planning principles, which form the guardrails for the grid planning process at Swissgrid.

The grid planning process is carried out on a statutory basis periodically every four years. The roles of the players involved are clearly defined. The process is made sustainable by documenting procedures, assumptions and results in detail. This improves the quality cyclically.

4.1 Objectives of strategic grid planning

A robust, economically optimised grid ensures security of supply for different scenarios and forms the basis for the energy transition.

This means that the Strategic Grid will be planned so robustly that it can cope with the challenges of the energy transition and so that a Swiss transmission grid that can guarantee security of supply will still be available in 2040. This objective is achieved with a solution that is optimised as much as possible from an economic perspective. To this end, Swissgrid takes a holistic view of the electricity system (market and grid) and finds sustainable, optimised solutions at reasonable costs.

Grid planning considers resource conservation and minimal environmental impact.

This means that the existing grid is used as efficiently as possible before grid expansion takes place (NOVA principle). It also means that conscientious, sustainable planning is an essential success factor to ensure the acceptance and thus realisation of the Strategic Grid. When implementing grid projects, Swissgrid endeavours to keep the impact on the population and the environment to a minimum. An assessment of how effectively this is achieved is carried out in the cost-benefit analysis (cf. Benefit Z4 in section 9).

4.2 Framework conditions for grid planning

Developments in generation and consumption in Europe and Switzerland are specified in the SZR CH.

In order to be able to successfully address future developments and challenges, an efficient transmission grid is needed that is adapted to these requirements. The following points should be noted:

- With its Energy Strategy 2050, Switzerland is aiming to decarbonise the economy and society as part of its climate goals (net-zero greenhouse gas emissions by 2050). Electricity consumption will continue to increase despite efficiency measures. Grid expansion planning is based on the SZR CH, which is subject to public consultation and has been approved by the Federal Council, and from which the future requirements for the transmission grid can be derived.

- According to the SZR CH, the supply of electricity in Switzerland should be ensured in the long term by a combination of decentralised, renewable production, hydropower, electricity imports and storage technologies[5]. Switzerland will continue to be dependent on electricity imports in the future, especially in the winter months. Swissgrid takes into account and evaluates the constantly changing framework conditions in Europe (e.g. the decentralisation of electricity generation, the phasing out of nuclear energy and coal, relations between Switzerland and the EU, energy crises, international conflicts), which influence the opportunities for importing energy from abroad.

- The three scenarios set out in the SZR CH contain different possible developments in terms of generation and consumption in Switzerland and Europe. In particular, the phasing out of coal and nuclear power will reduce export opportunities for Switzerland's neighbouring countries. One SZR CH scenario therefore envisages the construction of gas-fired power plants for Switzerland. Swissgrid assumes locations for these gas-fired power plants in consultation with ElCom and the relevant stakeholders.

The unclear relationship with the EU is leading to uncertainty regarding Switzerland's cross-border capacity and import possibilities.

The following points should be noted:

- Looking ahead to 2040, there is hope that Switzerland and the EU will find a way to work together for mutual benefit. The EU can benefit from Switzerland, which lies in the middle of Europe, as a transit country. No other country in Europe has a comparable number of cross-border lines and transit flows. Europe is important for Switzerland, both for the marketing of Swiss hydropower and for ensuring security of supply in winter.

- Swissgrid is an ENTSO-E member[6] and, as such, is integrated into the European grid development process. Switzerland uses the ENTSO scenarios for modelling development in other European countries.

- The implementation of the EU's «Clean Energy Package», which provides for the 70 % minRAM criterion and Flow-Based Market Coupling (FBMC), could have a negative impact on the usable cross-border capacity at the Swiss borders. It is therefore important for Switzerland to be fully reintegrated into the European processes as soon as possible[7]. During the transition period, Swissgrid and the neighbouring TSOs must find a way to involve Switzerland properly in the capacity determination process (e.g. by means of private-law agreements such as SAFA).

- It is uncertain how and when the Swiss borders will be integrated into FBMC capacity allocation. To take this into account, Swissgrid is assuming a minimum guaranteed transfer capacity for grid planning for 2030, while full integration into the FBMC is assumed for 2040.

- It is also uncertain what decisions the Federal Council will make in the next few years as a result of the unclear relationship with the EU. The consequences of these decisions for grid planning must be analysed and appropriate measures taken if necessary.

The further development of grid operation and of operating facilities for load control increases the robustness of the future transmission grid.

Grid operation is becoming even more efficient and secure, but also more complex and demanding, as a result of further developments in terms of forecasting, coordination, sensor technology, analysis technology, the use of new flexibility products and the controllability of electricity flows. The following points should be noted:

- Forecasts of supply-dependent electricity generation (PV, wind) and consumption are needed in order to be able to recognise electricity flows and possible grid congestion at an early stage. For this purpose, weather forecasts, which are already available today in very good resolution, must be linked with information on existing systems (output, location, orientation, etc.).

- Swissgrid will define its observability area by 2023 in association with foreign TSOs and Swiss DSOs. Shutdowns and switching operations are coordinated for the operating facilities in the observability area and real-time measured values are exchanged.

- Electricity flows, temperatures, line sag etc. will be measured in the future for heavily loaded lines. This will allow line capacity and any redispatching costs to be optimised.

- Flexibility products for consumers, generators and storage systems (integrated market, Equigy, etc.) are being created and used in a targeted manner.

- Operating facilities for load control and voltage maintenance (e.g. FACTS, PST, transformers with longitudinal and quadrature control) enable optimised use of the existing grid, e.g. by loading parallel lines as evenly as possible. This can also reduce active power loss. Large volumes of electricity can be transported over long distances in a targeted manner with HVDC lines. This technology would be suitable, for example, to connect large PV/wind farms abroad with pumped storage power plants in Switzerland.

In principle, it should be noted that the market configuration and regulatory framework conditions cannot be assumed to be constant. For example, there are currently no market-based incentives for seeking to ensure system security with an economically optimal solution (e.g. flexibility products). This may change in the next few years, which in turn may reduce the need for grid expansion.

Paradigm shifts due to a sharp rise in e-mobility or the sudden phase-out of nuclear energy etc. are conceivable. They must be addressed immediately. The approval of grid expansion projects takes at least 10 to 15 years. These different time factors must be taken into account when planning a robust grid.

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[5] The SZR CH assumes that nuclear power stations in Switzerland have an operational life of 50 years, which means that they will not contribute to electricity generation in the long term.

[6] Switzerland's exclusion from ENTSO-E cannot be ruled out. In such an eventuality, comparable contractual solutions need to be found in the interest of both parties to enable planning of the interconnected grid. This eventuality is therefore not considered in further detail here.

[7] Full integration requires an electricity agreement with the EU, which in turn requires a framework agreement or similar. It could take a good ten years to conclude such an agreement.

4.3 Planning principles for the Strategic Grid

Environmental impacts are minimised by the NOVA principle, infrastructure bundling, technology neutrality (cables, overhead lines) and the reduction of the number of substations.

- Swissgrid is not expanding the grid to create advance capacity. Swissgrid first uses the existing grid as efficiently as possible (through remedial actions), enhances it as required and only builds new lines if absolutely necessary. Lines that are permanently unnecessary are dismantled wherever possible (NOVA principle[8]).

- In principle, Swissgrid does not expand the grid for the purpose of allowing arbitrary decommissioning for maintenance and grid expansion work at any time. This principle may only be deviated from in justified cases, e.g. if secure grid operations cannot be guaranteed by means of temporary grid elements or redispatching measures.

- The bundling of transmission lines with trunk roads and railway lines[9] is intended to reduce the number of parallel routes in the long term. Swissgrid takes into account the results of the Federal Spatial Planning Conference and coordinates with the responsible federal offices (FEDRO, FOT), SBB and affected project partners (e.g. second Gotthard tunnel, Grimsel tunnel).

- Swissgrid takes into account the impact on space and the environment, technical aspects and economic viability when looking for the best line corridor and when selecting the transmission technology to be used. Swissgrid examines the overhead line and underground cable options for every grid project[10]. Both technologies have their advantages and disadvantages with regard to project planning, construction as well as operation and maintenance. The Strategic Grid project makes assumptions about the implementation option in order to be able to produce a cost estimate. The line corridor and transmission technology are not determined until later within the framework of the subsequent spatial coordination in the National Sectoral Plan Procedure.

- Compared to other countries, Switzerland has a large number of substations in a small area. One reason for this is that several large hydropower plants are located close together. As far as replacement investments are concerned, checks are carried out in coordination with the local DSOs to determine which substations can be merged or dismantled if necessary. This can lead to cost savings in the long term.

- An incorrect financial incentive in grid utilisation costs (basic tariff) is currently prompting DSOs to reduce the number of their TS connection points as much as possible. This reduces the security of supply and grid security of the DSOs and makes grid operation and maintenance at Swissgrid more difficult. The Confederation intends to delete the corresponding provision in the Electricity Supply Ordinance (StromVV). According to the dispatch on the consolidation legislation[11], this could take place in around 2025.

Future grid congestion and voltage violations must be avoided.

- With the help of the grid simulation, Swissgrid can see which grid elements will repeatedly experience n–1 or voltage violations in the future.

- It also examines whether there is congestion in current grid operations that was not shown by the grid simulation. These cases will also be taken into account if necessary.

- Existing and future congestion will be resolved by grid expansion measures if remedial actions are not possible, sufficient or more expensive than grid expansion.

- As Switzerland's cross-border grid is very well developed, most of the projects are expected to serve the expansion of the grid in Switzerland. A nationally robust grid forms a good basis for international electricity exchange.

- Grid expansion is driven by demand and serves to eliminate grid congestion, regardless of where it is located. This ensures a reliable supply of electricity in all parts of Switzerland.

Dynamic grid stability must be ensured.

- As a result of the dismantling of large thermal power plants in Europe, the rotating mass on the transmission grid is reduced, which makes ensuring dynamic grid stability more important.

- Therefore, the reference grid is tested for its dynamic stability by means of stress tests.

Grid projects are generally implemented if they have a positive cost-benefit ratio.

- For each grid project costing more than CHF 1.0 million, Swissgrid carries out and documents a uniform cost-benefit comparison.

- Benefit categories include: economic added value, reduced CO_2 emissions, improved integration of renewable resources, reduction of electric system loss and redispatching costs, increase in grid security/security of supply, reduction in environmental impact, resilience[12].

- Depending on the criterion, the benefit is shown in monetary, quantitative or qualitative terms.

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[8] The dispatch on the «electricity grids strategy» states the following: «The distinct measures that make up a grid project must be considered in their entirety. In specific grid projects, the NOVA principle has to be applied across the many distinct measures in such a way that it results in a sustainable and efficient solution. The grid planning principles based on the NOVA principle do not necessarily lead first to optimisation, then to enhancement and finally to expansion. In particular, environmental protection legislation may restrict the optimisation or enhancement of a grid by means of mandatory limit values, for example relating to non-ionising radiation or noise.»

[9] Cf. Bundling of transmission lines with trunk roads and railway lines (admin.ch).

[10] The choice of technology is based on the Evaluation System and Transmission Lines Manual issued by the Federal Office for the Environment.

[11] The dispatch on the consolidation legislation (cf. p. 49) states: «The roll-up of costs from the transmission grid (NE1) into the distribution grid (NE2–7) should no longer be in proportion to 30 % of the working tariff, 60 % of the power tariff and 10 % of the basic tariff, but in proportion to 10 % of the working tariff and 90 % of the power tariff.»

[12] The more scenarios that prove the need for a project, the greater its benefit.

A secure, efficient and sustainable energy supply is at the heart of the Strategic Grid.

The flexibility of storage systems, generators and consumers will only be considered if it can be utilised.

- Thanks to artificial intelligence, decentralised consumption control and smart peak shaving for PV/wind production, it is possible to reduce the load on both the local grids and the transmission grid.

- In grid planning, this potential is only taken into account if Swissgrid can actually use it at all times and on a permanent basis. To do so, regulatory framework conditions must be created and contracts concluded, which is not yet sufficiently the case today. From the current perspective, these options primarily serve to increase operational security, but rarely to reduce the need for grid expansion.

- Grid planning shows what flexibility would be required from consumers, power plants or storage systems in order to avoid a specific line project. On this basis, it can be examined whether the necessary flexibility can be reliably obtained by contract and at what cost, thus avoiding grid expansion.

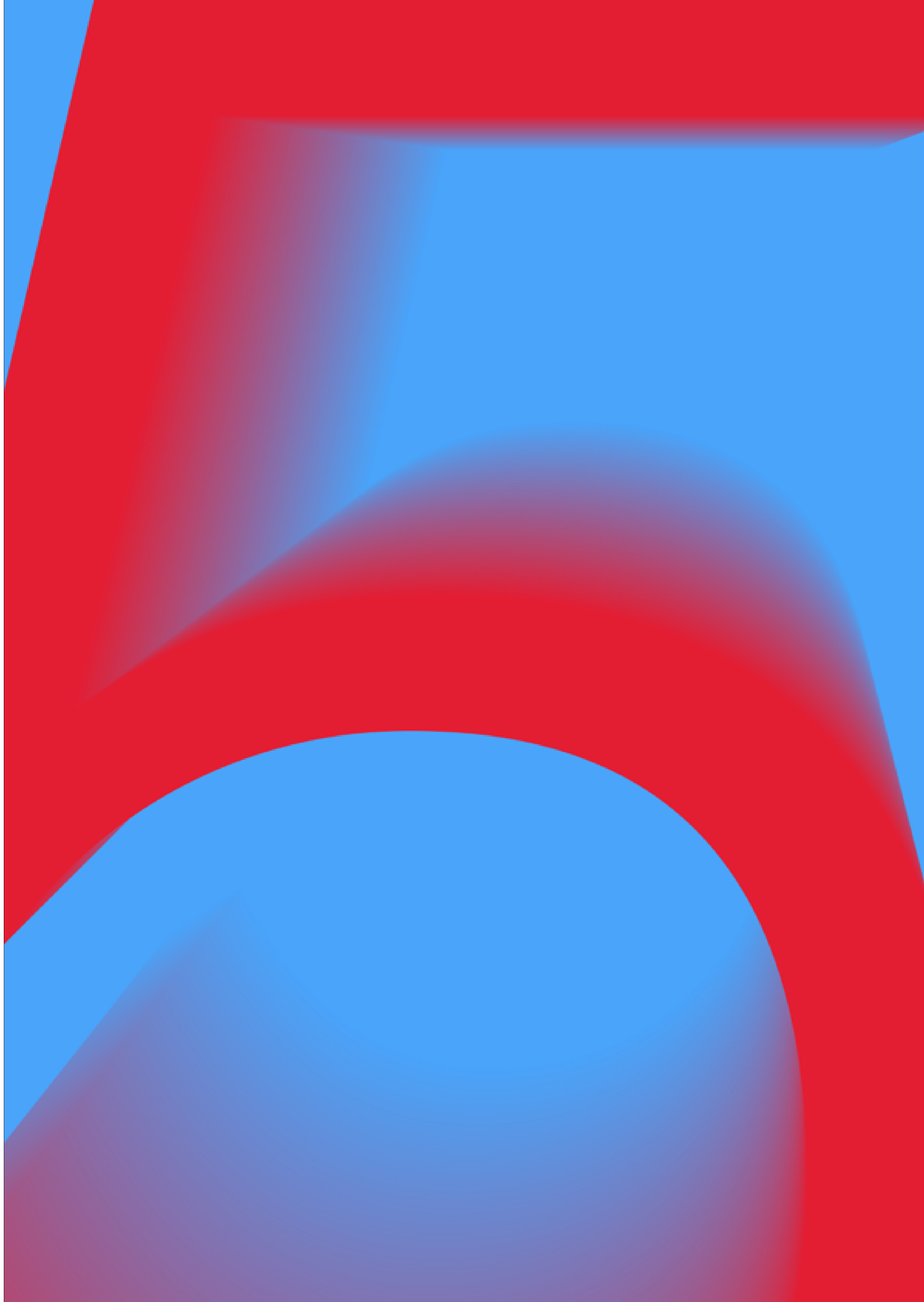
Relevant stakeholders are involved in the grid planning process and the results are communicated transparently and comprehensibly.

- Swissgrid coordinates the planning of the transmission grid with the planning of the transmission grids of neighbouring countries, the planning of the distribution grids and power plants on the Swiss transmission grid and the planning of the SBB high-voltage grid.

- Swissgrid works closely with partners from the industry and the authorities in defining the necessary data requirements, in regionalising the national requirements and in completing the implementation process.

- Swissgrid communicates information about the Strategic Grid and about the process for its establishment in a transparent and comprehensible manner.

5 Process for determining the Strategic Grid



5 Process for determining the Strategic Grid

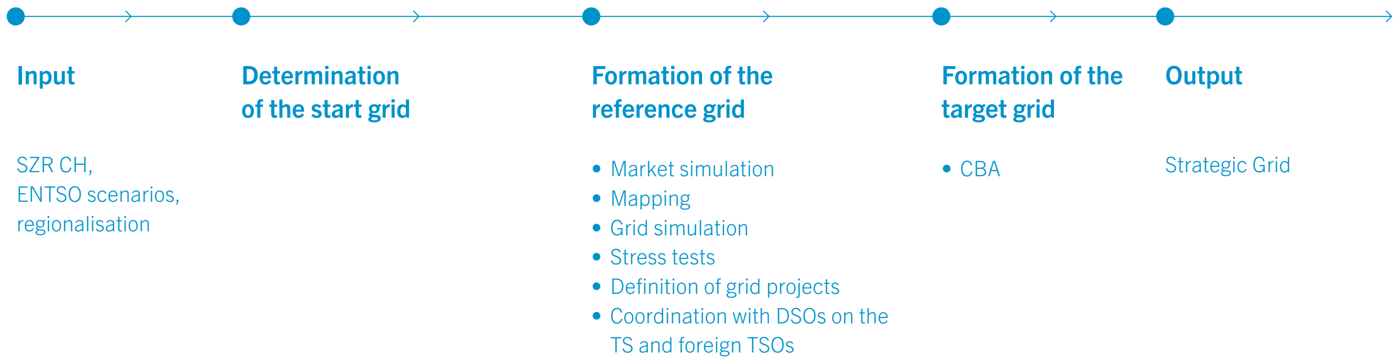


Figure 6 – Steps in the grid planning process

Figure 6 shows the steps that make up the grid planning process at Swissgrid.

The SZR CH[13] and the ENTSO scenarios[14] assigned in it are essential **input values** for the grid planning process. In addition, Swissgrid receives information on the development of generation and consumption within Switzerland from the regionalisation process from the distribution system operators (DSOs) and power plant operators (PPOs) that are directly connected to the transmission system (TS), as well as from SBB.

The **start grid** represents the starting point for the grid planning process. This European grid model includes all grid elements that are in operation today and that will still be in operation or will be put into operation by 2030[15].

Subsequently, with the help of market and grid simulations, as well as stress tests, the **reference grid** is formed by adding new grid projects to the start grid and coordinating them with DSOs on the TS and foreign TSOs.[16]

After the finalisation of the reference grid, the **target grid** is formed. With the help of the **cost-benefit analysis**[17], all additional grid projects in the reference grid are evaluated. In principle, only those projects where the benefits prevail will become part of the target grid. The totality of the additional grid projects in the target grid 2040 compared to the start grid forms the **Strategic Grid.**

> **The start grid represents the starting point for the grid planning process. This European grid model includes all grid elements that are in operation today and that will be put into operation by 2030.**

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[13] The SZR CH is approved by the Federal Council and is binding for the planning of the Strategic Grid. In this document, selected ENTSO-E scenarios are also declared as forming a binding basis for developments abroad.

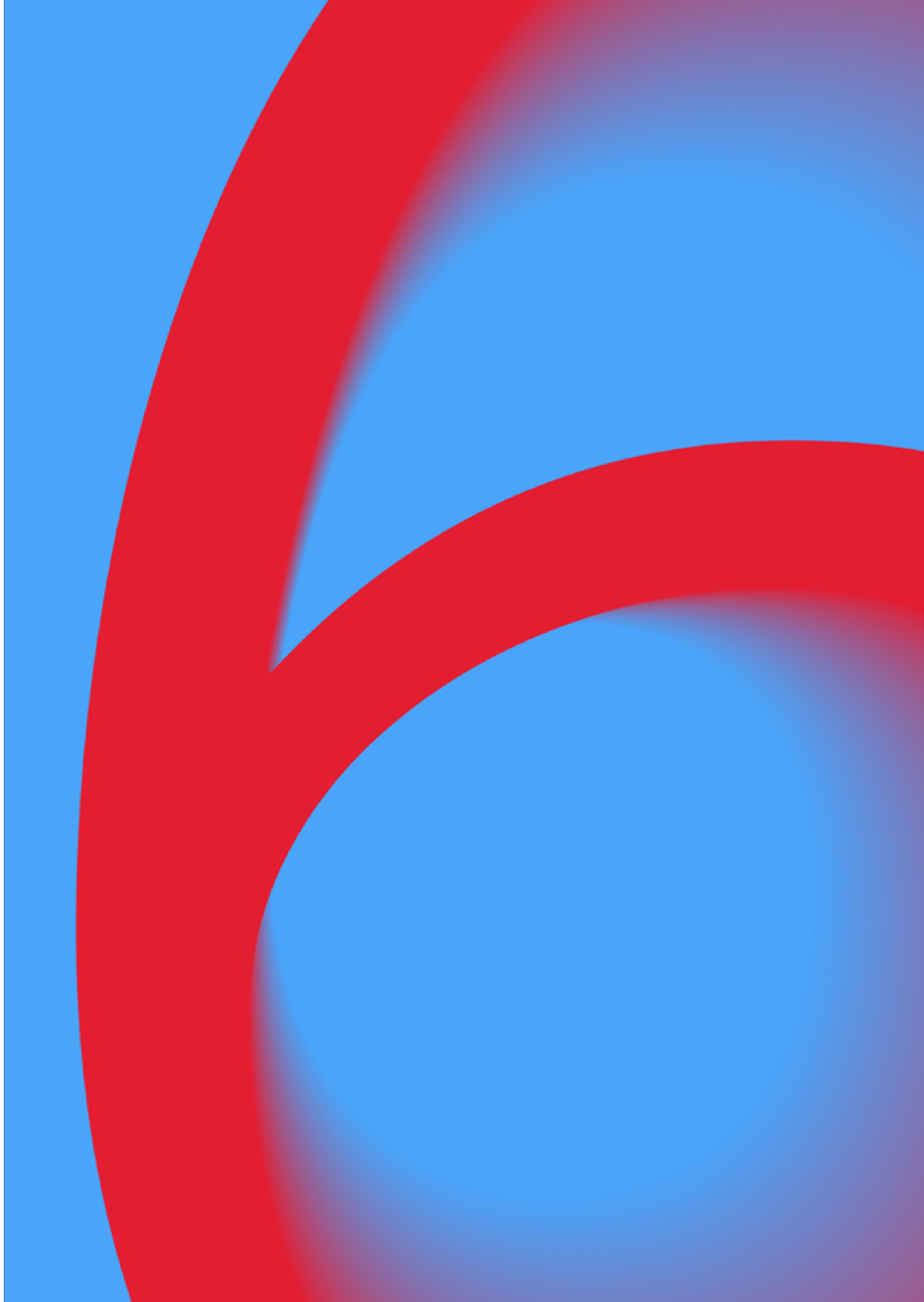
[14] ENTSO-E and ENTSO-G jointly develop the ENTSO scenario framework for electricity and gas in Europe every two years.

[15] Due to ongoing legal proceedings, some uncertainty surrounds this hypothesis.

[16] It is impossible to finalise this coordination in the space of nine months, particularly if joint studies are required.

[17] The cost-benefit analysis is based on the ENTSO-E document «Guideline for Cost Benefit Analysis of Grid Development Projects»

6 Scenarios and regionalisation



6 Scenarios and regionalisation

Input

SZR CH,
ENTSO scenarios,
regionalisation

Determination of the start grid

Formation of the reference grid

- Market simulation
- Mapping
- Grid simulation
- Stress tests
- Definition of grid projects
- Coordination with DSOs on the TS and foreign TSOs

Formation of the target grid

- CBA

Output

Strategic Grid

This section describes the national and European scenarios and their regionalisation, which form the external input variables for the subsequent grid planning process at Swissgrid.

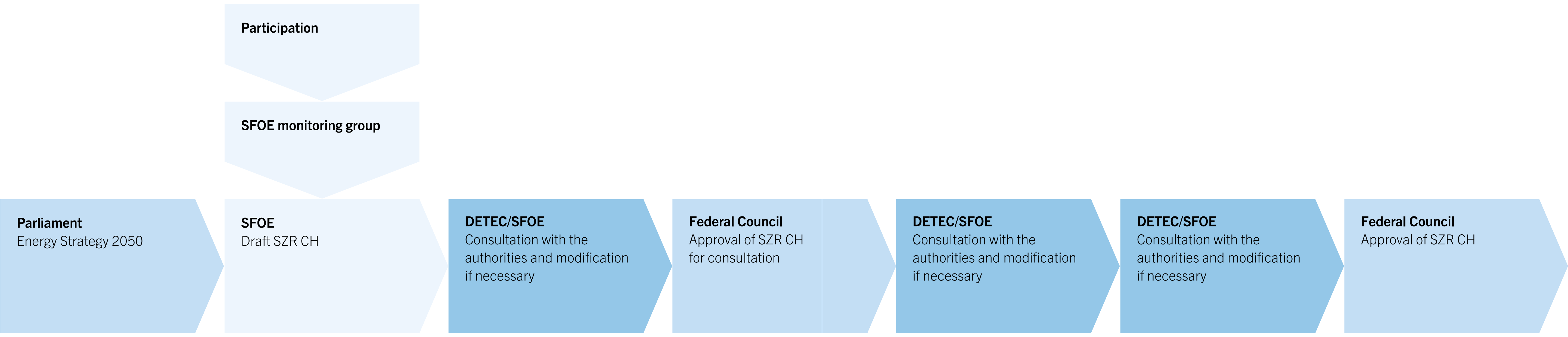


Figure 7 – The preparation and approval process for the SZR CH

6.1 Scenario Framework Switzerland

The SFOE prepares an SZR CH as the basis for grid planning of the transmission grids and extra-high-voltage distribution grids (NE1–3). The SZR CH is based on the energy policy objectives of the Federal Government and macroeconomic framework data, and takes into account the international environment (in particular the ENTSO scenario framework). The SZR CH is approved by the Federal Council and represents a binding basis for the authorities (incl. ElCom) and Swissgrid as far as grid planning is concerned.

When drawing up the SZR CH, the SFOE involves the national grid company, representatives of the distribution system operators, the cantons and other stakeholders (including PPOs, SBB, and trade and environmental associations, which together form a monitoring group). The SZR CH shows the range of possible energy industry developments (periods of 10 and 20 years). Figure 7 illustrates the preparation and approval process for the SZR CH.

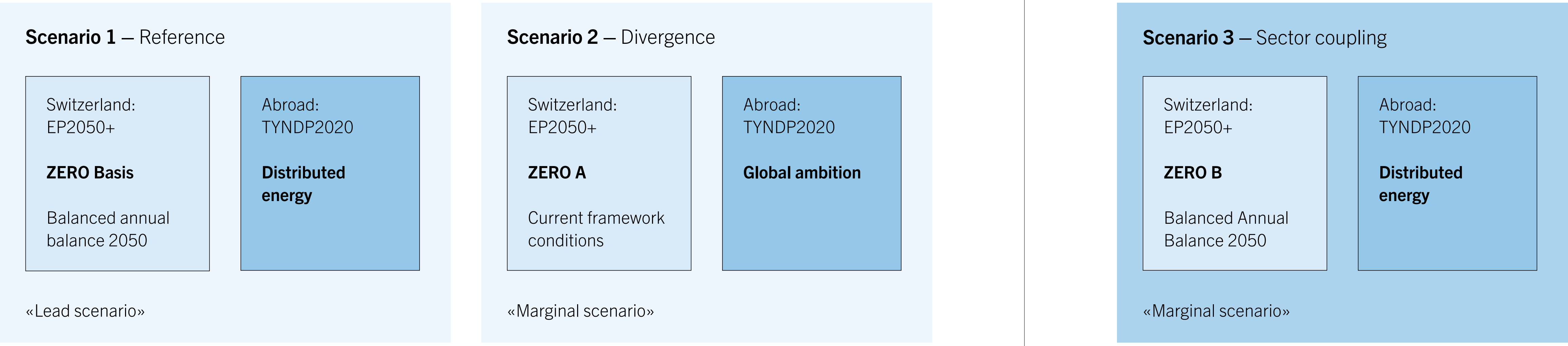
A scenario describes the potential development of the power generation mix and electricity consumption in Switzerland.

The SZR CH consists of a number of scenarios. According to Art. 9a, para. 3 of the Electricty Supply Act there are a maximum of three.

A scenario is not a forecast of the future. Each scenario describes a conceivable, coherent and possible future development. The probable future development envisaged by the policy must be within the area covered by the scenario framework. The greater the number of challenges in the different scenarios the Strategic Grid can cope with, the more robust is its planning.

The SZR CH, which forms the basis for the Strategic Grid 2040, comprises three scenarios. All three scenarios are based on the Energy perspectives 2050+ (EP2050+)[18] published by the SFOE in November 2020 and with the goal of net-zero greenhouse gas emissions by 2050. The target years for the first scenario framework are 2030 and 2040. The scenarios published by the European Transmission System Operators for Electricity and Gas (ENTSO-E and ENTSOG) form the basis for developments abroad.

The scenarios differ in terms of the power plant park and consumption. The scenarios set out in the SZR CH were linked to two ENTSO scenarios (cf. figure 8). Swissgrid can therefore take the data for Switzerland from the SZR CH and the data for European countries from the ENTSO scenarios assigned in each case.



All three scenarios are compatible with the net-zero goal to be achieved by 2050.

Figure 8 – The SZR CH

According to the SFOE, **scenario 1, «Reference»**, is the lead scenario that is to be given priority in grid planning. It is based on the «Balanced Annual Balance 2050» alternative from the «ZERO Basis» EP2050+ scenario. It is characterised by strong electrification of the energy system and a rapid expansion of domestic, renewable electricity generation.

Development in Europe is based on ENTSO's «Distributed Energy» scenario. This assumes a large number of distributed generation systems in Europe.

Scenario 2, «Divergence», is based on the «Current framework conditions» alternative from the «ZERO A» EP2050+ scenario. It is characterised by an even stronger electrification of the energy system than in the «ZERO Basis» scenario, combined with a limited expansion of domestic, renewable electricity generation. This combination leads to a high load on the grids, especially from imports, making it a «load scenario».

For Europe, reference is made to ENTSO's «Global Ambition» scenario, which includes a greater number of centralised large generating plants. The associated increased long-range load flows also lead to higher loads on the transmission grid.

Scenario 3, «Sector coupling», is based on the «Balanced Annual Balance 2050» alternative from the «ZERO B» EP2050+ scenario. It is characterised by weaker electrification of the energy system than in the «ZERO Basis» scenario and a greater use of biogas and synthetic gases for power generation, as well as gas-fired power plants (reserve power plants that can feed power into the grid at short notice if required) that will be operated with mostly imported hydrogen in the long term. Lower demand for electricity and higher domestic electricity generation decrease the load on the grids.

Like scenario 1, it is combined with ENTSO's «Distributed Energy» scenario.

The cross-border capacities (NTC values) agreed with the neighbouring countries for the year 2025 are assumed uniformly for all scenarios in the SZR-CH. If Swissgrid recognises in the course of its analyses that an increase in cross-border capacities is necessary, Swissgrid would discuss the associated projects with the foreign TSOs and justify their necessity to ElCom.

All three scenarios are used to create the reference grid. The evaluation of the projects using the CBA methodology (cf. section 9), on the other hand, is only carried out for the «Reference» lead scenario, as this is assumed to be the most likely scenario in the SZR CH.

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[18] Energy perspectives 2050+ (admin.ch)

6.2 Regionalisation in Switzerland

The SZR CH contains aggregated data at national level for the different types of power plants, storage systems and consumers for three scenarios for the years 2030/40. The aim of regionalisation is to determine the change per parameter, per grid node of NE1 and 3. This creates the data basis necessary for grid planning.

Possible methods of regionalisation are described in the SFOE document «Regionalisation guidelines». The SFOE guidelines are not part of the SZR CH and are not legally binding. Specific arrangements for regionalisation remain under the responsibility and jurisdiction of the relevant grid operators.

Swissgrid and the DSOs have coordinated the regionalisation implementation process in an industry working group. The jointly prepared document «Grid planning data for the Strategic Grid 2040» describes the regionalisation as carried out in 2022.

The SFOE guidelines distinguish between four principles for regionalisation. The description of these principles can be found in figure 9.

Installed capacity	Principles	Description
≥ 10 MW	**A** No regionalisation	• Location and capacity are known. • Decommissioning/increases in capacity and additional capacity of new plants per grid node are subject to compliance with the following principles by energy producers, storage system operators and large users: – Notification of the grid operator to whose grid the system is/will be connected. – No consideration during grid planning without notifications and construction permits. – Construction permits and grid connection applications must be submitted by a deadline published by the grid operator.
< 10 MW	**B** Existing locations	• The regional key figure for capacity development can be distributed to existing plant locations in proportion to the capacity already installed.
	C Potential areas	• The regional key figure for capacity development cannot be linked to specific existing plant locations, as there are still too few or unevenly distributed locations or no locations at all. • Potential areas are identified on the basis of additional information. The capacity increase is distributed to the grid nodes that are located in the potential areas.
	D Nationwide development	• Regional development takes place proportionally per grid region or grid node, e.g. according to population change or economic development. • Also suitable for nationwide new constructions for which no specific locations/potential areas are available.

Figure 9 – Principles for regionalisation according to the SFOE guidelines

Figure 10 contains the various parameters of the SZR CH and the principles for regionalisation recommended per parameter in the SFOE guidelines. In the case of photovoltaics, the SFOE guidelines in the text also consider that a combination of principles C and D would make sense.

Utility power generation	Principle
Run-of-river power stations	A
Storage power plants	A
Pumped storage power plants	A
Small hydropower plants	B or C
Nuclear power plants	A
Combined power plants	A
Waste incineration	A and B or D
Other thermal power plants	A and B or D
Biomass (wood)	A and B or D
Biogas power plants	A and B or D
Wastewater treatment	B or D
Geothermal energy	A
Photovoltaics	D
Wind power	C

Storage system	Principle
Pumped storage power plants	A
Decentralised batteries	D
Electricity consumption	
Conventional consumption	D
• Household sector	
• Industry sector	
• Services sector	
• Transport sector	
Electric mobility	D
Heat pumps	D
Power-to-X plants	A
Carbon capture plants	B
Supply pumps	–

Figure 10 – Regionalisation methods per parameter according to the SFOE guidelines

Figure 11 gives a rough overview of how the target values per grid node, and thus the basis for grid planning, are determined according to the data in the SZR CH, the data in the SFOE guidelines, any cantonal specifications and data collected from existing and planned plants.

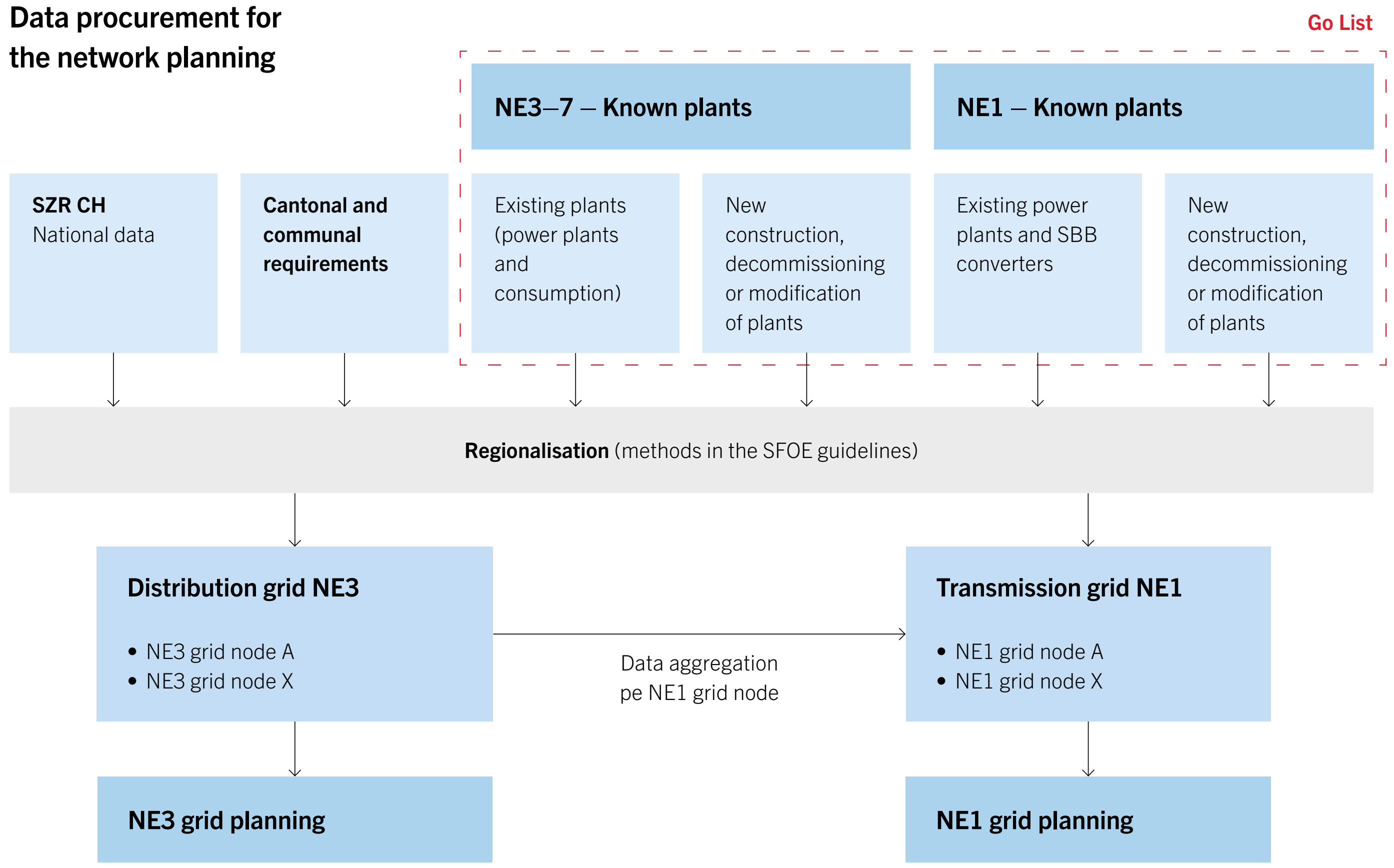

Figure 11 – Overall process for the provision of data for grid planning incl. the regionalisation process

During the regionalisation process, the national target values from the SZR CH are distributed to the grid nodes by Swissgrid and the DSOs on the TS. For each parameter and scenario, the value to be regionalised is the difference between the target value in the SZR CH and the total of all existing plants, plus any plants that are certain to be realised from a current perspective.

The DSOs on the TS coordinate with each other and with downstream DSOs in the registration of existing plants, the identification of planned plants and, as part of regionalisation, the recognition of any remaining expansion requirements for which no specific projects currently exist.

The DSOs on the TS transmit to Swissgrid per grid node NE1 the data for the current plant park per type of plant together with the data for the assumed plant park in the target years 2030/40[19]. The DSOs on the TS also use the data transmitted to Swissgrid for their own NE2–3 grid planning. It is crucial that NE1–3 are planned on the basis of the same assumptions.

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[19] The number of plants in the target years is obtained by adding planned projects and the regionalised values to the current number of plants and then subtracting the number of plant closures.

In general, it should be noted that within the framework of regionalisation, Swissgrid and the DSOs on the TS make assumptions regarding the locations at which the additional power plants that are to be built according to SZR CH are likely to be constructed. For each power plant type, there is a specific methodology for regionalisation, which is based on the proposals in the SFOE guidelines (cf. figure 10). The assumptions for large power plants, which are to be regionalised according to Principle A, are particularly relevant. The initial situation is as follows:

The SZR CH envisages the expansion of large hydropower plants in all three scenarios, as well as the construction of large gas turbines in scenario 3 with a connection to the transmission grid, without naming specific locations and outputs of the power plants.

- **Storage power plants (+750 MW):** According to the SZR CH, 750 MW are to be installed in new storage power plants. In the analysis of the potential of hydroelectric power, storage water projects are listed with a probability of implementation and without an electrical output. On 18 August 2020, Federal Councillor Simonetta Sommaruga convened the «Hydropower Round Table», which signed a declaration on 13 December 2021 naming 15 hydropower plant projects in five cantons that should be implemented as a priority in order to realise additional electricity generation of 2 TWh by 2040 (link: Press release).[20] Note: The additional energy is obtained by adding the drainage from further regions to the power generation. The construction of new power plant output is only partly associated with this. Existing plants are used to generate some power, whilst at the same time increasing the storage volume by raising dams – data for any increase in output is collected by the grid operators per connection point during the project planning stage.
- **Pumped storage power plants (+3,000 MW):** The focus is on five specific projects. Nant de Drance and Ritom II are being commissioned. The implementation dates for Grimsel 1E, Grimsel 3 and Lago Bianco have not yet been finalised.
- **Gas-fired power plants (+2,500 MW):** The output of the gas-fired power plants could be between 250 and 500 MW per plant. Specific locations are still unclear.

Swissgrid assumes the following:

- Grid planning is only based on the specific gas/storage hydropower plants that are considered likely to be implemented. This means that the target outputs for these two technologies according to the SZR CH will not be achieved. The background to this is that regionalisation makes sense for small power plants (PV, wind, etc.), while it harbours the risk of stranded investments for large power plants.

Swissgrid holds talks with potential power plant investors to find out whether they believe in the implementation of the respective power plant projects and which output increases they are planning at which grid nodes.

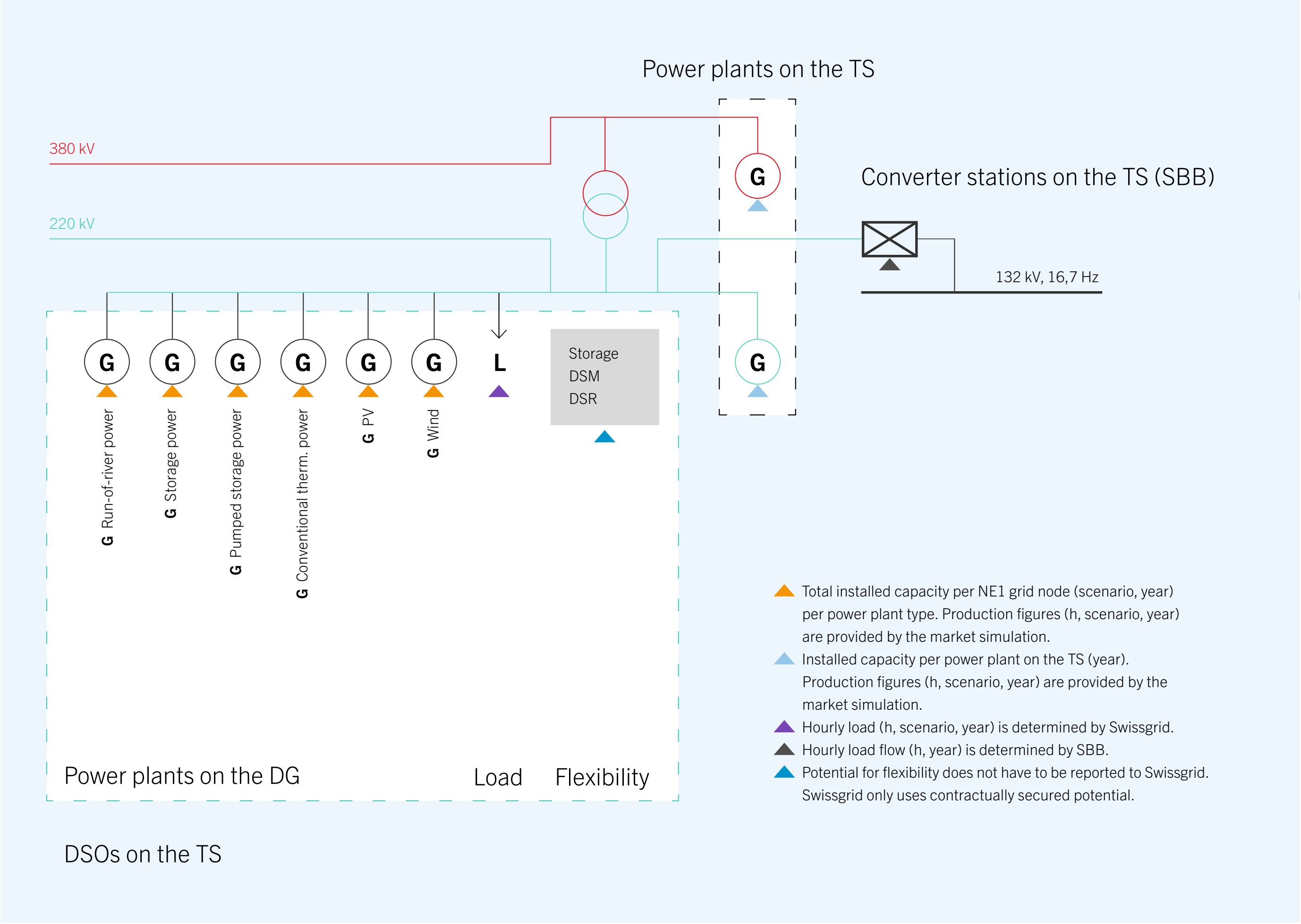
Swissgrid will coordinate the assumptions regarding power plant locations with the SFOE and ElCom.

For grid expansion, this means the following:

- **Power plant connection:** A grid project that is only necessary for the grid connection of a new power plant is not included in the Strategic Grid until the construction decision for the power plant has been made, in accordance with principle A.
- **Grid enhancement requirements in the upstream grid:** This is usually based on the sum of several drivers (power plant, storage and/or consumer projects). If power plant projects that have been definitively decided and approved require grid expansion in the upstream grid, this will be carried out. However, the increase in transmission power is already selected in such a way that the subsequent connection of the known probable projects is still possible without having to expand the grid again. This is to avoid time delays and additional costs.

Swissgrid collects data on the planned expansion, new construction and decommissioning of generating plants and on the construction of large users from power plants on the TS, from SBB and from the DSOs on the TS.

Figure 12 illustrates the data that Swissgrid receives from partners and the grid modelling used by Swissgrid. The entire NE1 (380 kV (red), 220 kV (green), 380/220 kV transformers) is shown. The power plants feeding directly into NE1 are explicitly mapped. The illustration also shows the 50/16.7 Hz grid couplings (frequency converters and static frequency converter systems) through which SBB exchanges energy with the TS. The NE2–7 are not shown in detail. They are described below, modelled by substitute elements per grid node. The totality of all power plants feeding into a grid node is represented by a virtual backup power plant per power plant type (note: the illustration does not show all conceivable types of power plant), the load by a cumulative load curve and the flexibility by a potential.



▲ Total installed capacity per NE1 grid node (scenario, year) per power plant type. Production figures (h, scenario, year) are provided by the market simulation.
▲ Installed capacity per power plant on the TS (year). Production figures (h, scenario, year) are provided by the market simulation.
▲ Hourly load (h, scenario, year) is determined by Swissgrid.
▲ Hourly load flow (h, year) is determined by SBB.
▲ Potential for flexibility does not have to be reported to Swissgrid. Swissgrid only uses contractually secured potential.

Figure 12 – Illustration of the data collected per grid node

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[20] Press release: https://www.uvek.admin.ch/uvek/de/home/uvek/medien/medienmitteilungen.msg-id-86432.html

The power plants on the TS transmit their data on the planned change in installed capacity directly to Swissgrid.

SBB provides reports to Swissgrid on planned adjustments to the transformation power in the converter stations as well as an exchange profile for the target years.

The DSOs on the TS transmit data to Swissgrid on the installed capacity per power plant type, aggregated to the NE1 grid nodes. This applies both to the current plant park and to the target years 2030/40.

The DSOs on the TS also provide information on major projects (e.g. large users, data centres) planned in their area of responsibility and the potential reactive power that they can make available per grid node or per grid region.

Grid planning only takes into account the flexibility that can be activated by Swissgrid itself at any time (e.g. redispatching contracts, integrated market, temporary load reduction, ripple control systems). Grid planning does not take into account the potential flexibility that may be activated in the future by consumers/power plants/storage systems in the distribution grid. Grid planning, on the other hand, shows which flexibilities (controllable generators, storage systems and consumers) would be necessary to possibly avoid line projects.

Swissgrid determines the load per NE1 grid node for each scenario by converting the total consumption in Switzerland per scenario in the target year into an hourly annual load profile using an ENTSO-E standard load profile.[21] This is then allocated to the NE1 grid nodes.[22] Today's consumption distribution (taking into account today's main points of consumption) is used as a basis for this. Consumption changes due to known major projects can be directly assigned to grid nodes. The remaining increase in consumption between today and the target year is allocated to the grid nodes in proportion to local population development. Note: In the long term, the application of customer group-specific load profiles would be conceivable. However, there is currently no sufficiently reliable data on this.

6.3 Regionalisation abroad

As part of the TYNDP process, ENTSO-E provided its members with grid models containing data that had already been regionalised, which Swissgrid uses in its grid planning.

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[21] The ENTSO-E load profile is generated for each bidding zone by taking the number of heat pumps, e-mobility vehicles, data centres, etc. from the SZR CH and inputting it into the ENTSO-E tool.

[22] Each municipality was allocated proportionately to the NE1 gride nodes by the DSOs on the TS.

7 Determination of the start grid

7 Determination of the start grid

Input	Determination of the start grid	Formation of the reference grid	Formation of the target grid	Output
SZR CH, ENTSO scenarios, regionalisation		• Market simulation • Mapping • Grid simulation • Stress tests • Definition of grid projects • Coordination with DSOs on the TS and foreign TSOs	• CBA	Strategic Grid

In addition to the external input data from the scenarios and regionalisation, Swissgrid also needs a grid model, i.e. the start grid, that it can take as the initial situation for the grid planning process. As a result of the grid planning, the Strategic Grid 2040 comprises all grid projects that have to be added to the start grid in order to be able to guarantee secure grid operation in 2040.

The start grid includes the following Swiss grid elements:

- Grid elements that are in operation today or whose decommissioning is not foreseen by 2030
- Grid elements that will be commissioned before 2030 (that are under construction or have a construction permit)

The decision as to which of the grid projects that have not yet been put into operation will be included in the start grid is based on Swissgrid's technical multi-year planning.

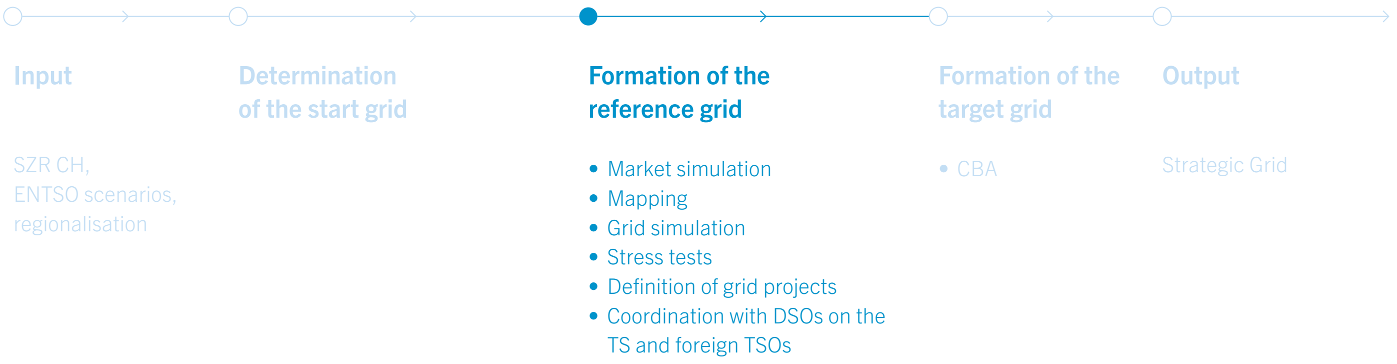
Grid projects from the Strategic Grid 2025 that are not part of the start grid will only be pursued if their necessity is confirmed in the Strategic Grid 2040 project.

For the rest of continental Europe, Swissgrid uses a grid model from ENTSO-E. The current grid model is expanded to include further grid projects in order to represent the probable state in 2030/40. The TYNDP lists all grid projects with the respective targeted year of commissioning and the current project status. On this basis, Swissgrid decides whether the project will be included in the grid model for 2030 or 2040. The decision matrix can be seen in the following table.

TYNDP projects	**Year of commissioning**			
	2030 scenarios		**2040 scenarios**	
Project status	**≤ 2030**	**2030–2040**	**≤ 2030**	**2030–2040**
Under Consideration	No	No	Yes	No
Planned But Not Yet in Permitting	No	No	Yes	Yes
In Permitting	Yes	No	Yes	Yes
Under Construction	Yes	No	Yes	Yes

8 Formation of the reference grid

8 Formation of the reference grid



This section describes how Swissgrid moves from the start grid to the reference grid. To do so, grid projects are added to the start grid until there is largely no more grid congestion in grid simulations with the scenarios from the SZR CH and until the reference grid also passes the stress tests (e.g. multiple failures, short circuits, dynamic calculations, voltage analysis, etc.).

8.1 Description of the reference grid formation process

The overall process is shown in simplified form in figure 13 and described in the following text.

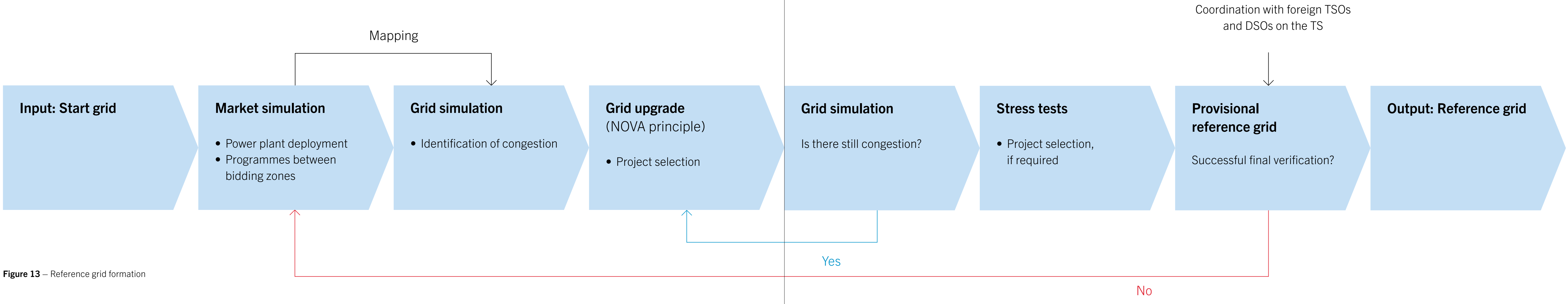


Figure 13 – Reference grid formation

Input values: The start grid according to section 7 and the data from the SZR CH, from the ENTSO scenarios and from the regionalisation process according to section 6, form the starting point for the formation of the 2030/40 reference grid.

Market simulation with FBMC: Based on the scenarios per bidding zone, the market simulation recognises the hourly consumption, the available power plant output per power plant type, the current cross-border capacity between the bidding zones, and hourly climate data, as a basis for supply-dependent generation (e.g. PV, wind). Market simulations are carried out for the various scenarios set out in the SZR CH. The market simulation delivers a result that indicates the hourly power plant deployment per bidding zone and the resulting cross-border electricity exchange. The target function is to cover the load in each bidding zone, at minimum generation cost, taking into account the maximum cross-border capacity between bidding zones.

In the past, the bilaterally agreed, fixed NTC values were taken to represent cross-border capacity. The FBMC algorithm is now used to determine cross-border capacity.

The 70 % minRAM rule is applied to the critical grid elements (CNECs). This rule means that according to the EU requirement (Clean Energy Package), at least 70 % of the transfer capacity of each CNEC (Critical Network Element and Contingency) must be made available for crossborder trading. For this to succeed, the transmission system operators have to use redispatching, which can lead to high costs. The EU's aim is to create an incentive for transmission system operators to expand cross-border capacities between bidding zones in order to avoid redispatching costs. This creates the basis for a successful energy transition.

To ensure that the remaining long-term contracts at the Swiss borders are taken into account, the cross-border capacities are adjusted accordingly.

Mapping: The results per bidding zone from the market simulation are allocated to the nodes of the European grid model by means of mapping. This means that the hourly generation[23] and the consumption per grid node are taken as input values for the grid simulation.

Grid simulation: For each scenario, grid simulations are calculated with the European grid model, and any congestion (n–1 violations)[24] is detected. The utilisation of the grid elements per scenario is created from this, at which point it becomes clear where there is still a need for grid expansion.

Grid upgrading according to the NOVA principle: the NOVA principle is always applied when upgrading the grid. The NOVA principle stands for grid optimisation before grid enhancement before grid expansion. It aims to minimise the impacts of grid expansion on the environment and the landscape. If more efficient grid operation (e.g. topological measures, redispatching or use of flexibilities) is not sufficient to control the congestion identified, then the first measure is grid optimisation. If this does not achieve the objective, grid enhancement (e.g. more powerful conductor cables, higher voltage) is then carried out and, as a last resort, grid expansion (new route). Figure 14 illustrates how the 2030/40 reference grid is gradually formed from the start grid.

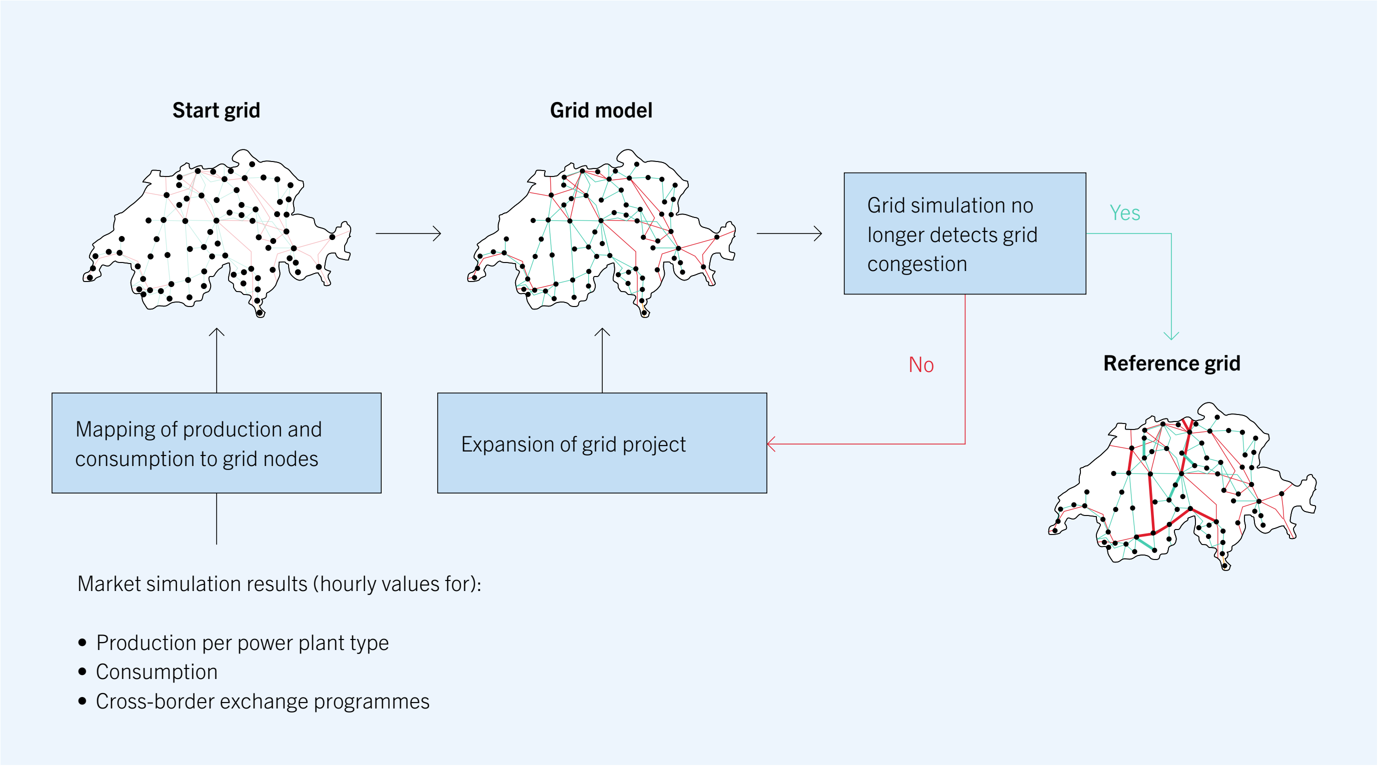


Figure 14 — Reference grid formation (Note: This is determined from the European grid model)

New grid simulation to determine whether congestion still exists: The grid simulation is carried out again for the scenarios set out in the SZR CH with the upgraded grid. If the significant congestion has not all been removed, then further grid upgrade measures must be taken (either by introducing new projects or by combining projects that have already been created in a more favourable way).

Stress tests: The start grid, supplemented by additional grid projects, is now subjected to various stress tests (e.g. multiple failures, short circuits, frequency/voltage variations, etc.). If the stress tests reveal a need for further grid upgrades, then additional grid projects are added in this step to make the grid sufficiently robust to cope with the extreme situations that are conceivable. The provisional reference grid is then available.

Coordination with foreign TSOs and the «Regional Coordination of Grid Planning» (AG RKN) working group: The additional grid projects that are relevant to other grid operators are presented to them. Bilateral exchanges take place for this purpose with the neighbouring TSOs, and coordination in Switzerland is ensured in the AG RKN (DSOs, PPOs and SBB). Negative influences on neighbouring grids, double investments due to parallel infrastructure projects and blind spots should thus be avoided.

Final verification of the temporary reference grid: The new grid projects change the sensitivity factors (PTDF matrix) and flows on the CNECs (RAM). The market and grid simulations must therefore be carried out again for control purposes. Theoretically, congestion could be identified again, which in turn could be resolved with the help of a grid upgrade according to the NOVA principle.

Output reference grid: The result represents the reference grid.

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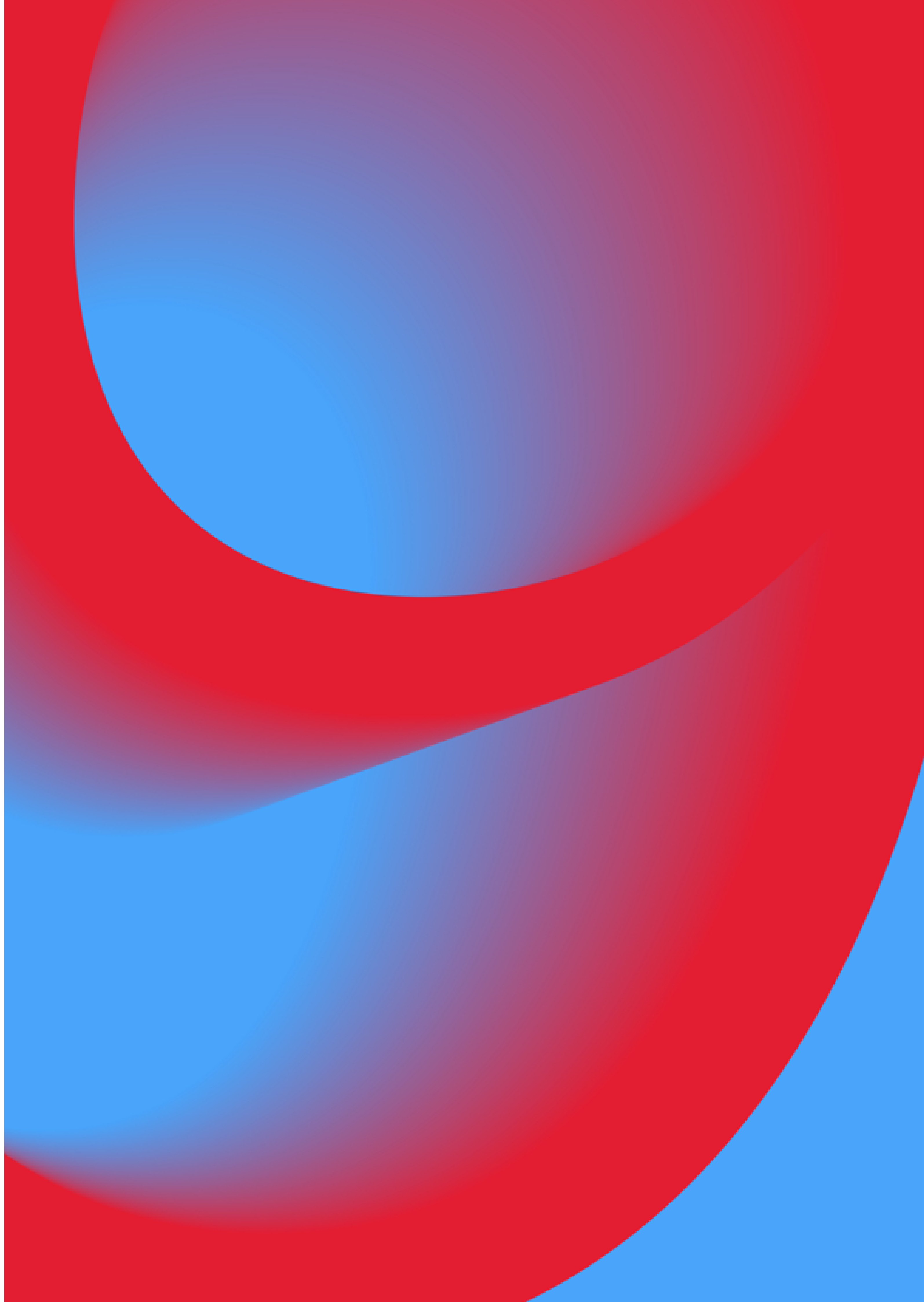
[23] For each grid node, the mapping calculates the percentage of installed capacity that is utilised for each power plant type and thus the total local feed-in.

[24] Future voltage violations are determined using the provisional reference grid during stress testing.

9 Determining the target grid via a cost-benefit analysis



9 Determining the target grid via a cost-benefit analysis

Input	Determination of the start grid	Formation of the reference grid	Formation of the target grid	Output
SZR CH, ENTSO scenarios, regionalisation		• Market simulation • Mapping • Grid simulation • Stress tests • Definition of grid projects • Coordination with DSOs on the TS and foreign TSOs	• CBA	Strategic Grid

This section describes how the additional projects of the reference grid are evaluated by means of a cost-benefit analysis (CBA) and how decisions are made as to which of these projects from the reference grid will actually be included in the target grid, i.e. the Strategic Grid.

The CBA gives a evaluation of each individual grid expansion measure from an economic, environmental and technical perspective, and thus serves as proof of need.

The «CBA 3» document prepared by ENTSO-E (version from 28 January 2020) forms the basis for the CBA. Compared to the previous versions, the CBA has three new benefit categories (e.g. B4, B8, etc.) for which practical experience is not yet available. All other benefit categories were already part of previous CBA versions and were already considered in the Strategic Grid 2025 project.

The CBA is only carried out for the lead scenario set out in the SZR CH and thus the proof of need is given per project. If appropriate, up to three different climate years can be used in order to visualise the effects of different climatic developments on the benefit categories. The selection of climate years is based on the current TYNDP. In the TYNDP 2022, these are the climate years 1995 (weighting factor: 0.233), 2008 (0.367) and 2009 (0.4). Since all scenarios are taken into account in the reference grid formation, the grid is technically planned according to demand.

For each additional grid project X[25], the CBA is carried out as follows: costs and benefits are first determined for the reference grid. Costs and benefits are then determined for the reference grid without project X. By comparing the results once for the reference grid with project X and once for the reference grid without project X, the benefits of project X become clear. On this basis, a decision is made as to whether the benefits are sufficiently relevant for project X to be included in the target grid (Strategic Grid). This method of cost-benefit analysis is also called TOOT – «take one out at a time». Figure 15 illustrates the methodology.

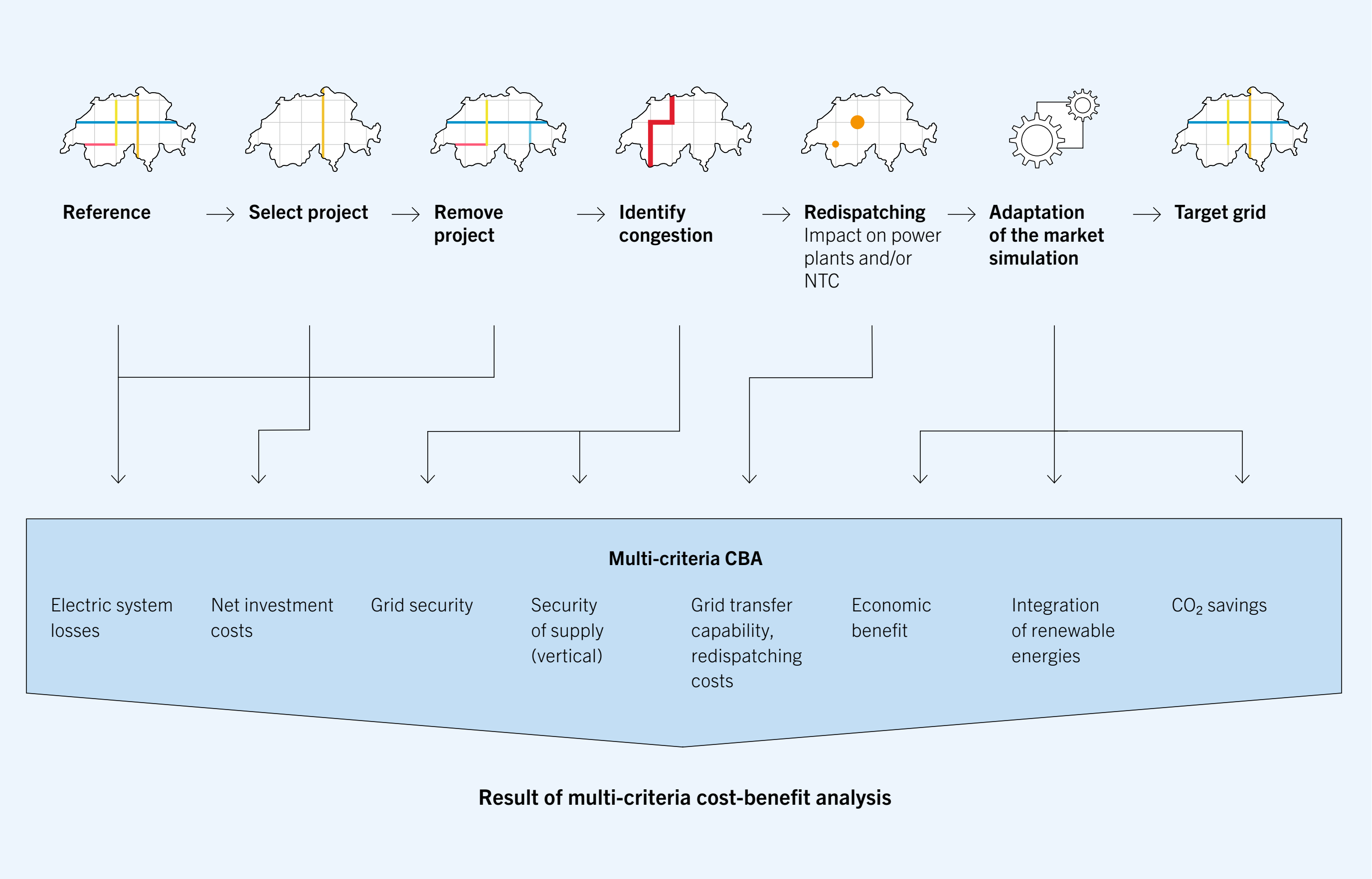


Figure 15 – Application of a cost-benefit analysis to determine the target grid

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[25] A cost-benefit analysis is not conducted for smaller-scale projects costing less than CHF 1 million.

Only grid projects whose benefits exceed the costs are included in the Strategic Grid.

The Net Present Value (NPV) method is used to determine the current monetary benefit of projects. All costs and the monetised benefits that are specified in [CHF/a] and are directly related to project X are taken into account; however, benefit categories that are specified in physical units (e.g. [t/a]) or qualitatively (e.g. 0 / + / ++) cannot be integrated into the NPV calculation.

If a grid project has a negative NPV, its implementation is not automatically ruled out. In individual cases, the non-monetary criteria can be decisive, if, for example, security of supply/grid security is significantly increased. In this case, a project-specific, comprehensible justification is given on the basis of the qualitative indicators.

For grid projects that could be replaced by the contractual development of existing or yet to be built flexibilities of power plants, consumers and/or storage facilities, the redispatching quantities that would be necessary annually are shown together with their estimated costs (benefit B10).

Figure 16 is based on ENTSO-E's CBA 3 and provides an overview of the different categories of benefits (B), costs (C), residual benefits (S) and additional benefits (Z) that are assessed. It also becomes clear which categories found in CBA 3 are methodologically applied in Switzerland and which are not. There are also additional benefit categories that only exist in Switzerland. The benefit categories that are monetised are also visualised.

Benefit categories		
B1: Socio-economic welfare	⛁	
• Fuel savings thanks to integration of RES • CO$_2$ emission costs avoided	✓ ⛁ ✓ ⛁	
B2: Change in CO$_2$ emissions	× ⛁	
B3: Integration of renewable resources	✓	
B4: Change in non-CO$_2$ emissions	×	
B5: Electric system losses	✓ ⛁	
B6: Adequacy	× ⛁	System adequacy
B7: Flexibility • Balancing energy • Balancing capacities	×	System security
B8: Stability • Frequency stability • Automatic start-up • Voltage/reactive power	×	
B9: Avoidance of infrastructure modernisation/replacement	× ⛁	
B10: Redispatching	⊞ ✓ ⛁	

Cost categories	
C1: CAPEX	✓ ⛁
C1: OPEX	✓ ⛁

Other impacts	
S1: Environment	×
S2: Society	×
S3: Other	×

Benefit categories and impacts specific to Switzerland	
Z1: Grid security (horizontal)	✓
Z2: Security of supply (vertical)	✓
Z3: Resilience of the project	✓
Z4: Environmental impact	✓
Z5: ITC net revenue	⊞ ✓ ⛁

✓ Part of the Swiss CBA
× Not part of the Swiss CBA
⛁ Monetised
⊞ New (compared to SN2025)

Figure 16 – Cost and benefit categories in the CBA

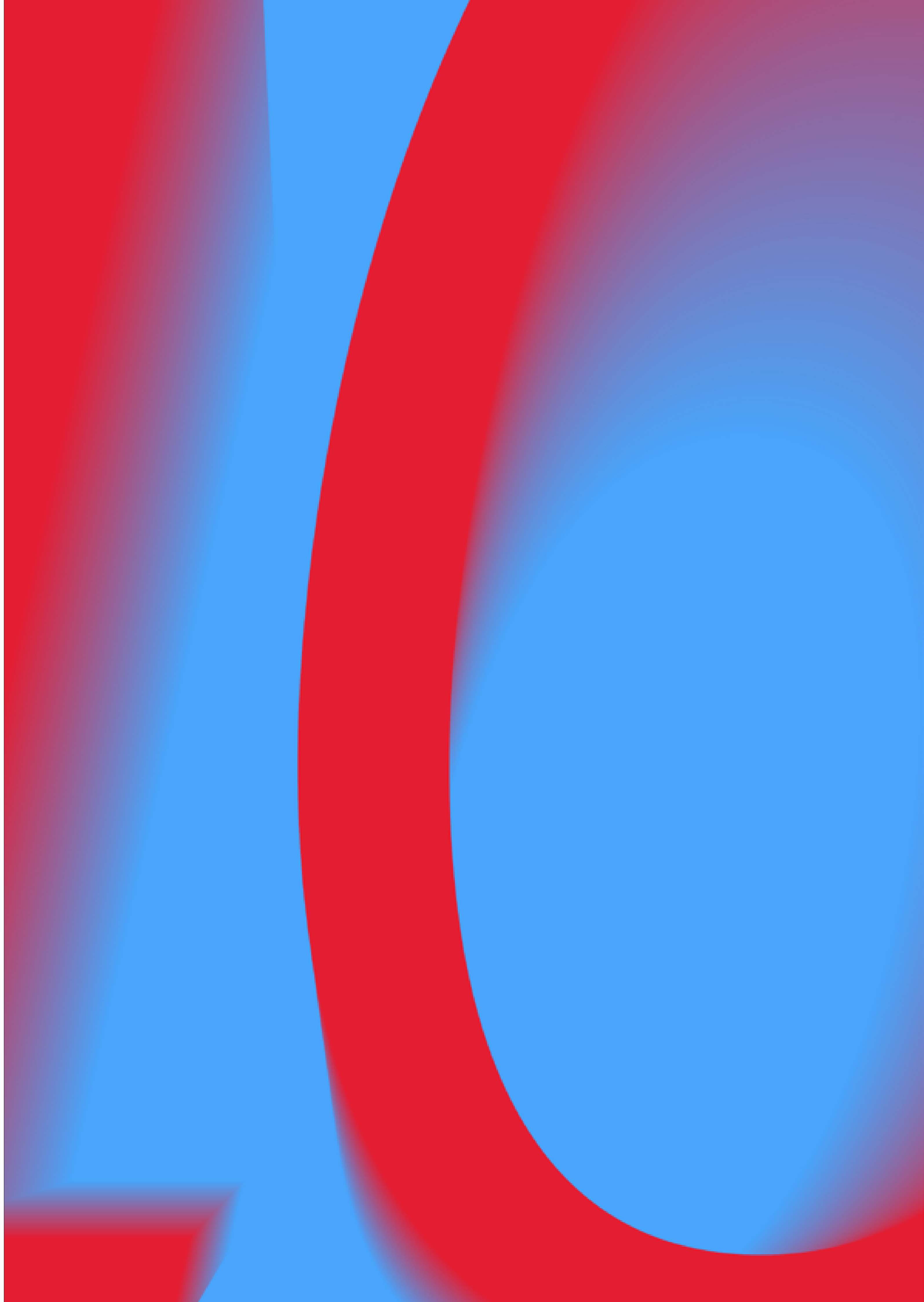
The costs for a Swiss grid project are incurred in Switzerland (exception: cross-border line with cost sharing), the benefits from a Swiss grid project can be realised in Switzerland but also abroad. Within the framework of the CBA, Swissgrid only takes into account the costs and benefits that are incurred in Switzerland. The cost and benefit categories are defined as follows:

B1 Socio-economic welfare	The increase in socio-economic welfare (SEW) due to the project is the difference in the sums of the profits of consumers, producers and transmission system owners that arise with and without the project, in [CHF/a].
B3 Integration of renewable resources	This benefit consists of two components: • The output part [MW/a] corresponds to the capacity of PV/wind power plants that can be newly integrated into the grid thanks to the project • The energy part [MWh/a] corresponds to the avoided curtailment of PV and wind power plants (e.g. peak shaving)
B5 Electric system losses	This benefit determines the change in electric system losses [MWh/a] resulting from the project and monetises this in [CHF/a].
B10 Redispatching	This benefit shows how much redispatch energy [MWh/a] and how many redispatching costs [CHF/a] can be avoided by the project.
C1 CAPEX	This shows the total investment costs of the project [CHF].
C2 OPEX	This indicates the annual operating costs in [CHF/a].
Z1 Grid security (horizontal)	This benefit qualitatively describes the extent to which the project increases operational security in the transmission grid by reducing the number or level of n–1/n-k violations or voltage violations and thus reducing the risk of grid failures or cascades.
Z2 Security of supply (vertical)	This benefit qualitatively describes to what extent the project increases the security of supply of end consumers, for example by increasing the number of grid connections from the distribution grid to the transmission grid or by reinforcing spur lines in the transmission grid with a parallel line.
Z3 Resilience of the project	The more scenarios that prove the need for a project, the greater its benefit.
Z4 Environmental impact	The S1 and S2 benefits of ENTSO-E's CBA 3 are not applicable to Switzerland. The Z4 benefit qualitatively assesses the extent to which the project complies with Swiss environmental regulations. The four possible evaluations are: • **Positive:** Positive environmental impacts are to be expected. This is the case, for example, when a route is relocated, if the new route is further away from a village, or a nature/landscape conservation area is no longer affected. • **Neutral:** The project consists mainly of either grid optimisations or grid enhancements that do not lead to any significant change in the route or visible change in the pylon layout. • **Quite negative:** The environmental impacts of the project are acceptable because, for example, the route of the line will only be modified over short distances or the pylon pattern will only be changed by a moderate increase in height. • **Negative:** The project essentially consists of grid expansion on a new route.
Z5 ITC Net revenue	This benefit includes the increase in ITC net revenue for Switzerland generated by the project in [CHF/a].

A project profile with the same structure is created for each project. This includes the costs, the benefits per category, an implementation proposal and a statement on priority and urgency.

The grid planning process ends when the Strategic Grid is handed over to ElCom for review. It is then published following approval.

10 Appendix – glossary and abbreviations



10.1 Glossary

The following terms and abbreviations are important for understanding the document.

Bidding zone	In this zone, a uniform market price applies at a given time or for a given billing period (hour or quarter hour). It is therefore referred to as a market area, price area or bidding zone. For market players, a bidding zone is an area without any congestion where there are no restrictions on energy exchange. The grid operators control congestion within the bidding zone by implementing topological measures or by redispatching generators, storage systems or consumers. Bidding zones are often identical to national borders. In Switzerland, this applies to a large extent, whereby the Swiss bidding zone also includes peripheral areas of neighbouring foreign countries, and peripheral areas of Switzerland belong to foreign bidding zones. In Italy and the Scandinavian countries, for example, there are several bidding zones on the national territories.
CNEC	Critical network element and contingency: grid elements that have a limiting effect on the cross-border capacity between bidding zones.
ENTSO scenarios	ENTSO-E and ENTSOG jointly develop a scenario framework for electricity and gas in Europe every two years.
ERAA	Annual, comprehensive adequacy analysis by ENTSO-E, prescribed by the Clean Energy Package (CEP) as a tool for assessing the need for capacity mechanisms.
GO List	List of guarantees of origin: a list of all existing Swiss power plants
Grid node	A grid node in the TS is a substation where power plants and/or distribution grids are connected to the TS.
Grid simulation	The load and production from the market simulation are allocated to the grid nodes in the start grid via a defined key (mapping). Grid congestion can now be detected. Projects are added until there is no more congestion. The grid achieved by this is called the reference grid. Results of the grid simulation include the necessary grid expansion projects, location and frequency of grid congestion and voltage violations, electric system losses, etc.
Market simulation	For each bidding zone, hourly curves showing load, solar radiation and wind, as well as the composition of the power plant park (separated by technologies), fuel and CO_2 prices etc., are available for the target year based on the scenarios set out in the SZR CH and on the ENTSO scenarios. For each bidding zone and each scenario, the simulation indicates the hourly market prices, power plant deployment, the emissions resulting from the power plant deployment and the net position of the bidding zones. The latter is determined in an FBMC calculation. The prices in these bidding zones are equalised by exchanging energy between bidding zones.
minRam criterion	The 70 % minRAM criterion means that according to the EU requirement (Clean Energy Package), at least 70 % of the transfer capacity of each CNEC must be made available for cross-border trading.
NOVA principle	The NOVA principle stands for grid optimisation before grid enhancement before grid expansion. It aims to minimise the impacts of grid expansion on the environment and the landscape. If more efficient grid operation is not sufficient to manage the congestion that has been identified, the first step is to pursue grid optimisation and, if this is not effective, grid enhancement and, as a last resort, grid expansion.
RAM	Remaining available margin. The relative capacity of a CNEC available to the market.
Reference grid	This is the Swiss transmission grid which does not show any significant structural congestion when applying the scenarios for the target year.
SAFA	Synchronous Area Framework Agreement: in 2019, with the «Synchronous Area Framework Agreement» (SAFA), continental Europe's transmission system operators, including Swissgrid, became contractually obliged to abide by the network codes as well as the jointly developed implementation rules, which are necessary to ensure operational grid security.
Scenario framework	There is a national scenario framework (SZR CH) and a European scenario framework (ENTSO scenarios). The scenario framework is prepared for the target year (2040) and the support year (2030).
SEW	Socio-economic welfare: the SEW of project X is the difference in the sums of the profits of consumers, producers and transmission system owners that arise with and without project X. ENTSO-E authorises two methods for determining SEW: the generation cost approach and the total surplus approach. The total surplus approach allows for country-specific project assessment and is used by Swissgrid.
Start grid	This refers to the transmission grid in Switzerland and the transmission grid in other continental European countries. It includes all the grid elements that are currently in operation or will be in operation by 2030.
Strategic Grid	This is the entirety of the grid expansion and grid decommissioning projects in Switzerland by means of which the start grid is transformed into the target grid.

Target grid	This is the Swiss transmission grid which is actually targeted for the target year. By applying the CBA procedure to the additional projects from the reference grid and carrying out stress tests, it becomes clear which projects offer sufficient added value and should therefore actually be implemented.
Target year	The target year is the year for which the next Strategic Grid is determined.
TOOT	Take one out at a time: a method used by Swissgrid and ENTSO-E to determine the added value of each additional project X from the reference grid. In order to be able to determine the CBA costs and benefits, the analysis is first carried out for the complete reference grid. Project X is then dropped and the analysis is carried out again. By determining and comparing the costs and benefits in both cases, the costs and benefits of project X can be determined. This is done in a similar way for each project, at which point the costs and benefits of each project become clear. On this basis, Swissgrid decides which additional reference grid projects will become part of the target grid. Market and grid simulation are used as analysis methods.

10.2 Abbreviations

AG RKN	«Regional Coordination of Grid Planning» working group
CBA	Cost-benefit analysis
DETEC	Federal Department of the Environment, Transport, Energy and Communications
DSM	Demand-side management
DSO	Distribution system operator
DSR	Demand-side response
ElCom	Federal Electricity Commission
ENTSO-E	Association of European Transmission System Operators
ENTSOG	European Network of Transmission System Operators for Gas
EP	Energy perspectives
ESTI	Swiss Federal Inspectorate for Heavy Current Installations
FACTS	Flexible AC transmission system
FBMC	Flow-based market coupling
FEDRO	Federal Roads Office
FOT	Federal Office of Transport
HVDC	High-voltage direct current transmission
ITC	Inter-TSO compensation
MW	Megawatt
NE	Grid level

NTC	Net transfer capacity
PPO	Power plant operator
PST	Phase shift transformer
PTDF matrix	Power transfer distribution function matrix
PV	Photovoltaics
ROK	Spatial Planning Conference
SFOE	Swiss Federal Office of Energy
StromVG	Electricity Supply Act
StromVV	Electricity Supply Ordinance
SÜL	Sectoral planning process for transmission lines
SZR CH	Scenario Framework Switzerland
TS	Transmission system
TSO	Transmission system operator
TSOW	Transmission system owner
TYNDP	Ten-year network development plan

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