Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of the Environment,
Transport, Energy and Communications DETEC

**Swiss Federal Office of Energy**
Energy Research and Cleantech

**Interim report from 31 August 2025**

# MOSES

## Impact of Market Design Measures on the Swiss Electricity System

Source: USNW Sydney, https://www.businessthink.unsw.edu.au/articles/australia-electricity-price-volatility-forecasting-model

**Publisher:**
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech
CH-3003 Berne
www.energy-research.ch

**Subsidy recipients:**
Université de Genève
Boulevard Carl-Vogt 66
CH-1205 Genève
https://www.unige.ch/

Artelys France
81 rue Saint Lazare 12
F-75009 Paris
https://www.artelys.com/fr/

**Authors:**
Emma Moulan, Artelys, Emma.moulan@artelys.com
Francesco Colaci, Artelys, Francesco.moulan@artelys.com
Christopher Andrey, Artelys, Christopher.andrey@artelys.com
Arven Syla, University of Geneva, Arven.syla@unige.ch
Martin K. Patel, University of Geneva, Martin.patel@unige.ch

**SFOE project coordinators:**
Anne-Kathrin, Faust, Anne-kathrin.faust@bfe.admin.ch
Wolfgang Elsenbast, wolfgang.elsenbast@bfe.admin.ch

**SFOE contract number:** SI/502847-01

# Summary

The electricity markets in Europe are undergoing transformation due to the high and continuously increasing share of renewable energy sources and due to energy security concerns largely related to gas supplies. Given its interaction with the pan-European electricity market, any new market design at the European level will impact the Swiss electricity system (and its producers and consumers). This study analyses the impacts of currently discussed changes in the European electricity market design on the Swiss electricity system. Firstly, a state-of-the-art review of the current measures being debated such as contract-for-differences (CfDs) under European electricity markets is conducted, assessing their potential implications for the Swiss electricity markets. Secondly, the study will sequentially model and optimise (i) the European system at the national level for different market design scenarios and (ii) the Swiss electricity system at finer granularity. Finally, a set of recommendations will be developed for the Swiss electricity system based on the comprehensive analysis of results and impacts, encompassing investment signals, risks for consumers and producers, and the need for flexibility sources. This version of the report describes the Swiss and European context based on a literature review. Future versions of this report will include the model-based analyses and the resulting recommendations.

# Zusammenfassung

Die Strommärkte in Europa befinden sich aufgrund des hohen und kontinuierlich steigenden Anteils erneuerbarer Energiequellen und aufgrund der Besorgnis über die Energiesicherheit, die vor allem mit der Gasversorgung zusammenhängt, im Wandel. Angesichts seiner Wechselwirkungen mit den paneuropäischen Strommarkt wird sich jedes neue Marktdesign auf europäischer Ebene auf das Schweizer Stromsystem (und seine Produzenten und Verbraucher) auswirken. Diese Studie analysiert die Effekte der derzeit diskutierten Änderungen im europäischen Strommarktdesign auf das Schweizer Stromsystem. Zunächst wird eine Bestandsaufnahme der für den europäischen Strommarkt diskutierten Massnahmen wie Differenzkontrakte (Contracts for Differences, CfDs) vorgenommen und deren mögliche Auswirkungen auf die Schweizer Strommärkte bewertet. Anschliessend werden in der Studie nacheinander (i) das europäische System auf nationaler Ebene für verschiedene Marktgestaltungs-Szenarien und (ii) das Schweizer Stromsystem mit höherer Granularität modelliert und optimiert. Schliesslich werden auf der Grundlage einer umfassenden Analyse der Ergebnisse und Auswirkungen eine Reihe von Empfehlungen für das Schweizer Stromsystem entwickelt, die Investitionssignale, Risiken für Verbraucher und Produzenten sowie den Bedarf an Flexibilitätsquellen umfassen. Diese Version des Berichts beschreibt den Schweizer und europäischen Kontext auf der Grundlage einer Literaturrecherche. Zukünftige Versionen dieses Berichts werden die modellbasierten Analysen und die daraus resultierenden Empfehlungen enthalten.

# Résumé

Les marchés de l'électricité en Europe sont en pleine mutation en raison de la part élevée et en constante augmentation des sources d'énergie renouvelables et des préoccupations liées à la sécurité énergétique, notamment en ce qui concerne l'approvisionnement en gaz. Compte tenu de ses interactions avec le marché paneuropéen de l'électricité, toute nouvelle conception du marché au niveau européen aura un impact sur le système électrique suisse (et ses producteurs et consommateurs). Cette étude analyse les effets des changements actuellement discutés dans la conception du marché européen de l'électricité sur le système électrique suisse. Elle commence par dresser un inventaire des mesures discutées pour le marché européen de l'électricité, telles que les contrats pour différence (Contracts for Differences, CfD), et évalue leurs effets possibles sur les marchés suisses de l'électricité. L'étude

modélise et optimise ensuite successivement (i) le système européen au niveau national pour différents scénarios de conception du marché et (ii) le système électrique suisse avec une granularité plus élevée. Enfin, sur la base d'une analyse approfondie des résultats et des implications, une série de recommandations pour le système électrique suisse sont formulées, couvrant les signaux d'investissement, les risques pour les consommateurs et les producteurs, ainsi que les besoins en sources de flexibilité. Cette version du rapport décrit le contexte suisse et européen sur la base d'une revue de la littérature. Les prochaines versions de ce rapport contiendront les analyses basées sur des modèles et les recommandations qui en découlent.

# Contents

# List of abbreviations

| | |
|---|---|
| SFOE | Swiss Federal Office of Energy |
| EU | European Union |
| CfD | Contract-for-Difference |
| PPA | Power Purchase Agreement |
| DSO | Distribution System Operator |
| TSO | Transmission System Operator |
| ASE | Association of Swiss Electricity Companies |
| ELCOM | The Electricity Commission |
| ENTSOE | European Network Transmission System Operator |
| GHG | Greenhouse Gas Emissions |
| RES | Renewable Energy Sources |
| PV | Photovoltaics |
| EV | Electric vehicles |
| HP | Heat pumps |

# 1 Introduction

The objective of this project is to analyse the impact of new electricity market design measures currently being discussed at the EU level on the Swiss electricity system, including the role of capacity expansion and flexibility solutions, and to provide recommendations for the future evolution of the Swiss electricity market design. Given the rapid expansion of renewable energy generation and the fast-paced electrification of the demand side (e.g., heating and/or transport), combined with policy objectives such as reducing the exposure to volatile electricity prices for households and businesses, it is important to assess how EU market reforms may affect Switzerland. It should be ensured that the EU and Swiss electricity systems evolve in a harmonious way, without the potential deviations that could induce excessive risks in terms of economic viability of investments in the Swiss electricity system or in terms of price evolution that consumers may face.

This study aims to provide a better understanding of the impacts that potential EU policies could have on investment signals and flexibility requirements in the Swiss electricity system, while also considering the recently enacted policies in Switzerland. This will help to identify and anticipate the potential risks these measures may pose for domestic consumers and producers, while also identifying opportunities for partial alignment with EU market design, thus enabling Switzerland to proactively manage and mitigate these risks.

To analyze the proposed electricity market designs at the EU level, this project uses two complementary energy optimization models, thereby applying an iterative modelling approach: **Artelys Crystal Super Grid**, which captures the impact of measures at the pan-European level, and **GRIMSEL**, which provides a high-resolution/granular representation of the Swiss electricity system. Combining both models allows for a detailed comprehensive evaluation of market design interactions at both the EU level and the Swiss level as well as the interdependencies and reciprocal effects of these measures. Finally, the objective and the contribution of the project is to design a set of recommendations to support the design of a resilient, future-proof Swiss electricity market that is well adapted to the evolving European context and its own setting.

## 1.1 Context and motivation

In 2023, the European Commission launched a reform process targeting the market design of the European electricity system. The proposed reforms seek to adapt the existing framework to emerging challenges, such as the increasing integration of renewable energy sources, the gradual phase-out of natural gas, and the growing need for flexibility solutions such as storage, demand-response and power-to-H2. The objective is to decarbonize the electricity sector while protecting consumers from price volatility, as exposed by the energy crisis following the war in Ukraine. To this end, the reforms promote instruments such as Power Purchase Agreements (PPAs) and Contracts for Difference (CfDs) (European Commission, 2025). Although these measures are introduced at the EU level, they are also expected to influence the Swiss electricity market. Negotiations between the European Union and Switzerland, concerning a new bilateral agreement are continuing. At this stage, a high-level political agreement has been reached between the European Parliament and the Council, and the Parliament has formally adopted the legislative package. Nevertheless, it is anticipated that further reforms will be necessary in the coming years, as the current measures represent only marginal adjustments to the underlying structure of the electricity markets.

The European Commission has already carried out several impact analyses on various topics and policies related to the proposed electricity market reforms. However, despite the urgency of adapting the

EU market design, the European Commission has not yet published a formal, comprehensive impact assessment specifically addressing the envisaged reforms. Nonetheless, the core elements of the reform, particularly the introduction of two-way Contracts for Difference (CfDs) has been publicly communicated and discussed (European Commission, 2025). CfDs have already been studied by a several studies published by other sources such as those by Zachmann et al. (2023) and Schlecht et al. (2024). In addition, as announced in the context of the Clean Industrial Deal published by the European Commission, the European Investment Bank (EIB) is currently developing the new guarantee product for Power Purchase Agreement (PPA) (European. Commission, 2025; Pexapark, 2025)

At the national level, Switzerland approved a new energy and electricity supply act in autumn 2024, known as the *Mantelerlass* (Swiss Federal Office of Energy (BFE), 2024). This legislation outlines three primary objectives: the expansion of renewable energy capacity, the promotion of energy efficiency, and the enhancement of security of supply, with a particular focus on the winter season (the content of the *Mantelerlass* is summarized in section 4.5 of this report). The expert group on security of supply from ETH emphasizes the importance of electricity imports for Switzerland, noting that significant supply shortages may occur if import interconnection capacities are restricted (ETH Zurich ESC, 2023). Their analysis highlights that continued participation in the EU electricity market is essential to ensure supply security and that hydropower plays a critical role in mitigating shortages under least favourable scenarios. A more recent study using the NEXUS energy model developed at ETH by (Schwarz et al. 2024) assesses the implications of the Manterlerlass for the Swiss electricity market. The authors find that winter electricity deficits are likely to persist due to low PV production generation, increased electrification of heating (e.g., HP), and the phase-out of nuclear power plants (NPPs), considering that the latter accounts for approximately half of electricity production during the period studied. They further assess the role of extended NPP lifetimes and find that such extensions would enable Switzerland to maintain a positive net-import balance and reduce the overall system costs. In contrast, if NPPs are not extended, significant investments in alpine PV and wind power will be necessary, given their higher generation potential during winter months.

Similarly, a report by the Association of Swiss Electricity Companies (ASE) (VSE, 2022 & VSE, 2025) analyzes the impact of implementing the Manterlerlass. It concludes that the combination of Mantelerlass and an agreement with the EU is essential for a resilient Swiss electricity system. The ASE report also identifies two key challenges for the future Swiss energy system: managing winter deficits, potentially through additional wind expansion, extended NPP operation, gas-fired generation, or increased imports (ranging from 5 to 10 TWh in winter); and addressing summer PV surpluses. The latter requires designing effective flexibility solutions to cope with excess and increase overall system efficiency.

Among the studies reviewed, while they have analyzed the effect of the Manterlerlass in the Swiss context, the assessment of the currently proposed EU market design measures coupled with their interplay with the Swiss energy system is missing, particularly at a level of detail that captures local Swiss characteristics while maintaining a pan-European representation that reflects ongoing electricity market reforms at the EU level.

As mentioned above, in this project, the proposed market design measures are assessed using two complementary energy optimization models: Artelys Crystal Super Grid, representing the pan-European level, and GRIMSEL, which models the Swiss electricity system with higher spatial granularity. The results from GRIMSEL allow for a more accurate and localized analysis and will be aligned with the broader European model. This study advances the state of the art both in terms of subject focus and modelling methodology. First, conducting an impact assessment of EU-wide market design reforms and their implications for a non-member state like Switzerland is itself a contribution. Second, the use of sequential modelling where the European electricity system is represented at the country level and the

Swiss system at the local offers an innovative compromise to integrate all spatial granularity levels into one single optimisation problem.

The added value of the two-stage modelling approach is to iteratively compare results at the national level from the first optimization (Artelys Crystal Super Grid) with those from the second, more granular model representation (GRIMSEL). This iterative modelling framework enables a robust impact assessment of key performance indicators (KPIs), including investments in generation and flexibility solutions, revenues of generation and flexibility assets, flexibility needs, greenhouse gas emissions (GHG) emissions, total system costs, electrolysers management and electricity prices. These KPIs will be extracted for each of the market design scenarios that will be considered in the project. The key outcomes from this iterative and comparative analysis will be translated into recommendations for the future development of the Swiss electricity market design. These recommendations will consider both the potential risks for producers and the impacts on electricity prices faced by consumers.

## 1.2 Project objectives

The aim of this project is to analyse the impact of new European market design reforms on the Swiss electricity system and to provide recommendations on its evolution. The project addresses the following key research questions:

1. What are the key electricity market design proposals currently being implemented and/or discussed in Europe and Switzerland?
2. What would be their implications for the Swiss electricity system?
3. How should the Swiss market design adapt in response to these electricity reforms?

This impact assessment will precede the formulation of recommendations and will focus on investment signals for both generation and flexibility solutions, including interconnectors, battery storage, and demand-side management. The study will analyse in detail the risks and opportunities these signals present such as risks for Swiss consumers and producers, opportunities for investors and the advantages and drawbacks of aligning Swiss practices with those of the EU.

The study will focus on identifying the potential benefits and risks for investors (e.g., project developers) and market participants (e.g., consumers), while also evaluating opportunities and threats from a social planner perspective (system level). Based on these findings, the project will analyse and develop a set of recommendations for the future evolution of the Swiss electricity market design. These recommendations aim to support policy-making processes and ensure that the Swiss market framework is fit-for-purpose and well aligned with the reforms implemented in the EU single electricity market.

**Expected outcomes of the project:**

1. A comprehensive state of the art review of ongoing and proposed electricity market reforms in Europe and Switzerland
2. An in-depth assessment of the effects of potential EU market design changes on the Swiss electricity system
3. Open-access datasets and analyses to support further research and policy dialogue

# 2 From volatile European electricity markets toward robust market mechanisms to incentivise investments in renewables

## 2.1 Need to ramp up investments in renewable energy sources (RES) and flexibility solutions

The electrification of end-use sectors, particularly heating and transport, combined with a rapid expansion of renewable electricity generation are the cornerstones and key strategy for achieving deep decarbonisation. To reach this objective a significant capacity expansion from renewables is required across Europe. By 2050, total electricity production based on renewable energy sources is expected to reach around 6,000 TWh at the EU level (ENTSO-E & ENTSOG, 2024), with Switzerland aiming 45 TWh (SFOE, 2023). Due to intermittent nature of renewable energy sources, particularly sun and wind, the integration of flexibility solutions is needed. These include various type of storage options such as stationary batteries for short-term storage and hydrogen as energy carrier allowing long-term storage.

In Switzerland, excluding hydropower, photovoltaics (PV) are expected to be the dominant renewable energy source. According to the Energy Perspectives 2050+, around 85% of non-hydro electricity generation will come from PV, followed by wind (10%) and other sources (5%) (SFOE, 2022). Solar installations are projected to be mainly installed in the built environment, while large-scale, open-space PV development is limited due to environmental protections and public acceptance concerns (Cousse, 2021). The high share of PV in the Swiss electricity mix will result in even more pronounced surpluses during the summer periods and deficits in winter months, potentially making the system more vulnerable. Hence, there is an increasing need for both short-term (daily to weekly) and long-term (seasonal) flexibility solutions to ensure efficient PV integration. Wind energy presents another valuable potential renewable energy option for Switzerland, as its generation profile often complements PV by producing more during winter periods aligning with the time periods when electricity production from PV and hydropower is lower and imports from neighbouring countries typically increase. However, the development of wind energy faces strong public opposition, posing a barrier to its expansion (Cousse, 2021).

## 2.2 Role of market instruments in facilitating investments

In recent years, European electricity markets have undergone significant changes. As illustrated in Figure 1, wholesale electricity prices have experienced substantial fluctuations, driven by multiple factors. The COVID-19 pandemic led to widespread lockdowns and a decline in economy activities, resulting in significantly reduced electricity demand and prices in 2021. This was followed by a post-pandemic rebound, during which economic reactivation led to rising energy demand corresponding to an increase in electricity prices. Electricity prices peaked in 2022 and 2023 due to the gas price increases as a consequence of the war in Ukraine following Russia’s invasion. Crisis management resulting in the replacement of Russian gas as well as the increased deployment of renewable energy sources, characterised by zero marginal costs, resulted in lower wholesale electricity prices, occasionally resulting in negative price occurrences since mid-2023. In 2024, Europe recorded the highest number of negative electricity price events (Financial Times, 2024). The increased level of renewables also increases price volatility. Figure 2 shows the increasing volatility of wholesale electricity prices in Switzerland from 2020 to 2025. As illustrated, the electricity price volatility has increased significantly since 2020. This trend aligns with the growing share of renewable energy sources, both within Switzerland and in neighbouring countries. The extent of this volatility is influenced by weather conditions, which drive temporal fluctuations in renewable energy generation. These fluctuations widen the spread of the electricity prices and reduce the capture rates for renewables energy producers, which face lower electricity prices during periods of high renewable output. Such trends result in increasing investment risks for renewable energy projects, potentially deterring market participation. To address these challenges and ensure continued/stable investment in renewables, new market instruments may be needed. Designing and assessing such instruments will be a key focus of this project.

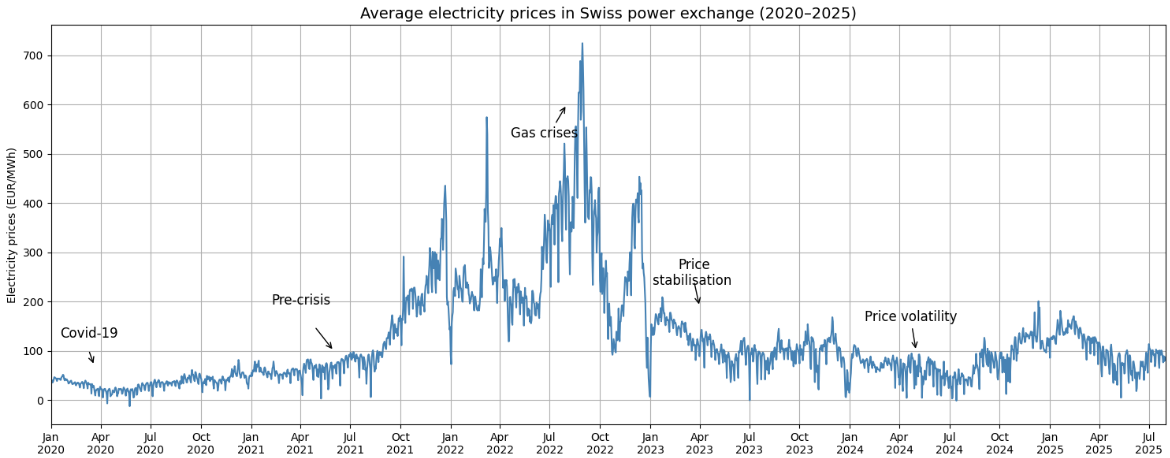


Figure 1. Evolution of the wholesale day-ahead electricity prices in Switzerland from 2019 to 2024. Data source: ENTSO-e transparency platform.

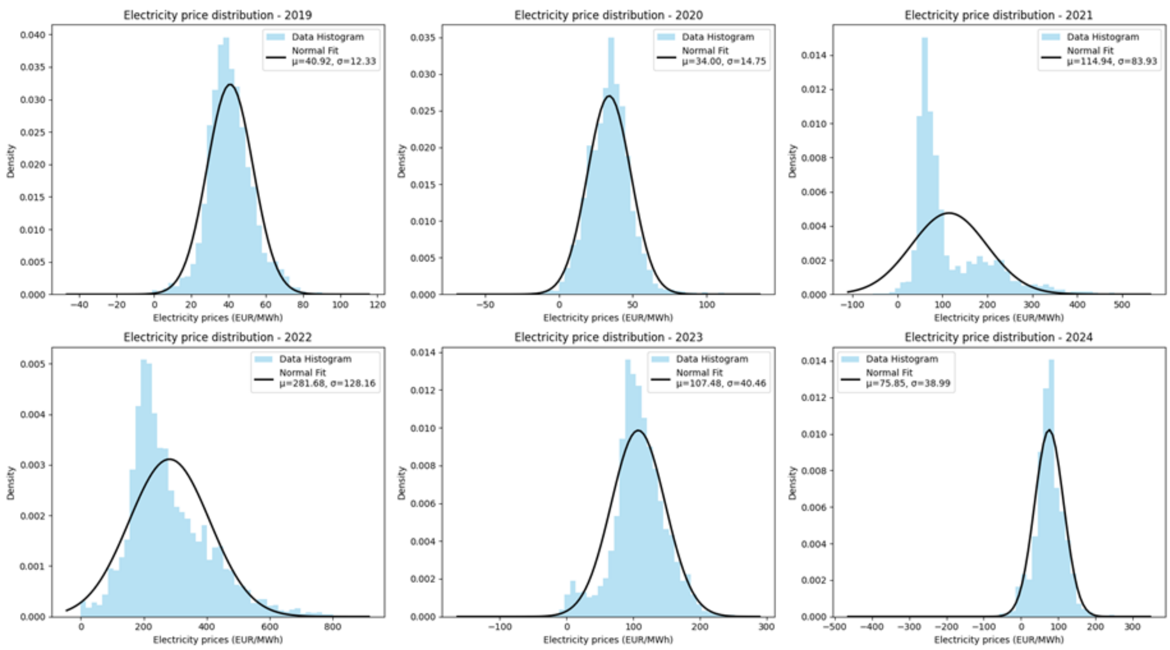


Figure 2. Volatility of the wholesale day-ahead electricity prices in Switzerland from 2019 to 2024. Data source: ENTSO-e transparency platform.

## 2.3 Switzerland vs EU electricity markets

Switzerland's electricity system is highly interconnected with the EU through cross-border interconnections with neighbouring countries. However, the further integration of Switzerland's into the EU electricity market framework remains uncertain, as political negotiations between the EU and Switzerland are still ongoing. A positive outcome from these negotiations could lead to further integration of the Swiss system into the European market (e.g., granting access to key balancing platforms such as MARI and PICASSO), and would enhance grid stability and operational efficiency. This includes better coordination of reserve planning, reductions in unplanned electricity loop flows, and optimized use of interconnection capacities.

Conversely, with the ongoing changes of the EU electricity market, particularly changes in price signals, is expected to influence the interaction between two systems. Switzerland's electricity exchanges (exports/imports) are already closely tied to EU market dynamics (e.g., day ahead) and will likely be further affected by new policy measures adopted at the EU level. To provide an indication of the size of these interactions between the EU and Swiss systems: in 2022, Switzerland exported 29.7 TWh and imported 33.1 TWh amount of electricity. During the winter of 2021/2022 alone, net imports into Switzerland amount to 7.8 TWh, nearly one-quarter of total electricity consumption during that season (BFE, 2023). These figures indicate Switzerland's dependence on the European market for the winter supply security. Any changes in the outcome of the EU-Swiss electricity agreement, followed with the implementation of new EU market reforms, may not only affect the future of the EU electricity system but also have an influence and implications for the Swiss electricity system.

# 3 Approach

The project is structured in three work packages:

- **Work package 1 (WP1):** Identification of key electricity market design proposals
- **Work package 2 (WP2):** Quantitative assessment of shortlisted measures
- **Work package 3 (WP3):** Recommendations for the Swiss electricity system

While the work packages are structured chronologically, with the results of one feeding into the next, certain tasks addressed by the different work packages will be carried out in parallel.

## 3.1 Identification of key electricity market design proposals

This first work package is dedicated to the identification of key electricity market design proposals that are considered in Europe. It is split into two tasks:

- **Literature review:** carry out an exhaustive state of the art of currently proposed electricity market design measures, based on the measures discussed in Europe.
- **Shortlisting of measures to be addressed:** select relevant measures which the impact study will focus on.

## 3.2 Definitions

To ensure a consistent and efficient literature review, we create a framework of definitions that will structure the research on market design reforms.

- *Measure:* A specific market reform proposal or policy (ex: Regulation ensuringwider adoption of two ways CfDs).

- *Instrument:* The tools or mechanisms employed within a measure to achieve its intended effect (ex: CfDs, PPAs, electricity markets, etc).
- *Objective:* The overarching goal or macro-level purpose that market design reforms aim to achieve. Each measure contributes to one or more of these broader objectives.
- *Contribution to the objective:* The specific way in which a measure, through the use of its instrument(s), supports or advances the overarching objective(s).

We can choose as example the following measure from the European Parliament:

*"To mitigate the impact of high electricity prices on the energy bills of consumers, Member states should ensure that any revenues collected from producers subject to two-way CfDs are passed on to final consumers"*

Here, the objective is to protect consumers, the instrument used is CfDs and the contribution of the objective is to mitigate the impact of high electricity prices on the energy bills of consumers.

#### 3.2.1. Literature review task

To create a comprehensive literature review of European market design measures, it is crucial to understand both the functioning of various instruments and the measures currently being discussed. This involves conducting parallel research on:

- **Measures**: Analyze the market design reforms being debated and implemented within the EU.
- **Instruments**: Study how the different tools involved in these measures operate.

Insights from the research on measures inform the study of instruments, while the analysis of instruments provides critical details on the specifics of the measures. To streamline this process and support the shortlisting of relevant measures, a database of electricity market design measures that organizes key information for easier analysis is built.

For each measure, the database includes:

- The definition of the measure
- The objective(s) it serves
- The instrument(s) it involves
- The measure's contribution to the objective

This structured approach ensures consistency and makes it easier to identify the most relevant measures for the project.

The primary sources used to build the database of market design measures are:

- Documents published by the European parliament:
  - 2024 EP Directive of market design
  - 2024 EP Regulation of market design
- Country specific documents:
  - The UK department for energy security and net zero: Review of electricity market arrangements
- Stakeholder positions:
  - European Energy Association (EAA) and Agency for the Cooperation of Energy Regulators (ACEER): Review of electricity market arrangements (REMA) 2$^{nd}$ consultation
  - EASE: The Electricity Market Design Revision Proposal
  - Position articles from Eurelectric, European energy forum, etc.

To better understand the potential impacts of measures on the Swiss electrical system, the research will also examine the Swiss electrical grid, its unique characteristics, and its anticipated evolution, including potential agreements with the European Union. Particular attention will be paid to existing and emerging legislation such as the Mantelerlass, providing valuable insights into the likely effects of measures.

#### 3.2.2.Shortlisting task

Given the wide range of measures currently being discussed and considered as part of electricity market reforms, it is essential to shortlist the measures that will be assessed moving forward. This shortlisting process ensures that our focus remains on measures with the highest potential to provide meaningful insights.

The measures to be shortlisted are drawn from the database of the literature review. The database includes key information about the measures' objectives and impacts.

The shortlisting process uses a combination of insights, including (cf Figure 3):

- Findings from the literature review
- Input and recommendations from the Swiss Federal Office of Energy (SFOE)
- Internal resources and expertise

To guide this evaluation, the following criteria will be considered

- **Nature and feasibility of the measure:** The likelihood of the measure being implemented, based on current policy discussions and regulatory frameworks.
- **Impact on European and Swiss system:** The potential implications and significance of the measure on the electrical system.
- **Modelling possibilities:** The practicality of assessing the measure's impact through our models, including availability of necessary data and capability to simulate the measure effectively.

By evaluating the measures against these criteria, we develop a focused list of measures. These measures will form the foundation for the creation of scenarios.

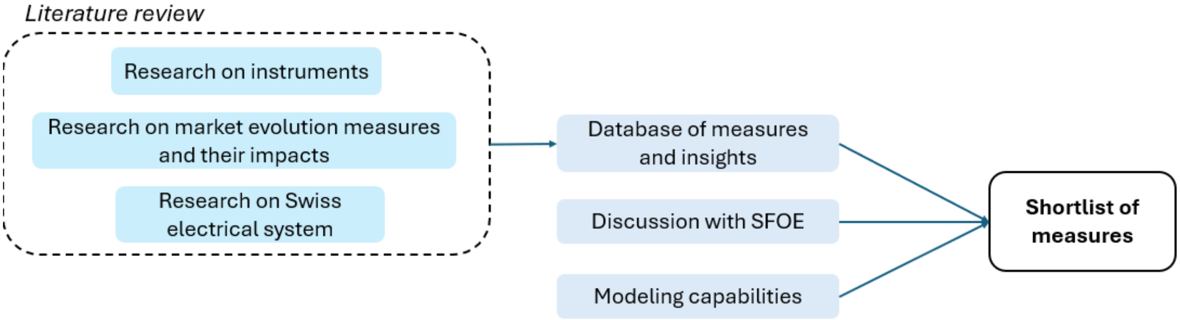


Figure 3. Structure of the work package (WP) 1: literature review and shortlisting of new proposed market design reforms

# 4 Identification and characterisation of market instruments

## 4.1 Objectives and goals of market instruments

The transition to a low-carbon energy system necessitates significant investments in renewable energy sources (RES) and flexibility solutions to ensure the reliability and affordability of electricity supply. Market instruments play a critical role in creating the conditions for these investments by addressing critical challenges such as price volatility, insufficient investment signals, integration of renewable energy into the electricity grid, protection of consumers, etc.

The primary objectives, which drive the creation of market instruments in electricity markets, are:

- **Revenue stability**: Market instruments aim to provide clear, stable, and predictable revenue streams for investors in RES and flexibility solutions. Mechanisms like Contracts for Difference (CfDs) mitigate market price risks, thereby encouraging long-term investments in renewable technologies (ENTSO-E, 2024).
- **Renewable energy sources (RES) development**: Further development of renewable energy sources is key to reaching EU policy goals for the green transition, as well as improving the economic viability of the technologies themselves. To this end, it is fundamental to create favorable economic conditions for RES project developers in order to invest in clean energy. Contracts for differences (CfDs) and Power Purchase Agreements are some examples of instruments which foster these objectives (ENTSO-E, 2024).
- **Security of supply and system flexibility**: As electricity systems become increasingly dependent on variable renewable energy, flexibility solutions are essential to balance supply and demand. Instruments like flexibility reserves, demand-side response (DSR), energy storage, and peak shaving products incentivize these solutions (ACER, 2023).
- **Ensuring Consumer Protection**: By stabilizing electricity prices and mitigating exposure to market volatility, market instruments contribute to consumer welfare. This is particularly relevant in the context of high energy prices and economic uncertainty, where mechanisms like price caps, revenue stabilization funds, and different energy contracts can shield consumers from unpredictable market fluctuations (Simon et al., 2025).

A rapidly evolving energy landscape, characterized by technological innovation and policy shifts, demands adaptive market instruments. These tools must account for risks associated with regulatory changes, fluctuating demand, and geopolitical factors.

These objectives are particularly critical for Switzerland to align its electricity market design with European frameworks while addressing the unique challenges posed by its reliance on imports and its hydro-dominated energy mix. Through careful design and implementation, market instruments can foster a resilient, decarbonized electricity system that supports Switzerland's climate and energy goals.

## 4.2 Description of market instruments

The market instruments analysed in this literature review of the MOSES project include contracts for difference (CfDs), power purchase agreements (PPA), the electricity markets (wholesale, retail, and ancillary services), self-consumption, planning (in terms of forecasting, designing, and implementing strategies for reliable energy production and consumption), demand-side response and peak shaving products, energy contracts, the physical connection to the grid and the establishment of the balancing and capacity markets.

### 4.2.1. Contracts for difference (CfD)

Contracts for Difference (CfDs) are long-term financial agreements designed to stabilize revenues for electricity generators and to promote investment in renewable energy projects. Generally speaking, a CfD is a financial contract between a renewable energy generator (e.g., wind, solar, nuclear) and a counterparty, typically a government-backed entity or market operator. Under a CfD, the producer commits to producing electricity at the so-called "strike price", which is defined in the contract between the two entities and is often established in auction. The strike price is compared to the market price, on an hourly, monthly or yearly basis depending on the type of the design of the CfD (more details available below). The comparison has the aim to decide the amount and direction (toward the producer or the other party) of the payment.

Different designs of Contracts for Difference (CfDs) have been developed with the aim of progressively improving three key aspects: reducing market distortions, protecting consumers, and enhancing the bankability of renewable energy sources (RES) and flexibility solutions. The main key designs have been listed and explained below:

#### One-way CfD Contract

In the case of one-way CfD contract, the payment follows this structure:

- **If market price < strike price**: the generator is paid the difference by the counterparty to top up their revenue to the strike price.
- **If market price > strike price**: the generator retains the surplus without any reimbursement obligation toward the counterparty.

This type of CfD design helps project developers secure financing by offering a safety net against low market prices, encourages the development of renewables, especially in markets with price volatility or where renewable technologies are still emerging. Furthermore, it avoids complexities associated with repayments and can be more attractive for private investors. On the other hand, it has its limitations and entails risks from the perspective of the government, consumers, and the overall energy market. First of all, the one-way CfD contract does not allow for consumers protection during high prices (when the market prices exceed the strike price, the generator keeps all the excess revenue), leading to windfall profits for generators while consumers continue paying higher market prices. Secondly, it increases the public expenditure risk considering that the government or the system operator only pays out, meaning the financial burden lies entirely on the public side. Lastly, it can generate market distortion considering that generators, under one-way CfDs, have less incentive to respond to market signals, as their income is partly decoupled from real-time prices (ENTSO-E, 2024).

### Two-ways CfD contract

As renewable costs fall and markets mature, some governments shift to two-ways CfDs to better balance consumer and producer interests.

In the case of two-way CfD contract, the payment follows this structure:

- **If market price < strike price:** the generator is paid the difference by the counterparty to top up their revenue to the strike price.
- **If market price > strike price:** the generator reimburses the surplus to the counterparty (claw-back).

Two-way CfD offers a balanced financial support mechanism for renewable energy projects by protecting both consumers and investors. They provide revenue certainty for generators by ensuring a top-up when market prices are lower than the strike price. Additionally, when market prices exceed the strike price, the generator is required to pay back the excess revenue, which are generally redistributed by the counterparty to the consumers lowering their electricity bill, helping to protect consumers from high prices and reduces the financial burden on the public. This structure encourages market responsiveness from generators, ensuring they remain sensitive to supply and demand fluctuations, which can lead to greater market efficiency. Furthermore, it reduces the public expenditure risk compared to one-way CfDs, as the system benefits from repayments during high price periods.

However, two-way CfDs have limitations and risks as well. Firstly, they increase complexity for developers and investors, as the potential for repayment during high prices introduces financial uncertainty, which may make financing more challenging, particularly for emerging technologies. Secondly, this added complexity can result in less attractive terms for renewable projects, especially in early-stage markets where developers may prefer the more straightforward financial structure of one-way CfDs. Lastly, while the mechanism provides consumer protection, it could still potentially result in lower returns for generators during high market price periods, making it less appealing for developers seeking guaranteed returns (ENTSO-E, 2024).

### Production-based CfDs

Production-based CfDs provide payments based on the actual electricity injected into the grid. For instance, a wind farm with a 10MW capacity that experiences curtailment down to 8MW will receive CfD payments based on the 8MW produced. This means that the generator is paid based on the amount of energy the producer actually delivers to the grid. Generally, the production-based CfD follows the logic of comparison between the market and strike price and subsequent payment methodology, as for two-ways CfDs.

Production-based CfDs can lead to inefficient bidding behavior. Since the payment is based on the actual generation, generators may prioritize maximizing production to earn higher payments, even when electricity prices are negative or low. This can distort the functioning of the market, as generators continue to produce even at a loss when market prices are below their marginal cost. There is also limited incentive under production-based CfDs for generators to consider system efficiency when choosing the location or design of their assets. For example, a generator might not invest in locations that match the system's needs (e.g., sites that can deliver power during peak demand times) if the payment is based purely on volume rather than the value of electricity at different times. Additionally, Production-based CfDs can help hedge against price risk for generators by providing a guaranteed price floor (strike price).

However, they do not fully hedge against volume risks (e.g., not being dispatched due to grid congestion or market conditions). This might create challenges for project developers in terms of financing and investment (ENTSO-E, 2024).

### Non-production-based CfDs

Unlike production-based CfDs, non-production-based CfDs are not directly linked to actual electricity injected into the grid. Instead, they are based on a counterfactual estimation of the potential for generation, which avoids many of the market and system distortions associated with production-based CfDs. More specifically, the reference volume is an estimation of what could have been produced under optimal conditions. This is often referred to as the "potential production" of the asset, considering factors such as weather conditions and asset capabilities. One common metric used to determine the potential production is the Available Active Power (AAP), which indicates the maximum possible output at any given time, factoring in real-time weather conditions and other relevant parameters. This metric can be continuously updated and provides a reliable way to estimate the capability of a renewable energy asset like wind or solar power plants.

Similar to production-based CfD, non-production-based CfD also compare a market price with a strike price. The difference between these two prices determines the payment (or clawback) to the generator. However, because payments are tied to estimated potential production rather than actual output, this avoids the incentive to overproduce when market conditions are unfavourable.

Non-production based CfD presents the following key design features:

- **Capability-Based CfD**: These are non-production-based CfDs where the reference volume is based on the maximum potential output of an asset, not the actual production. The generator receives payments as if they had produced at their maximum capability, regardless of actual output. This decoupling from real production means that an asset owner continues to receive CfD payments even when curtailing, as opposed to production based CfD, where asset owners aim to maximise production and will therefore be less inclined to curtail. However, to prevent perverse incentives, capability-based CfDs are typically paired with availability obligations or performance tests: the declared capacity must remain available to the system. If the system operator calls on the asset and it cannot deliver, penalties apply. This ensures that systematic curtailment or withholding capacity is not a profitable strategy
- **Financial RES CfD**: These CfDs use a reference generator model, where the potential for production is estimated based on a generic reference generator (rather than an individual asset's potential). This model aims to balance risk while avoiding the overproduction incentives seen in production-based CfDs.
- **Yardstick CfD**: This is another non-production-based design that compares the performance of a generator to that of other generators in the same technology category, further refining the estimation of potential output.

One of the main benefits of non-production-based CfD is that they avoid market distortions caused by the "produce-and-forget" behaviour seen with production-based CfDs. Because the reference volume is based on potential rather than actual output, generators do not need to produce during low-price or negative price periods to secure revenues. They are still remunerated even if curtailed, whereas under production-based CfDs, generators must produce to earn revenue- reducing their incentive to curtail when the system would benefit from it. Furthermore, this design fosters the efficiency of the dispatch, since it allows generators to bid more efficiently based on market conditions rather than focusing solely on maximizing output. This ensures that energy is produced when it is most valuable to the grid, which benefits overall system operation and security.

From a risk coverage point of view, non-production-based CfDs provide better coverage of price risks for generators, as they are not directly affected by the actual market prices during periods of negative pricing. Under non-production-based CfDs, operators can receive a payment based on their capability even when market prices are low, reducing the financial risks associated with market price volatility. Additionally, this design allows to cover some volume risks, especially those caused by curtailment or negative market prices. Since the reference volume is based on an estimated potential rather than actual production, the generator is not penalized for circumstances outside their control, such as being unable to produce due to grid constraints (ENTSO-E, 2024).

### CfD with hourly or monthly/yearly reference market price

As mentioned before, the way the market price is considered can change. Some CfD contracts consider the hourly market price, while some others can choose the average monthly or yearly market price to be compared with the strike price. Those options have pros and cons, further explained below.

- **Hourly CfD**: In the early phases of the CfD implementation, for example in the UK, the market price (day ahead price) was chosen with an hourly time-granularity. The drawbacks of this approach are many:
  - Increased risk for producers due to exposure to market fluctuations.
  - Higher complexity in calculations and monitoring.
  - Potential market distortions, e.g. because CfD-backed producers might bid lower prices, disrupting fair competition.
  - The risk of generators manipulating production to align with market price trends.
- **Monthly/Yearly CfDs**: To reduce market distortions and computational complexity, some CfDs are based on a historical yearly average market price rather than hourly prices. This approach minimizes speculation but introduces new risks:
  - Generators focus on long-term price trends rather than responding to real-time market conditions.
  - Since the reference market price is based on historical spot prices the CfD payment (positive or negative) is known before the Day-ahead (DA) timeframe, and this can lead to dispatch distortions in Day-ahead market.
  - Volume risk persists, as payments depend on total annual production rather than short-term fluctuations (ENTSO-E, 2024).

### CfD auction process

The auction process is a fundamental component in the implementation of Contracts for Difference (CfDs), ensuring the efficient allocation of support for renewable energy projects while promoting competitive pricing. The primary goal of the auction process is to determine the strike price for CfDs, which serves as the guaranteed price at which renewable energy producers will generate electricity. This process ensures that developers who bid the lowest strike prices receive the CfD, ultimately minimizing costs to the government or consumers.

In CfD auctions, competitive tendering is employed to determine the strike price for each project. Developers submit bids, with the lowest bid securing the contract. The competitive auction mechanism drives prices down, ensuring that the strike price reflects the minimum amount needed to support renewable energy projects without imposing unnecessary financial burdens on governments or consumers. By relying on market forces, the auction system strives for cost-efficiency and encourages developers to submit realistic, competitive bids. Competitive tendering has been widely implemented in countries across Europe and is a standard practice in renewable energy auctions (ENTSO-E, 2024).

**Two-Stage Tender Process**

A key auction model discussed in the paper (ENTSO-e, 2024) is the Two-Stage Tender process. This model aims to balance government-backed CfDs and commercial Power Purchase Agreements (PPAs). In this process, commercial PPAs are prioritized during the first stage of the auction, where developers secure long-term, market-based agreements for a portion of their output. The remaining capacity is then allocated in the second stage of the auction, where CfDs are awarded to projects that haven't been able to secure PPAs. This approach ensures that market-based mechanisms like PPAs grow alongside government-supported contracts, reducing distortions and promoting competition in the market. The Two-Stage Tender model is already in use in some countries, though it is not universal (ENTSO-E, 2024).

**Carve-Out Model**

The Carve-Out model is another approach that seeks to allocate specific volumes of renewable energy projects to commercial PPAs while allowing the remaining capacity to be awarded through CfD auctions. This ensures that PPAs continue to thrive without being displaced by the CfD system. The Carve-Out model encourages private sector participation and reduces the dependency on government support, thus fostering a more competitive market for renewable energy. The Carve-Out model is a proposed future option and is not yet widely implemented, though it is being discussed for further use in the future.

The design of the auction is critical to minimize market distortions. Key considerations include:

- Ensuring that bidding behaviour remains competitive and transparent, so developers are incentivized to submit realistic and fair bids.
- Avoiding incentives that might lead to overbidding or underbidding, which could destabilize the market or lead to inefficiencies in the allocation of support.
- Deciding on the reference volume for CfD payments, as the choice between production-based and non-production-based CfDs influences the behaviour of developers in the auction. Non-production-based designs tend to reduce distortions in bidding behaviour and promote efficient market integration (ENTSO-E, 2024).

#### 4.2.2. Power purchase agreement (PPA)

Power Purchase Agreements (PPAs) are long-term contracts between electricity producers and consumers, typically ranging from 10 to 25 years. These agreements are designed to facilitate the purchase of renewable electricity at a predetermined price, providing stability for both parties. PPAs have gained significant traction among corporations, small and medium-sized enterprises, and local authorities as they offer a reliable way to decarbonize electricity consumption and contribute to the energy transition (IEA, 2023 & Siapartners, 2023).

Power Purchase Agreements (PPAs) can be categorized based on the way electricity is delivered to consumers, the type of buyer, the stage of the infrastructure development (already existing plants or to be built), and the electricity purchasing method.

**Classification - electricity delivery method to the consumer**

- **Onsite vs. Offsite PPA**
  - Onsite PPA: The renewable asset (e.g., solar PV panels, wind turbines) is directly installed in the consumer's own location. The energy provider installs, owns, and maintains the renewable energy system (Siapartners, 2025).
  - Offsite PPA: The renewable energy source is connected to the consumer via the electricity grid. This allows the energy producer to be located at a distance, sometimes even in another country, while still delivering power under contract (Siapartners, 2025).

- **Physical vs. Virtual (Financial) PPA**
    - Physical PPA: The electricity is physically delivered to the buyer, either through the local grid or by direct connection to the producer's facility (Siapartners, 2025).
    - Virtual (Financial) PPA: A financial instrument where the buyer and the energy producer agree on a fixed price for electricity over a specified period. The consumer commits to paying the difference between a negotiated reference price and the market price. The consumer does not directly use the electricity but benefits from price hedging. In fact, the main purpose of a Financial PPA is to hedge against fluctuations in electricity prices (Siapartners, 2025).

**Classification - type of buyer**

- **Corporate PPA (CPPA)**: A direct agreement (PPA contract) between an electricity producer and a corporate entity or local government (Siapartners, 2025).
- **Utility PPA**: A PPA contract between an energy producer and a utility company, which then distributes electricity to end users (Siapartners, 2025).
- **Merchant PPA**: A PPA contract where an intermediary or a third party sells electricity on the market on behalf of the producer, typically useful when the producer lacks direct access to the energy market or does not have the ability to enter into a direct contract with the buyer (Siapartners, 2025).

**Classification - stage of the infrastructure development**

- **Greenfield PPA**: These agreements facilitate the development of new renewable energy projects by securing long-term buyers prior to construction. They play a crucial role in attracting financing by ensuring predictable future revenue streams (Siapartners, 2025).
- **Brownfield PPA**: Extends the operational life of existing renewable assets, often applied to repowering projects for aging wind turbines (Siapartners, 2025).

**Classification - electricity purchasing method**

- **Pay-as-produced**: The consumer purchases all or part of the actual electricity generated by the renewable asset. This type of contract benefits the producer because it involves almost no risk, meaning all production will be sold at the agreed-upon price (Siapartners, 2025).
- **Pay-as-nominated/Pay-as-forecasted**: The consumer commits to buying electricity based on production forecasts provided the previous day (Siapartners, 2025).
- **Baseload PPA**: The consumer agrees to purchase a fixed amount of electricity at regular intervals (hourly, monthly, etc.), with the producer managing any discrepancies on the wholesale market (he decides to sell or buy the over or under production on the wholesale market) (Siapartners, 2025).
- **24/7 PPA**: Ensures continuous renewable energy supply throughout the day and year, though adoption is limited by higher costs and lack of standardization (Siapartners, 2025).

PPAs provide numerous benefits for both electricity buyers and producers:

- **For clients**:
    - Reduces energy cost volatility, offering a predictable pricing structure.
    - Avoids the need for upfront capital investment, as infrastructure costs are financed by the energy producer.
    - Reduces carbon emissions by directly sourcing renewable energy (IEA, 2023).
- **For electricity producers**:

- Secures long-term revenue streams, which are essential for financing new renewable energy projects.
- Supports the development of renewable energy parks with optimal production capacity.
- Enables investment in high-yield locations such as offshore wind farms or solar PV installations in sun-rich regions (IEA, 2023).

PPAs are fundamental for the modern electricity market, allowing businesses to secure low-carbon energy at stable prices while supporting renewable energy development (IEA, 2023 & Siapartners, 2025).

#### 4.2.3. Electricity markets

Electricity markets are systems that facilitate the buying, selling, and trading of electricity between producers, suppliers, and consumers. These markets are essential for balancing supply and demand while ensuring price efficiency, grid stability, and fair competition. Electricity markets are typically divided into different timeframes, ranging from long-term contracts to real-time transactions (IEA, 2022).

**Market structure and components**

Electricity markets operate through different segments, each serving a specific function in optimizing energy generation and distribution. These include:

- **Wholesale electricity markets**: they enable large-scale trading of electricity between generators and suppliers before it reaches consumers. They are typically operated by market exchanges or independent system operators (ISOs). The main market segments include:
  - Day-ahead market (DAM): Participants bid and offer electricity one day before physical delivery. Prices are set based on supply and demand forecasts.
  - Intraday market (IDM): Allows market participants to adjust their energy positions closer to the time of delivery. It includes two types:
    - ✓ Discrete intraday auctions: These are scheduled auctions that occur at specific intervals within the trading day, allowing market participants to make adjustments in blocks.
    - ✓ Continuous intraday market: Trading occurs continuously up until shortly before delivery, enabling real-time corrections based on updated forecasts and grid conditions.
- **Retail electricity markets**: Retail electricity markets allow end consumers (households, businesses, industries) to purchase electricity from suppliers. Liberalized markets enable consumers to choose their supplier based on price, service quality, and energy mix (e.g., renewable vs. conventional sources).
- **Ancillary services markets**: These markets ensure grid stability and reliability by providing services such as:
  - Frequency regulation: Balancing electricity supply and demand to maintain grid frequency.
  - Reserve markets: Holding generation capacity in reserve to respond to unexpected demand spikes or supply shortages (Joskow, 2021).

**Electricity market challenges and evolution**

While electricity markets have improved efficiency and competition, they face several challenges, including:

- **Market volatility**: Fluctuations in energy prices due to unpredictable demand and supply conditions.

- **Integration of renewable Energy**: The variability of wind and solar energy requires new market mechanisms for flexibility and storage.
- **Grid congestion**: Transmission constraints can lead to localized price variations and inefficiencies.
- **Regulatory and policy uncertainty**: Market structures and rules differ across regions, affecting investment incentives and long-term planning (Wang et al., 2024).

Electricity market developments, improvement and diversification are key for securing energy distribution, competitive pricing, and system reliability. As the energy transition accelerates, market structures must adapt to accommodate increasing shares of renewable energy, demand-side participation, and grid modernization efforts.

#### 4.2.4. Self-consumption

Self-consumption refers to the direct use of electricity generated from renewable energy sources by a producer, typically at the same location where it is generated. This concept has gained significant traction as individuals, businesses, and industries seek to reduce energy costs, increase energy independence, and contribute to decarbonization efforts (IEA, 2022).

##### Types of self-consumption

Self-consumption can take various forms depending on the setup and objectives of the producer-consumer. It is typically categorized into individual and collective self-consumption. The first involves the generation and consumption of electricity by a single entity, such as a household or business, using renewable sources like solar photovoltaic (PV) panels or small wind turbines (IEA, 2016). Collective self-consumption, on the other hand, refers to multiple consumers (e.g., households, businesses) sharing electricity from a common renewable energy source within a localized area, such as a residential complex or industrial park. This form may involve a specific legal and operational framework that allows for energy sharing among participants. A third category is that of energy communities, where groups of individuals or organizations collectively generate, share, and consume renewable energy. These communities are often supported by regulatory frameworks that promote decentralized energy systems and provide the governance and organizational structure necessary for shared energy use (IEA, 2022).

##### Benefits of self-consumption

- **Cost savings**: Reduces electricity bills by using on-site generation rather than purchasing from the grid.
- **Grid independence**: Minimizes reliance on centralized electricity supply, increasing energy security.
- **Environmental benefits**: Lowers carbon footprint by prioritizing local renewable energy sources.
- **Grid support**: Can reduce congestion and peak demand on the grid when combined with storage solutions (IEA, 2022).

##### Challenges and barriers

- **Intermittency of renewable energy**: Solar and wind generation depend on weather conditions, requiring storage or grid support for reliability.
- **Regulatory and financial constraints**: Incentives, subsidies, and policies vary by country, influencing the financial viability of self-consumption projects.
- **Technical integration**: Requires investments in smart meters, inverters, and storage systems to optimize consumption and ensure stability (IEA, 2022).

Self-consumption is expected to grow as technological advancements in energy storage, smart grids, and demand-side management improve efficiency and economic feasibility. Regulatory frameworks are also evolving to support decentralized energy production, allowing consumers to participate more actively in energy markets (IEA, 2022).

#### 4.2.5.Planning

Planning in electricity markets refers to the structured process of forecasting, designing, and implementing strategies to ensure reliable, cost-effective, and sustainable energy generation, transmission, and consumption. Effective planning is critical for balancing supply and demand, integrating renewable energy, and maintaining grid stability in evolving market conditions (IEA, 2022).

**Types of planning in energy markets**

- **Short-Term Planning**
  - Involves real-time grid operations, market adjustments, and demand-response strategies.
  - Ensures immediate stability and optimal energy dispatch based on current conditions.
- **Medium-Term Planning**
  - Focuses on demand forecasting, capacity adequacy, and investment needs over the next few years.
  - Helps optimize energy resources while accounting for policy changes and market fluctuations.
- **Long-Term Planning**
  - Aims to achieve energy sustainability and resilience by incorporating future trends in demand, technology, and decarbonization.
  - Ensures that infrastructure development aligns with energy transition goals and regulatory frameworks (IEA, 2022).

**Challenges in planning**

Planning is key in the prospective of the future energy landscape but, at the same time, it holds many challenges. Planning means dealing with uncertainty such as price volatility and fluctuating electricity demand, which complicates long-term investment decisions. The variability of renewable generation and the subsequent need of forecasting bring challenges in terms of requirement of advanced modelling and forecasting techniques (IEA, 2024). Finally, the ongoing and rapid changes in government policies and subsidy schemes can impact market confidence and investor interest.

Planning remains a foundation of effective electricity market operation, ensuring a stable energy system in an era of rapid technological and environmental transformation.

#### 4.2.6.Demand-side response (DSR) and peak shaving products

Demand-Side Response (DSR) refers to mechanisms that allow electricity consumers to adjust their power consumption in response to market signals, grid needs, or price incentives. It plays a crucial role in improving grid stability, reducing electricity costs, and supporting the integration of renewable energy sources. DSR helps mitigate supply-demand imbalances by either shifting or reducing electricity consumption during peak periods.

Peak shaving refers to specific DSR strategies designed to reduce electricity demand during peak hours when grid stress and energy prices are highest. By flattening demand peaks, peak shaving enhances grid efficiency and reduces reliance on expensive peaking power plants.

### Types of demand-side response

- **Price-Based DSR**: Consumers adjust their consumption in response to dynamic electricity prices
  - Time-of-Use (ToU) pricing: Different electricity prices apply depending on the time of day, encouraging consumers to shift consumption to off-peak hours.
  - Critical Peak Pricing (CPP): During identified critical peak times, the price per kilowatt-hour of electricity is much higher (often 2-3 times higher than normal). The high prices during critical peak periods are meant to encourage consumers to reduce their consumption or shift it to off-peak hours, thereby alleviating stress on the electricity grid.
  - Real-Time Pricing (RTP): Prices fluctuate based on wholesale market conditions, allowing consumers to adjust their usage accordingly.
- **Incentive-Based DSR**: Consumers are financially rewarded for reducing demand in response to grid operator requests:
  - Interruptible load programs: Large consumers agree to reduce their electricity use when requested.
  - Capacity markets participation: Consumers commit to reducing demand when the system is constrained.
  - Ancillary services: Consumers provide frequency regulation or other grid-balancing services by modulating demand (Wang et al., 2015).

### Peak shaving products and mechanisms

- **Battery Energy Storage Systems (BESS)**: Store excess electricity during low-demand periods and discharge during peak times to reduce grid stress.
- **Automated demand management systems**: Smart technologies and IoT solutions enable real-time load adjustments based on grid needs.
- **On-site generation and microgrids**: Businesses and industries use their own renewable generation (e.g., solar PV, CHP) to reduce dependency on the grid during peak hours (Rizvi et al., 2023).

#### 4.2.7. Energy contracts

Energy contracts are legally binding agreements between energy producers, suppliers, and consumers that define the terms of energy procurement, pricing, and delivery. These contracts play a crucial role in electricity markets by providing stability, reducing risks, and ensuring financial viability for market participants.

### Types of energy contracts

Energy contracts can be categorized based on their duration, structure, and market participation:

- **Long-term contracts**
  - Power purchase agreements (PPAs): Agreements between electricity producers and buyers (corporations, utilities, or governments) that secure energy supply at predetermined prices for 10-25 years (Siapartners, 2025).

- Contracts for difference (CfDs): Mechanisms that stabilize revenue for renewable energy producers by guaranteeing a fixed price for electricity (ENTSO-E, 2024).
- Capacity market contracts: Agreements ensuring that generators or demand-side resources provide electricity when required to maintain system stability (IEA, 2022).

**Short-term contracts**

- Spot market contracts: Buyers purchase electricity in real-time or day-ahead markets based on current demand and supply conditions (IEA, 2022).
- Bilateral agreements: Direct contracts between producers and consumers negotiated outside market exchanges for flexible and customized energy supply (IEA, 2022).
- Intraday trading agreements: Contracts allowing energy trading within the same day to adjust for demand fluctuations and unexpected generation issues (ENTSO-E, 2025)

**Retail energy contracts**

- Fixed-rate contracts: Consumers pay a constant price per unit of energy over the contract duration, providing price certainty.
- Variable-rate contracts: Energy prices fluctuate based on market conditions, exposing consumers to potential savings or higher costs.
- Green energy contracts: Consumers opt for electricity sourced from renewable energy, often at a premium price, to support sustainability goals.

**Benefits and challenges of energy contracts**

Energy contracts have many different benefits, such as providing financial stability to both producers and consumers, reducing exposure to market price volatility, encouraging infrastructure investment and supporting decarbonization. However, they also face different challenges. Energy contracts must be carefully structured, otherwise they can lead to market distortion. Rapidly changing policies can impact contract viability as well, considering that contracts must constantly adapt to the latest changes in policies. Lastly, future contracts may evolve to incorporate demand-side flexibility and dynamic pricing mechanisms to better adapt to renewable energy variability (Kirl et al., 2022).

#### 4.2.8. Grid connectivity

Cross-border electricity grid connections play a crucial role in today's energy markets, especially as countries work to integrate their electricity systems for greater efficiency and security. These interconnections allow electricity to flow between neighbouring countries, helping to balance supply and demand across borders. By linking different national grids, countries can share electricity in times of high demand or when local generation falls short, preventing blackouts and ensuring a more reliable power supply.

In addition to improving reliability, cross-border connections create opportunities for countries to access cheaper electricity, as they can buy power from regions with lower costs or excess supply. This also promotes competition in the market, which can lead to lower electricity prices for consumers. Another important benefit is the ability to better integrate renewable energy sources, such as wind and solar, which can be intermittent. If one region has a surplus of renewable energy while another region is facing a shortfall, cross-border connections help smooth out these fluctuations and make renewable energy use more stable and reliable.

Moreover, cross-border electricity infrastructure enhances overall energy security by providing countries with more options in terms of energy supply. In case of a local energy crisis or infrastructure failure, interconnected systems can provide backup power and reduce the impact of disruptions. As the world transitions to cleaner energy, the need for strong and reliable grid connections between countries is becoming even more important, not only for supporting renewable energy but also for ensuring a more resilient and sustainable energy future (European Commission, 2017).

#### 4.2.9. Capacity markets/mechanisms and flexibility reserves

Capacity markets and flexibility reserves are key mechanisms designed to ensure grid reliability and balance electricity supply and demand. These mechanisms provide incentives for power producers and demand-side resources to guarantee electricity availability during periods of system stress. As renewable energy penetration increases, capacity mechanisms and flexibility reserves become even more crucial to address variability and ensuring grid stability (European Commission, 2025).

**Capacity markets/mechanisms**

Capacity markets function as auction-based systems where electricity providers commit to supplying power during peak demand periods. These markets help prevent blackouts, reduce price volatility, and enhance system security. The key aspects of capacity markets include (Cramton et al., 2013):

- **Forward auctions**: Capacity obligations are procured years in advance to allow for investment planning.
- **Obligation contracts**: Participants commit to delivering capacity when needed, or face penalties for non-compliance.
- **Technology neutrality**: These markets allow different technologies to operate such as: thermal generation, demand response, and energy storage compete in ensuring system reliability.
- **Locational signals**: Some capacity mechanisms include location-based pricing to incentivize capacity in areas with higher grid constraints.

There are different types of capacity mechanisms:

- **Centralized capacity markets**: Organized by system operators where resources bid to provide capacity for future periods (e.g., PJM, UK Capacity Market) (Bushnell et al., 2017).
- **Decentralized capacity obligations**: Utilities or large consumers procure capacity directly through bilateral contracts.
- **Strategic reserves**: Capacity kept on standby to be dispatched during extreme supply shortages.

**Flexibility reserves**

Flexibility reserves ensure that the grid can adapt to fluctuations in generation and consumption. These reserves play a very important role in mitigating imbalances and maintaining frequency stability. They are categorized into:

- **Primary reserves (Frequency Containment Reserves - FCR)**: Activated automatically within seconds to stabilize frequency deviations.
- **Secondary reserves (Frequency Restoration Reserves - FRR)**: Adjust supply-demand imbalances within minutes to restore nominal frequency levels.
- **Tertiary reserves (Replacement Reserves - RR)**: Provide additional backup to replace exhausted primary and secondary reserves.
- **Fast reserve and inertia response**: Includes battery storage and flywheels that can provide immediate response to grid disturbances.

**Benefits of capacity mechanisms and flexibility reserves**

These mechanisms are key in ensuring sufficient electricity supply to meet demand, especially during critical times. By securing future generation capacity, they help maintain energy security over the long term. They also help keep electricity prices stable by preventing extreme price spikes when demand surges. Additionally, they support the integration of renewable energy by providing backup power to offset fluctuations from sources like wind and solar. Finally, they encourage investment in new energy projects, including storage solutions, by creating financial incentives for participation in grid balancing efforts and improving overall market efficiency (Gielen et al., 2019).

#### Challenges and future scenarios

One of the biggest challenges with capacity markets and flexibility reserves is making sure they are designed in a way that avoids unnecessary costs while still ensuring reliability. Finding the right balance between incentivizing investment and avoiding over-subsidization is crucial. Another issue is the difference in regulations between countries, which makes cross-border electricity trade and cooperation more complicated. As more countries move toward decarbonization, capacity mechanisms will need to evolve to prioritize cleaner and more flexible solutions rather than relying on conventional fossil-fuel power plants.

Looking ahead, advancements in technology will help improving these markets. The integration of AI and smart energy management systems will make capacity planning more efficient. At the same time, the growing use of battery storage and demand-side response solutions will provide new ways to enhance flexibility. As electricity grids continue to evolve, capacity markets and flexibility reserves will remain essential for keeping power systems resilient, cost-effective, and aligned with global clean energy goals (Sousa et al., 2025).

### 4.3 Contributions of market instruments to objectives

As mentioned in section 2.1, the electricity market design reform has a set of overarching goals, which are achieved through the contribution of measures, using different market instruments. The contribution of each measure to these goals varies, each contributing to unlock barriers, in order maximize the likelihood of successfully achieving the reform's goals.

Understanding how each measure contributes to the objectives is essential for assessing the intensity of its impact and determining whether and how the measure can be modelled. The overarching goals of the reform will be reflected in the outcomes observed in the results, while the specific contributions to objectives will guide how individual measures are represented in the modelling process. During the literature review, many contributions to objectives were identified. Although the list provided here is not exhaustive, it gives examples of contributions that can typically be expected from the measures.

- **Lower investment risks:** Several measures aim to provide greater revenue stability for asset owners. Although this stability may reduce potential profits during certain periods, it also protects against very low revenues during others, resulting in a more consistent revenue stream over time. In turn, this increased predictability lowers investment risks and strengthens investment signals, and encourages greater investment in renewable energy, thereby supporting the growth of the sector. While most measure aim at providing revenue stability for renewable assets, the reform also introduces the possibility to set up support schemes for energy storage. Those support scheme can also increase the revenue stability for storage assets, eventually also increasing investment in those types of assets.
- **Lowered energy bill:** One of the key objectives of the electricity market design reform is to protect consumers from extreme price volatility. Accordingly, the reform introduces measures designed to shield consumers from high energy bills. For instance, the requirement for Member States to redistribute revenues from two-way CfDs back to consumers — either directly through energy bill reductions or indirectly through investments in infrastructure or initiatives that lower future costs — ensures that consumers benefit from more affordable energy.

**Enhanced cross border exchanges:** The reform emphasizes that any reform on the market should contribute to a more integrated European electricity network. This principle is reflected in measures such as requiring Member States to regularly assess their flexibility needs to improve coordination at the European level. Additionally, the reform seeks to remove barriers to cross-border (PPAs). Better coordination and expanded opportunities for cross-border exchanges will increase electricity flows between European countries.

## 4.4 Switzerland's market and its evolution

### 4.4.1. General aspects

The electricity system of Switzerland features a unique governance structure characterized by a partial unbundling (Figure 4). Major electricity producers include companies such as ALPIQ and AXPO, while Swissgrid AG owns and operates the Transmission System Operator (TSO). In contrast, distribution and supply activities are typically managed at the cantonal or municipal level, often by vertically integrated utilities that also own generation assets. Regulatory oversight is provided by Elcom (the Swiss Federal Electricity Commission), which ensures the proper functioning of the electricity market and promotes transparency and non-discriminatory access for all market participants (Elcom, 2025) In many cases, distribution and supply are bundled, meaning that utilities are responsible for both grid operation and generation assets.

The Swiss electricity market is partially liberalized. Large consumers, typically those with annual consumption exceeding 100 MWh have the right to choose their electricity supplier. However, small consumers (e.g., households and small businesses) cannot choose suppliers and have a universal service supply with their local supplier. This regulation is currently under review (with Manterlerlass and EU dialogue) and may be subject to future reform leading to full liberalization.

The electricity market of Switzerland is organized through key markets, similar to those in the EU, such as day-ahead and intra-day markets, along with participation in balancing services. Switzerland participates in EU markets (e.g., EPEX) through its interconnections with neighbouring countries.

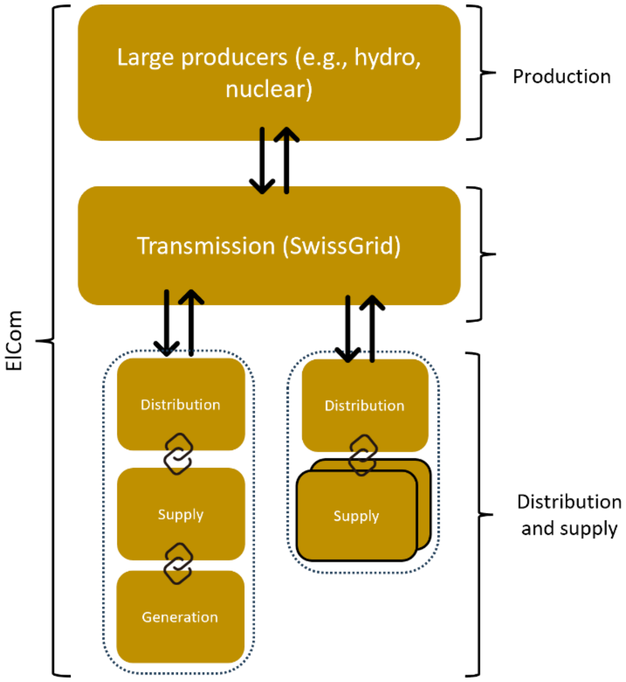


Figure 4. Configuration of the Swiss electricity system, illustrating the key chain (producers, transmission, distribution, and suppliers) monitored by the federal energy regulator, ElCom.

#### 4.4.2. Agreement between the EU and Switzerland

On 20 December 2024, a formal political agreement between was reached between the EU and Switzerland, marking a significant step toward further integration of Swiss electricity system within the EU internal energy markets. If the agreement fully materializes, Switzerland will gain full access to EU electricity markets. This would allow Swiss electricity suppliers and grid operators to participate in key market platforms (wholesale and balancing) such as MARI (Manually Activated Reserves Initiatives), PICASSO (Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation). This would offer several benefits for the Swiss energy system, including improved grid stability and operational efficiency, enhanced coordination in grid planning between Swissgrid and EU TSOs (e.g., through joint reserve planning), and increased security of supply. Importantly, the agreement implies no restrictions on interconnection capacities between Switzerland and its neighbouring countries. The latest adequacy report by Swissgrid AG (Swissgrid, 2025) estimates allocation of final interconnection capacities that will be disclosed in an upcoming study in May/June 2025.

With regard to market liberalization, the agreement foresees that all electricity consumers in Switzerland will have the right to freely choose their supplier, i.e. that the Swiss electricity market will be fully liberalized. Nevertheless, consumers will retain the option to remain under the regulated basic supply. Furthermore, the agreement is expected to lead to enhanced renewable energy deployment and support schemes, including mechanisms such as Contracts for Difference (CfDs) and Power Purchase Agreements (PPAs). Given that the EU and Switzerland share the same ambition to reach the net zero carbon target, Swiss support mechanisms should be compatible with EU law.

At this stage, the agreement has been reached at the highest political level between the EU and Switzerland. Initial responses have been largely positive, with support expressed by stakeholders such as economiesuisse, research community, NGOs, and most political parties. However, opposition has been voiced by Swiss People's Party (UDC/SVP) and concerns have also been raised by UNIA and Swiss Trade Union Federation (SGB). The detailed content of the agreement has yet to be published, and the next key challenge lies in its domestic implementation, given Switzerland's complex multi-layered governance structure.

## 4.5 Manterlerlass

In Autumn 2023, the Swiss Federal Act introduced a comprehensive legislative package named Secure Electricity Supply Based on Renewable Energy (BFE, 2025). This set of packages referred to as Mantelerlass, was subject to a national vote and was approved by the Swiss population on 9th June 2024. The Manterlerlass represents an extensive set of packages that affect the entire chain of the electricity sector from generation to consumption. Its core objective is threefold:

- To provide incentives for the expansion of renewable energy capacities (see Section 4.5.1)
- To enhance security of electricity supply, particularly during winter months (see Section 4.6)
- To promote energy efficiency measures (see Section 4.8)

This package provides the foundation for the future planning of the Swiss energy system and reflects the country’s commitment to reach the climate and energy security goals toward decarbonization.

### 4.5.1.Support for renewable capacity expansion

Under the new Energy Act (Manterlerlass), Switzerland has set an ambitious target to expand electricity generation from renewable sources (excluding hydroelectric) by at least 45 TWh per year by 2050. To achieve this goal, illustrated in Figure 5, the Mantelerlass introduces two key financial support mechanisms: investment contributions and a floating market premium:

- **Investment Contribution** (single payments) provides upfront financial support with the aim of reducing the burden on the high initial capital costs for renewables.
- The **floating market premium** (*prime de marche flottante*) acts as a variable subsidy to ensure revenue stability against price changes in the market. This scheme functions similarly to a Contract for Difference (CfD) and applies to:
    - Hydropower installations >1MW
    - Other renewable (e.g., solar, wind or biomass) installations >150 kW without self-consumption

The eligibility and application process differ by system size (see Figure 5). For example:

- Installations <100 kW must apply for the investment contribution after commissioning.
- Installations >150 kW must apply for renumeration before commission and are eligible to choose between two support schemes, i.e. Investment contribution (up to 60% of the initial capital cost) or a Floating market premium.

In addition, a minimum remuneration for producers is guaranteed:

- <30 kW: 4.6 cents/kWh
- 30-150 kW with self-consumption: 0 cents/kWh (such systems are expected to reach amortization within a few years)
- 30 and 150 kW without self-consumption: 6.7 cents/kWh
- Hydropower plants <=150 kW: 12 cents/kWh

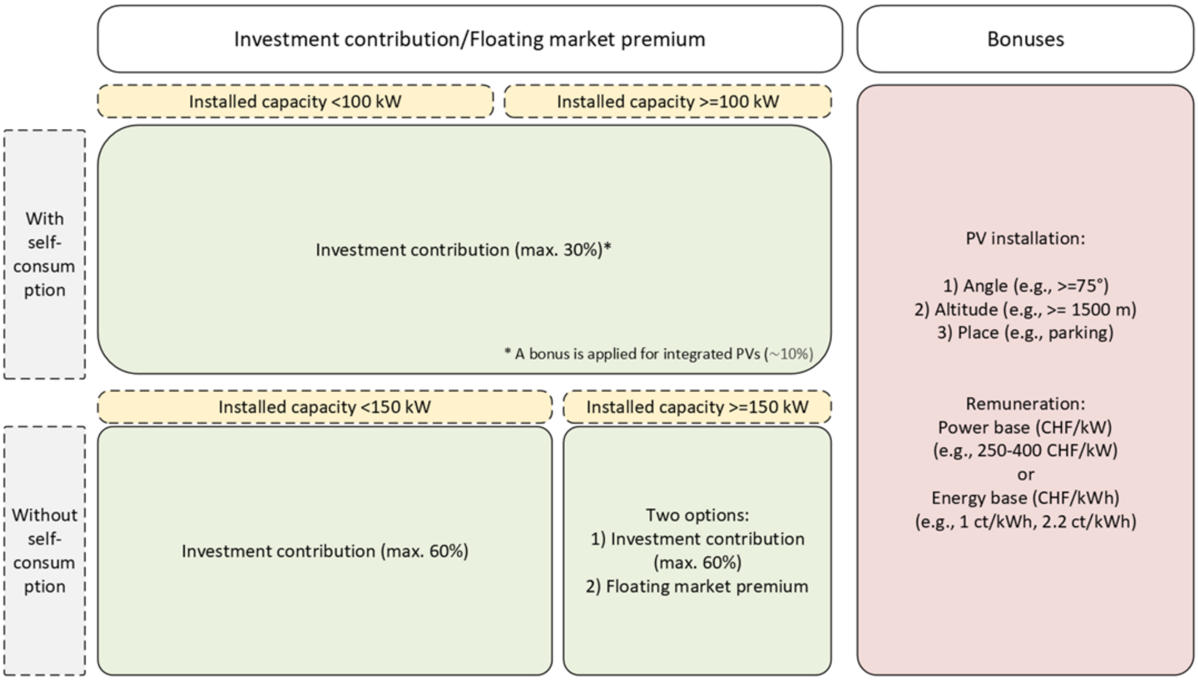


Figure 5. Two key incentive schemes (investment contribution and floating market premium) promoting the expansion of renewable energy capacity in Switzerland, under the Mantelerlass framework. Adapted from (SFOE, 2024).

How will the support scheme work?

The financial support under the Mantelerlass is funded through the Network Surcharge Fund (Netzzuschlagsfonds, NZF), which is financed via a levy of 2.3 CHF/MWh on electricity consumption. This funding mechanism will remain unchanged under the revised Energy Act. Should the available funds from the NZF be insufficient to meet support obligations, loans from the "Federal Finance Administration" may be utilized to cover the shortfall. These loans are subject to a repayment period of no more than seven years, ensuring financial stability of the support scheme framework for at least some time.

### 4.5.2. Floating market premium

As mentioned above, under the Manterlerlass, large scale renewable energy plants may benefit from a floating market premium (see Figure 6), which functions similarly to CfDs. This premium is applied on a production basis and settled quarterly (financially). The financial settlement depends on the captured curves which depends on typical profile production of technologies and day-ahead prices during those hours, resulting in the quarterly reference prices as illustrated in Figure 7. The design of the floating market premium support schemes proposed is illustrated in Figure 8 and described in detail as follows.

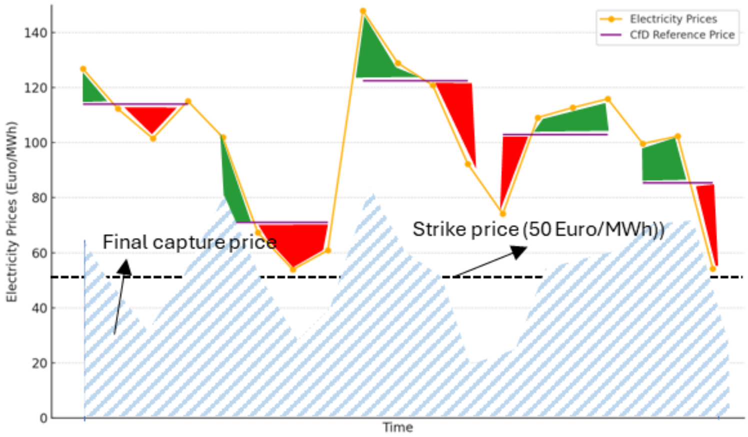


Figure 6. A stylized conceptual on how the floating market premium will operate in Switzerland under Manterlerlass

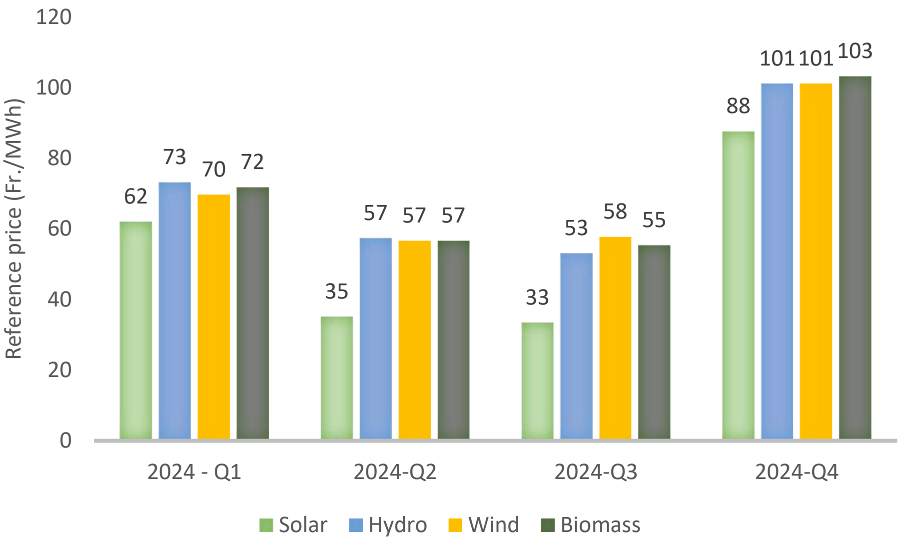

Figure 7. Reference prices on the quarterly basis depending on the technology (solar, hydro, wind, and biomass) in Switzerland for 2024, source: BFE, 2025.

| Eligibility | Support schemes | Compensation | Strike price | Duration | Bonuses |
|---|---|---|---|---|---|
| • Based on the capacity (e.g., capacity, year of installation) | • Floating market premium (quarterly reference)<br>• Investment contributions | • A clawback or payback is applied (e.g., in case of floating market premium) | • Costs of reference installations<br>• Auctions | • 20 years | • Bonuses are applied if plants meet certain criteria |

Figure 8. The key steps applied for floating market premium in Switzerland.

The design of the floating market premium scheme under Mantelerlass is structured around six key pillars, aimed to encourage efficient deployment of renewable expansion.

1. **Eligibility and minimum payment:** it depends on the technology and installed capacity, the installed capacity (>1 MW for hydro and >150 kW for others) and electricity produced fed into the grid without self-consumption.
2. **Support schemes:** Producers have the option to choose between floating market premium or investment contributions.
3. **Compensation and clawback mechanism**: the compensation includes a clawback provision. Producers receive the difference between the predetermined strike price and the actual market price. The strike price is based on the reference cost by technology (e.g., PV, wind, hydro) which results from competitive auctions for large-scale projects.
4. **Contract duration**: Contracts under the floating market premium scheme are valid for 20 years.
5. **Bonuses:** To promote installations on specific sites, location and design-based bonuses are granted, e.g., in parking places or for titled PV or façade (e.g., >75°; 250 CHF/kW à 400 CHF/kW).

### 4.5.3. PPAs in Switzerland

Power purchase agreements (PPAs) are still in an early stage in Switzerland. To date, only a limited number of PPAs have been publicly announced within Switzerland. PPAs are typically signed between producers and consumers or energy utilities as shown in Figure 9. For instance, two available PPAs in Switzerland include: a 2.2 MW solar PPA between Axpo & IWB and the Swiss retailer Denner, and a PPA between BKW and Denner, covering approximately 6 GWh per year (AXPO, 2022; BKW, 2021; BKW, 2023). While domestic PPAs remain limited, some domestic utilities are actively engaged in international PPA markets. For instance, BKW has signed over 500 MW in PPAs with producers across Europe. In 2023, BKW entered into a long-term solar PPA with MaxSolar.

PPAs are expected to gain further attention in the Swiss context under Mantelerlass. The revised Energy Act specifies that at least 20% of electricity base demand must be covered by domestically produced energy, which should be sourced from local generation facilities or prosumers and procured by Swiss energy operators. PPAs are seen as a potential mechanism to fulfil this requirement. However, this obligation remains subject to change which may depend on the future developments in PPA pricing trends both within Switzerland and in neighbouring countries. The evolution of prices may influence the competitiveness and attractiveness of PPAs as a procurement strategy for the Swiss market.

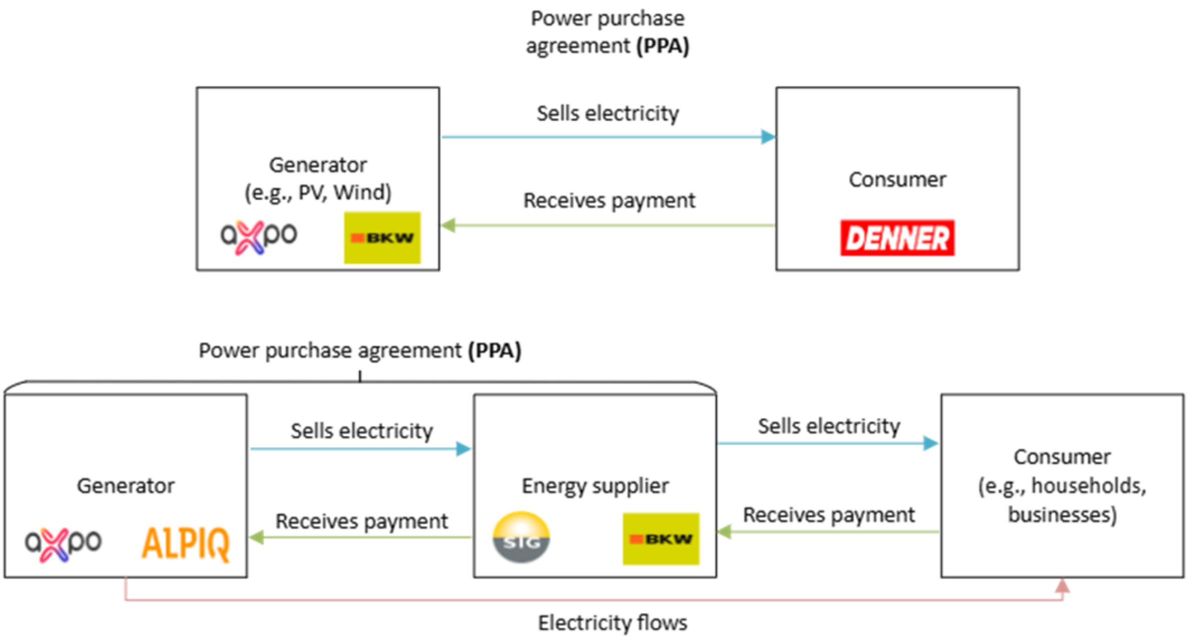


Figure 9. Stylized representation of two types of two types of Power Purchase Agreements (PPAs) in Switzerland. On top, direct PPA between the generator (seller) and the consumer (buyer). On bottom, PPA between the generator (seller) and an energy operator (buyer).

## 4.6 Winter reserve mechanism (OIRH)

One of the key pillars of the Mantelerlass is the enhancement of energy security, particularly during the winter season, when electricity demand in Switzerland is higher and domestic production is lower. In this context, the Winter Reserve Ordinance (Ordonnance sur une réserve d'hiver, OIRH) (Swiss Federal Council, 2024) introduces measures aimed at reducing dependence on electricity imports by setting minimum storage threshold for hydropower reservoirs. Under this framework, Elcom is responsible for calculating the required hydropower reserves for the winter period, defined as 1 February to 12 May.

The objective is to ensure that hydropower plants maintain sufficient energy in reserve for system needs, particularly during end of the winter, when storage levels are typically at lower level. At the beginning of the winter season, hydropower plants can generally meet peak demand; however, by the end of the season, storage reservoirs tend to be at lower levels. The target storage volume is estimated at approximately 300 GWh, with a margin of ±100 GWh. Hydropower plants providing this service receive a fixed compensation, calculated based on the opportunity cost (i.e., as if they would revenue from selling at the market). The associated cost for this service is then allocated to consumers through electricity tariffs. This applies to all hydropower plant with a storage capacity greater than 10GWh. This includes 93 out of 200 hydropower plants in Switzerland, representing 201 out of the total 8762 GWh of storage capacity.

## 4.7 Transmission and distribution (OApEL)

The Ordinance on the Expansion of Electricity Infrastructure (Ordonnance sur l'amenagement des reseaux electrique, OApEL) (Swiss Federal Council, 2024) introduces several measures to support the integration of renewable energy sources and storage in the Swiss electricity system. To encourage grid expansion for renewable integration, especially at the distribution level, the ordinance supports for instance connection grid infrastructure (59 CHF/kW) for new renewable installations. Furthermore, costs related to grid reinforcement will be socialized across all grid users, regardless of location. To further promote system flexibility, the OApEL incentivizes energy storage facilities by exempting them from grid usage fees. This includes storage technologies such as battery storage systems, vehicle-to-grid (V2G), and power-to-x (P2X) technologies.

## 4.8 Energy efficiency (OEne)

The Ordinance on Energy (Ordonnance sur l'energie, OEne) outlines several measures aimed to promote energy efficiency (Swiss Federal Council, 2024). A key target is introduced under OEne, namely annual electricity savings of 2 TWh/year by 2035. This is to be accomplished through efficiency programs led by utilities and upgrades in end-use technologies such as lighting systems, appliances, ventilation and cooling installations. Furthermore, to incentivize flexible consumption based on market conditions, dynamic electricity tariffs (e.g., 15-minute granularity) are to be introduced.

Additionally, the ordinance also promotes decentralized electricity generation and self-consumption through support of self-consumption groups (Regroupement dans la Consommation Propre – RCP), allowing multiple consumers to share locally produced electricity through introduction virtual self-consumption groups, without requiring physical connection.

# 5 Outlook (Shortlist of measures)

As a result of the literature review prepared in WP1, a shortlist of measures to be modelled has been prepared. The shortlisting decisions also account for the modelling possibilities in order to create a realistic shortlist from the start. For each objective detailed in Section 3.1 for which measures were kept, the general direction of the reform, its purpose and examples of instruments and measures are given, followed by the selection of measures for that objective. All measures described for Switzerland in section 4.5 and 4.8 will need to be reflected in the GRIMSEL model in one way or the other (possibly with some exceptions), whereas the shortlist presented in this chapter refers to modelling in Artelys Crystal Super Grid.

## 5.1 RES development

The development of renewable energy capacities in Europe is one of the major objectives of reforming the electricity market. The measures that contribute to this objective rely mainly on the following instruments:

- **Long term contracts**: CfDs, PPAs, etc.
- **Wholesale market:** Short- and long-term contracts
- **Grid connection:** The physical connection of renewable capacities to the grid

In order to contribute to the overarching objective of increasing the penetration of renewables into the grid, the measures aim to:

- **Strengthen investment signals:** The current design of electricity markets is often criticized for not providing strong enough investment signals for renewable energy sources. For instance, a key issue is self-cannibalization, where an increase in renewable capacity leads to lower market prices during peak production periods, reducing producer revenues. Considering also the high price volatility, this raises the investment risk. To strengthen investment signals, measures promote the use of long-term contracts such as CfDs and PPAs. These instruments offer more revenue stability, thereby lowering financial risk and encouraging investments in renewables.

- **Market integration:** Ensuring market integration of renewables helps align their production with system needs and unlocks additional revenue streams. For instance, the use of partial CfDs, where only part of a renewable asset's capacity is covered by a long-term contract, while the remainder is open to markets, ensures that a least some production is incentivized to respond to price signals. Moreover, another key market integration measure is the reduction of the cross-zonal intraday market date closure to 30 minutes before delivery by 2026 (instead of 60 minutes according to today's practices). This change supports the maximization of trading opportunities via access to a liquid market as closely as possible to the time of delivery of the electricity.
- **Integration into the grid:** Physical connection to the grid remains a major bottleneck for new renewable projects. To address this, measures aim to avoid administrative delays and facilitate connection to the grid. This includes requiring TSOs and DSOs to provide regular updates on the status of grid requests.

In the context of the ongoing electricity market design reform aimed at supporting the development of renewable energy sources (RES), the selected measures related to this objective are listed in **Error! Reference source not found.**. As the project progresses and the energy policy landscape continues to evolve, this list may be revised. Some measures may ultimately be excluded from modelling if they are considered no longer relevant.

Table 1. Shortlist of measures for RES development

| Measure | Impact of the measure considered |
|---|---|
| Widespread implementation of two-ways CfDs | Stability of revenue for asset owners which leads to a lower investment risk |
| Partial CfD coverage | Market integration of RES |
| CfD contracts for existing low carbon assets (here we consider nuclear plants) | Stability of revenues for asset owners which leads to a lower investment risk |

## 5.2 Security of supply/System flexibility

To deal with the variability of demand and production, the system requires a certain amount of flexibility, especially in times of peak demand. Historically, fossil fuel technologies have been relied upon to meet peak demand. The electricity market design reform seeks to phase out the use of fossil fuel solutions for flexibility needs, favour instead the use of fossil-free solutions such as demand side response (DSR) and batteries, while maintaining the grid's flexibility capabilities. Measures serving this objective mainly rely on the use of the following instruments:

- **Clean energy storage:** Batteries, hydro-storage, etc.
- **Demand side response:** The ability of demand to lower and shift when needed
- **Peak shaving products:** Market-based tools that enable market participants to reduce their electricity consumption during peak demand periods in exchange for compensation
- **Short-term electricity markets**
- **Capacity mechanisms:** Measure to remunerate capacity resources for security of supply services. It is mostly introduced if a resource adequacy concern has been identified.

Overall, the measures relate to:

- **Enabling flexible consumers:** To provide more flexibility to the grid, the possibility of consumers to use electricity in a flexible way must be unlocked, and consumers need to have access to market signals and incentives to shift or lower their consumption. A set of measures aiming to accelerate the deployment of smart meters, as well as to promote incentives to lower and/or shift consumption are therefore part of the reform.

- **Restriction of capacity mechanisms:** Participation in capacity mechanisms is subject to certain criteria. Criteria relating to $CO_2$ emission and technical performances can be modified to ensure that participation is restricted to flexible fossil-free technologies. The introduction of a minimum procurement target for desirable characteristics during the auction is also under discussion within the REMA consultation.
- **Support schemes for storage and DSR:** When a capacity mechanism is not in place or a capacity mechanism is not sufficient to meet flexibility needs, Member states may set up specific support schemes for energy storage and demand response.

Moving forward, the shortlist of measures will include the possibility of support schemes, for instance in the form of a capacity mechanisms for energy storage, which should provide additional revenue to assets such as batteries and hydropower. Additionally, the expected changes from Manterlerlass will be integrated along with the shortlist of measures in EU.

# 6 National and international cooperation

UNIGE and Artely are the only partners in the MOSES project. No national or international coopera-tion is foreeen with any further partners.

# 7 Publications and other communications

So far, no publictions have been prepared.

# 8 References

ENTSO-E, “Sustainable Contracts for Difference (CfDs) Design,” 2024

ACER and European Environment Agency, Flexibility solutions to support a decarbonised and secure EU electricity system, 2023

David N. Simon, L. Diaz Anadon, “Power price stability and the insurance value of renewable technologies,” Nature Energy, p. 329–341, 2025.

International Energy Agency (IEA), “Renewable Energy Market Update Outlook for 2023 and 2024,” 2023.

SIAPARTNERS, alterna énergie, group sorégies, “A practical guide to PPAs,” 2023.

International Energy Agency (IEA), “Electricity Market Report,” 2022

P. L. Joskow, “From hierarchies to markets and partially back again in electricity: responding to deep decarbonization commitments and security of supply criteria,” MIT Center for Energy and Environmental Policy Research.

G. Wang, E. Sbai, L. Wein, MS Sheng, “The impact of renewable energy on extreme volatility in wholesale electricity prices: Evidence from organisation for economic co-operation and development countries,” Journal of Cleaner Production, 2024.

International Energy Agency (IEA), “Unlocking the Potential of Distributed Energy Resources,” 2022.

International Energy Agency (IEA), “Introduction to System Integration of Renewables,” 2022

Y. Wang, Q. Chen, C. Kang, M. Zhang, K. Wang, Y. Zhao, “Load Profiling and Its Application to Demand Response: A Review,” Tsinghua Science and Technology, vol. 20, pp. 117-129, 2015

SSH. Rizvi, KT. Chaturvedi, ML. Kolhe, “A review on peak shaving techniques for smart grids,” AIMS Energy, vol. 11, pp. 723-752, 2023.

ENTSO-E, “Single Intraday Coupling (SIDC),”. Retrieved February, 15, 2025. Available: https://www.entsoe.eu/network_codes/cacm/implementation/sidc/.

D. Kirl, B. Couraud, V. Robu, M Salgado-Bravo, S Norbu, M. Andoni, I. Antonopoulos, M. Negrete-Pincetic, D. Flynn, A. Kiprakis, “Smart contracts in energy systems: A systematic review of fundamental approaches and implementations”, Renewable and Sustainable Energy Reviews, April 2022, vol. 158

European Commission, “Towards a sustainable and integrated Europe,” 2017

European Commission, “Capacity mechanisms,” [Online]. Available: https://energy.ec.europa.eu/topics/markets-and-consumers/capacity-mechanisms_en.

P. Cramton, A. Ockenfels, S. Stoft, “Capacity Market Fundamentals,” Economics of Energy & Environmental Policy, vol. 2, no. 2, 2013.

J. Bushnell, M. Flagg, E. Mansur, “Capacity Markets at a Crossroads,” 2017.

D. Gielen, F. Boshell, D. Saygin, MD. Bazilian, N. Wagner, R. Gorini, “The role of renewable energy in the global energy transformation,” Energy Strategy Reviews, vol. 24, no. ISSN 2211-467X, pp. 38-50, 2019.

J. Sousa, J. Lagarto, F. Barata, “Impact of Demand Flexibility on Renewable Energy Integration, Backup Capacity, Storage Use and Dispatchable Generation: A Case Study for Portugal's 2030 National Energy Plan,” Energy, no. ISSN 0360-5442, 2025.

ElCom – Federal Electricity Commission. (n.d.). Duties of ElCom. Retrieved March 13, 2025, from https://www.elcom.admin.ch/elcom/en/home/the-commission/duties-of-elcom.html

Energy Science Center, ETH Zurich. (2023, May 24). White paper: Energy security in a net zero emissions future for Switzerland. ETH Zurich. https://ethz.ch/en/the-eth-zurich/energy-science-center/white-papers.html

European Commission. (2025, February 26). The Clean Industrial Deal: A joint roadmap for competitiveness and decarbonisation. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (COM (2025) 85 final). Brussels: European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025DC0085

Federal Office of Energy (BFE). (2022, April 12). Energy perspectives 2050+: Summary report (updated edition). Bern: Swiss Federal Office of Energy. https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html

Federal Office of Energy (BFE). (2025). Federal act on a secure electricity supply from renewable energy sources. Retrieved August 25, 2025, from https://www.bfe.admin.ch/bfe/en/home/supply/electricity-supply/federal-act-renewable-electricity-supply.html

Financial Times. (2024, September 14). Negative European energy prices hit record level. Financial Times. Retrieved August 25, 2025, from https://www.ft.com/content/1f94d0b4-c839-40a2-9c8d-782c00384154

News Service Bund. (2023, April 20). Electricity consumption down by 1.9% in 2022. Swiss Confederation. Retrieved November 25, 2024, from https://www.news.admin.ch/en/nsb?id=94437

Pexapark. (2025, March). EIB's PPA guarantee system under the Clean Industrial Deal: How it works. Pexapark. https://pexapark.com

Schwarz, M., Boubat, M., Upadhyay, A., Geistlich, P., Garrison, J., Schaffner, C., & Savelsberg, J. (2024, March). The role of synthetic fuels in a net-zero emission electricity system in Switzerland: Final report. ETH Zurich, Energy Science Center.

Swiss Federal Council. (2024, November 20). Winter Reserve Ordinance (Ordinance on the Establishment of an Electricity Reserve for Winter) (RO 2024 693). Bern: Swiss Federal Council. Retrieved August 25, 2025, from https://www.fedlex.admin.ch/eli/oc/2024/693/fr

Swiss Federal Council. (2024, November 19). Ordinance on Electricity Supply (OApEl) (RO 2024 706). Bern: Swiss Federal Council. Retrieved August 25, 2025, from https://www.fedlex.admin.ch/eli/oc/2024/706/fr

Swiss Federal Council. (2024). Ordinance on Energy (OEne) (RO 2024 702). Bern: Swiss Federal Council. Retrieved February 16, 2025, from https://www.fedlex.admin.ch/eli/oc/2024/702/fr

Swiss Federal Office of Energy (BFE). (2024, November). Fact sheet: Support for photovoltaic installations – one-off remuneration, floating market premium and bonuses [Fiche d'information]. Bern: Swiss Federal Office of Energy.

Swissgrid. (2025, April 30). Final technical report on the "Strategic Grid 2040" project (part A) and optimisation of the grid development process and vision for the grid of the future (part B). Swissgrid Ltd.

Verband Schweizerischer Elektrizitätsunternehmen (VSE). (2022, December 13). Energiezukunft 2050 – The energy supply of Switzerland until 2050: Summary of results and foundations. VSE.

Verband Schweizerischer Elektrizitätsunternehmen (VSE). (2025, January 9). Update Energiezukunft 2050: Resilient power supply – Preparing the overall system for new realities. VSE.

ENTSO-E, & ENTSOG. (2024). TYNDP 2024 scenario results. In Ten-Year Network Development Plan (TYNDP) 2024. Retrieved March 04, 2025, from https://2024.entsos-tyndp-scenarios.eu/scenario-results/#supply

Axpo. (2022, December 2). *Grösste alpine Solaranlage der Schweiz vollständig in Betrieb*. Axpo Holding AG. Retrieved February 18, 2025, from https://www.axpo.com/ch/en/newsroom/media-releases/2022/groesste-alpine-solaranlage-der-schweiz-vollstaendig-in-betrieb.html

BKW. (2021, October 7). *Strom aus Wasserkraft: BKW und Denner gehen Partnerschaft ein*. BKW Energie AG. Retrieved February 12, 2025, from https://www.bkw.ch/de/ueber-uns/aktuell/medien/medienmitteilungen/strom-aus-wasserkraft-bkw-und-denner-gehen-partnerschaft-ein

BKW. (2023). *BKW and MaxSolar enter into long-term power purchase agreement for solar power*. BKW Energie AG. Retrieved February 13, 2025, from https://www.bkw.ch