



Interim report from 8 January 2026

Reg4Fuels

Maximizing the value of carbon-neutral fuels in
integrated energy networks through regulations



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The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.



Summary

This project investigates the role of carbon-neutral hydrogen and methane fuels in Switzerland's energy system transition to carbon neutrality by 2050. The research compares the existing Swiss and European regulatory landscapes and translates the findings into energy system modelling inputs. Using detailed energy system and grid models, it investigates the contribution of these fuels to replacing fossil fuels and providing temporal flexibility under various national and European transition pathways. Additionally, it assesses the impact of fuel supply chain evolution on electricity and energy supply security, as well as power grid resilience under extreme energy trade, climate, and weather scenarios. Finally, regulatory and policy recommendations are provided to maximize the value of carbon-neutral fuels.

Zusammenfassung

Dieses Projekt untersucht die Rolle von CO₂-neutralen Wasserstoff- und Methantreibstoffen für den Übergang des Schweizer Energiesystems zur Klimaneutralität bis 2050. Hierfür wird die bestehende schweizerische und europäische Regulierungslandschaft verglichen und zentralen Erkenntnisse in Energiesystemmodellierungsdatenübertragen. Anhand detaillierter Energiesystem- und -netzmodelle wird die mögliche Rolle dieser Brennstoffe für die Substitution fossiler Brennstoffe und für die Bereitstellung von Flexibilität unter verschiedenen nationalen und europäischen Transitionspfaden untersucht. Darüber hinaus werden die Auswirkungen der Entwicklung der Brennstoffversorgungskette auf die Strom- und Energieversorgungssicherheit sowie die Resilienz der Stromnetze gegenüber extremen Energiehandels-, Klima- und Wetterszenarien bewertet. Zudem werden regulatorische und politische Empfehlungen gegeben, um den Wert von kohlenstoffneutralen Brennstoffen zu maximieren.

Résumé

Ce projet examine le rôle des carburants neutres en CO₂ à base d'hydrogène et de méthane dans la transition du système énergétique suisse vers la neutralité climatique jusqu'à 2050. À cette fin, il compare les cadres réglementaires suisses et européens existants et transpose les principales conclusions dans des données de modélisation du système énergétique. À l'aide des modèles détaillés du système et du réseau énergétiques, le rôle potentiel de ces combustibles dans la substitution des combustibles fossiles et dans la fourniture de flexibilité dans le cadre de différentes voies de transition nationales et européennes est examiné. En outre, les effets du développement de la chaîne d'approvisionnement en combustibles sur la sécurité de l'approvisionnement d'électricité et d'énergie ainsi que sur la résilience des réseaux électriques face à des scénarios extrêmes en matière de commerce de l'énergie, de climat et de conditions météorologiques sont évalués. Des recommandations réglementaires et politiques sont également formulées afin de maximiser la valeur des combustibles neutres en carbone.



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List of abbreviations

SFOE	Swiss Federal Office of Energy
CO ₂	Carbon Dioxide



1 Introduction

1.1 Context and motivation

The transition to carbon-neutral energy systems is paramount in the global pursuit of climate change mitigation. Switzerland, committed to carbon neutrality by 2050 through the Climate and Innovation Act in 2023, has set ambitious targets for renewable energy deployment as part of these efforts. However, the Swiss energy transition is challenged by the seasonal mismatch of energy demand and supply, with high heating demand but low production potential from PV and run-of-river plants in winter. In this context, sector coupling emerges as a pivotal strategy, integrating various energy carriers to enable cost-effective carbon-neutral energy systems. While sector coupling offers temporal flexibility to the power system via power-to-gas and gas-to-power technologies, the electrification of heating and transport increases the power demand in winter. In addition, sector coupling can substitute fossil fuels with carbon-neutral hydrogen and derivatives, such as electricity based methane (e-methane), for hard-to-electrify end-uses such as aviation and specific industrial processes. In this project, we utilize our energy sector modelling tools and experience along with law and policy expertise to investigate 1) the future role of hydrogen and gas in Switzerland while carefully taking into account the role of energy trading with the rest of Europe and 2) how the legal and regulatory framework can support the design and implementation of policies that maximize their value, following a multi-layered governance approach.

1.2 Project objectives

This project aims to investigate the contribution of carbon-neutral fuels to the Swiss energy system and to identify the regulatory and policy prerequisites for their optimal deployment. The research questions are categorized into four topics:

1. Current legal and regulatory framework and corresponding policy space. How does Switzerland's current legal and regulatory framework for electro fuels compare to European counterparts? What does this imply for future policy planning in areas such as grid infrastructure development, expansion of renewable energy generation and electrolyser capacity, spatial planning, transport and logistics, considering the challenges and opportunities that arise from applicable international obligations assumed by Switzerland? Does the international legal and regulatory landscape foster or frustrate the development of a Swiss trade policy strategy that can support cross-border value chains in electro fuels that serve Switzerland's outstanding import needs? What are relevant regulatory and policy settings in energy system modelling to evaluate the role of carbon-neutral fuels in the Swiss energy transition based on ascertained trade-offs between domestic production and imports of carbon-neutral fuels?
2. The future value of hydrogen and methane in Europe and Switzerland. What value do carbon-neutral hydrogen and methane offer under various energy transition pathways? How do these fuels interact in replacing fossil fuels and providing flexibility for addressing power demand seasonality? In what scenarios is domestic production prioritized over fuel imports? How does the possibility for geological or above-ground storage of fuels influence their role?
3. The contribution of hydrogen and methane to energy supply security and system resilience. How do carbon-neutral fuels contribute to power and energy supply security under extreme trade, climate, and weather scenarios? How do the gas grid and hydrogen supply chain evolve considering the electrification of heating and the transition to carbon-neutral fuels?
4. Policy recommendations to maximize the value of carbon-neutral fuels. Given the optimal utilization of carbon-neutral fuels, what policy instruments and strategies can be recommended from a multi-level governance perspective? How can future regulations and policies maximize the value of carbon-neutral hydrogen and methane for the Swiss energy system?



2 Approach, method, results and discussion

2.1 General approach

The approach to tackle the research questions posed is structured into two pillars. The first pillar involves utilizing and expanding the modelling tools of the Nexus-e framework along with the recently integrated ZenGarden model. Combined, these optimization models represent the Swiss power, hydrogen, and methane supply chains with fine spatiotemporal resolutions, while accounting for demand flexibility via time-shifting and price-elasticity as well as the interaction with the entire European energy system.

The developed optimization framework explicitly models both power and gas infrastructure. Hence, it accounts for the heterogeneous distribution of energy supply potentials and demands, the physical constraints on energy transport, and the expansion of the power grid. In contrast to the simplified spatial representations used in reFuel.ch, our approach allows pinpointing congestions and potential expansions related to the physical grids. While some studies have focused on the power sector, the extended scope of our research enables assessing the role of power-to-gas-to-power technologies in flexibility transfer across sectors.

In the second pillar, these energy system models are combined with a law and policy framework analysis informed by the multi-layered governance theory. The current regulatory landscape applicable to carbon-neutral gases in Switzerland is compared to the latest policy developments in European counterparts and scrutinized under existing commitments arising from national laws, bilateral (mainly CH-EU) arrangements, and international obligations contracted by Switzerland. Key strategies such as the Swiss Hydrogen Strategy, are considered with a view to understanding challenges and opportunities entailed by the current and planned regulatory environment and identifying persisting gaps and hurdles vis-à-vis the policy space still available to Switzerland. Given the broader European transition, the Swiss power system transition is optimized by Nexus-e, providing a coordinated generation and transmission expansion plan for Switzerland, co-optimizing the generation and transmission expansions and the hourly operations of generators at the transmission system level.

We consider the potential integration of Switzerland into the European energy system by taking into account different potential pathways using the ZenGarden model which represents the entire European energy system and can provide crucial insights into the availability and cost of both electricity and hydrogen imports into Switzerland. In this, we take into account Swiss federal and cantonal frameworks and policies against the backdrop of existing approaches developed at the EU and at the national level in selected European counterparts. In a future stage of the project, we will perform system security analyses to evaluate the advantages of carbon-neutral hydrogen and methane to the power grid. For this purpose, we plan to use Cascades, a core model in Nexus-e. Cascades evaluates power system security by assessing the system's ability to cope with failures in various scenarios and operating conditions. The systemic responses are quantified by tracking the progression of these initiating failures, including islanding behaviour, frequency control, under-frequency and under-voltage load shedding, and disconnection of branches.

The assessment of the legal and regulatory framework applicable to hydrogen and e-methane follows a three-prong approach. First, the analysis will focus on the Swiss national legal framework applicable to covered electro fuels, namely green hydrogen and e-methane. This level of analysis implies covering a full range of instruments relevant to the development of the various sectors, technologies, value chains and markets implicated by the uptake of domestic production, transportation, storage and distribution of electro fuels (e.g., from power generation to carbon capture and storage, from transport infrastructure to heating) scattered across different layers of competences distributed between the confederation and the cantons. Second, we will reconstruct Switzerland's network of international obligations arising out of multilateral, regional and bilateral treaties, with a focus on those affecting prospects of trade in carbon-neutral fuels vis-à-vis domestic production. Third, we will perform a comparative analysis of the legal and policy frameworks developed/or and planned in European countries, with specific focus on those that bear the most relevance for Switzerland's definition of a trade strategy in carbon-neutral fuels trade based on inter alia planned grid infrastructure developments and transport network opportunities for



green electricity, hydrogen and CO₂. The three-prong approach will allow to assess how Switzerland's laws and policies compare with international standards and best practices developed in European counterparts and under existing international commitments. Building on these findings and the energy system modelling results, we will elaborate policy recommendations to maximize the value of hydrogen and e-methane under the Swiss legal framework as well as to foster the role of Switzerland in the global markets for electro fuels, for example, by setting supply chain trade policies aimed at consolidating Switzerland's position as exporter of relevant technologies and/or enabling imports/exports of electro fuels based on existing trade-offs.

The main novelties of our approach are 1) the use of a highly resolved combination of models that have been extensively tested to represent the interrelationships and evolution of the Swiss and European power, hydrogen, and methane sectors; 2) a strong and comprehensive multi-level legal and policy analysis to formulate recommendations premised on a multi-governance perspective to maximize the value of hydrogen and e-methane in Switzerland's energy transition.



2.2 Regulatory assessment

2.2.1. Methodological approach

The assessment has tackled the regulatory and policy framework applicable to hydrogen at the national and international level.

Considering the Swiss framework in particular, the work has focused on the current landscape and on prospective legal developments with the aim to identify best practices, barriers, gaps and opportunities. Textual and critical analysis has targeted carbon-neutral hydrogen in terms of technology, production, transportation, storage and distribution. It has also looked into the potential of renewable fuels for the heating sector.

Regarding the international perspective, the analysis has reviewed policy and regulatory frameworks designed to support the development of carbon-neutral fuels in selected countries bearing the most interest to Switzerland due to their geographical proximity, namely Germany, France, Italy and Austria. The analysis focused in particular on the regulatory and policy frameworks disciplining green hydrogen and biomethane. This choice reflects synergies with work packages that model energy scenarios for Switzerland, including projected hydrogen demand and production, as well as energy import prices and fuel demand at the EU level. It has also been guided by the consideration of the possible driving force that the development of those sectors will likely exercise on the Swiss economy related to such fuels. Accordingly, the research sought to identify specific legal provisions applicable to these two selected fuel types. As will be shown below, however, not all countries have established regulatory frameworks specifically tailored to green hydrogen or biomethane. In such cases, these fuels are often disciplined under the broader regulatory category of carbon-neutral fuels. This is partly because, as discussed in the following sections, countries may include not only green hydrogen in their energy transition strategies but also other forms of low-carbon hydrogen, such as pink, blue, or turquoise hydrogen. The methodology applied was twofold.

First, the analysis adopted a textual and doctrinal approach. Because all selected countries are Member States of the European Union (EU), their national legal frameworks on carbon-neutral fuels are closely linked to the relevant EU regulatory and policy framework, namely: the RED III Directive and related Delegated Acts on renewable fuels of non-biological origin (RFNBOs); the Hydrogen and Decarbonized Gas Market package; EU State Aid law specifically regarding Important Projects of Common European Interest (IPCEIs) and Projects of Common Interest (PCIs). National frameworks are therefore closely intertwined with relevant EU provisions. At the national level, the study reviewed a range of policy and regulatory sources, including National Climate and Energy Strategies, national Hydrogen Strategies, and other regulatory instruments. These instruments vary across countries and may include energy codes, environmental laws, and legal provisions establishing support schemes for relevant technologies. The research also examined calls for interest and public tenders to identify program requirements such as budget allocations, eligibility criteria for EU and non-EU operators, and the types of supported technologies. This was done to highlight potential market opportunities for Swiss operators arising from these initiatives. Second, a comparative approach was applied to identify synergies and divergences across the national frameworks examined, as well as emerging best practices relevant to Switzerland in view of the specific characteristics of its own framework.

At both stages, the analysis focused on (i) national targets; (ii) regulatory and economic measures designed to promote the development of green hydrogen and biomethane (and, where appropriate, support mechanisms for low-carbon hydrogen more broadly, particularly where a dedicated framework for green hydrogen has not yet been established); (iii) international trade-related aspects.



2.2.2. Assessment of the Swiss framework

2.2.2.1. The policy and regulatory framework relevant for green hydrogen in Switzerland

The Swiss hydrogen strategy of the 13 of December 2024

The Swiss hydrogen strategy sets out the Federal Council's vision and objectives for hydrogen and PtX derivatives in the Swiss energy system. It identifies priority measures to timely develop the domestic hydrogen market and secure its connection to the European market, while also outlining additional measures from energy and climate policy that support these goals, some of which are already underway, or which are included in current proposals in the fields of energy and climate policy.

In the Swiss strategy, the term hydrogen refers to hydrogen produced through CO₂-neutral processes. This includes hydrogen generated from renewable energy sources as well as from nuclear power. Unlike other countries, the Swiss hydrogen strategy does not define binding target values for either domestic hydrogen production or its utilization. Instead, the emphasis is placed on ensuring that hydrogen is deployed only in areas where it can compete economically with other carbon-neutral fuels. This market-based approach avoids the creation of artificial demand while still encouraging innovation and competitiveness.

Imports are projected to play a significant factor in shaping the Swiss hydrogen landscape. Given cost advantages in certain regions, imported hydrogen is expected to be cheaper than domestic production in many cases. This underlines the importance of ensuring Switzerland's connection to the European hydrogen infrastructure and of developing strategic collaborations within the energy sector. Accordingly, a strong international alignment will not only secure supply but also provide resilience against geopolitical risks and market fluctuations.

At the local level, cantons are encouraged to create an enabling regulatory environment. Specifically, bureaucratic obstacles should be minimized for the construction of hydrogen production, transport, and storage facilities. Moreover, harmonization of authorization practices is necessary to provide legal certainty, attract investment, and accelerate project implementation.

In the short to medium term, hydrogen will play a pioneering role in multi-energy hubs. Until approximately 2030–2035, overall demand is expected to remain low enough for national production capacity to meet consumption needs. In this transitional phase, production will generally take place close to the point of consumption, with on-site storage solutions ensuring reliability and efficiency. These hubs will serve as testbeds for technology deployment, business models, and regulatory approaches, paving the way for broader integration of hydrogen into the national energy system.

In conclusion, while hydrogen is not projected to become a dominant energy carrier in the immediate future, its strategic role as a complementary, flexible, and carbon-neutral fuel is clearly recognized. By aligning with European infrastructure, simplifying domestic regulatory frameworks, and supporting the development of pilot hubs, Switzerland aims to ensure that hydrogen evolves into a pillar of its long-term energy transition strategy.

CO₂ neutral hydrogen through nuclear energy

Switzerland's Energy Strategy 2050 mandates a gradual phase-out of nuclear energy, with existing nuclear power plants scheduled for incremental shutdown and construction of new plants currently prohibited. In February 2024, the popular initiative "*Electricity for All at All Times (Stop the Blackout)*" was launched, seeking to repeal this ban. In response, the Federal Council decided to submit an indirect counter-proposal that rejects the initiative outright while suggesting an amendment to the Nuclear Energy Act to remove the prohibition on general licenses for nuclear power plants.

The Energy Strategy 2050 remains the cornerstone of Swiss energy policy, and any new legislation is expected to align with its objectives, including promoting renewable energy and reducing nuclear dependency. In this light, the Federal Council's counter-proposal can be seen as a potential compromise to mitigate legal conflicts while preserving alignment with broader energy goals. Removing the ban on general licenses could allow future nuclear projects but does not guarantee immediate construction.



Approval for specific projects would still be subject to environmental, safety, and zoning regulations, ensuring appropriate legal oversight.

Nevertheless, uncertainty surrounding nuclear policy may affect investor confidence in renewable energy projects, as stakeholders could adopt a “wait-and-see” approach, potentially slowing the deployment of renewables. If new nuclear projects are pursued, they could influence energy market dynamics, including pricing and the prioritization of renewable energy integration into the grid. Simultaneously phasing out nuclear energy while potentially allowing new plants introduces policy ambiguity, making harmonization between the Nuclear Energy Act, Energy Strategy 2050, and federal energy regulations essential for long-term planning.

Overall, the legal framework currently supports a gradual nuclear phase-out, with limited potential for new projects pending legislative changes. While the counter-proposal addresses immediate citizen concerns, it introduces policy uncertainty that could indirectly slow renewable energy initiatives. Careful legislative drafting and clear regulatory guidelines will be essential to ensure that Switzerland’s renewable energy targets are not undermined.

Hydrogen infrastructure

Hydrogen infrastructure must be developed in compliance with applicable planning and building regulations. Recent legal provisions, however, facilitate such developments. Specifically, Article 24^{ter} of the Spatial Planning Act (RS 700) allows plants for producing energy from biomass, as well as plants converting renewable energy into hydrogen, methane, or other synthetic hydrocarbons, to be built outside designated building zones when necessary to ensure a secure supply of renewable energy. While the Ordinance on Spatial Planning (RS 700.1) will define the details, the Law emphasizes the importance of proximity between hydrogen plants and renewable energy facilities.

Likewise, Article 12, para 2 of the Energy Act recognizes the construction of plants necessary for renewable energy—such as photovoltaic, wind, electrolyzers, and methanation facilities—as being of national interest, in accordance with Article 6 of the Federal Act on Nature Protection. This provision gives such projects comparable weight to, and in certain cases can override, other interests in nature or landscape conservation. Nevertheless, a balance of interests must still be carried out, ensuring that environmental protection considerations are properly addressed.

Funding mechanisms for renewable gas production are defined in Article 34a, letter d of the CO₂ Act (RS 641.71), which allows support for new plants or significant expansions of existing infrastructure, primarily for plants that inject gas into the network. According to Article 113c, paragraph 1 of the CO₂ Ordinance (RS 641.711), funding is limited to the production of biomethane from biomass; plants producing green hydrogen or e-methane are excluded.

In alignment with the Hydrogen Strategy 2024, Cantons are encouraged to minimize bureaucratic obstacles for the construction of hydrogen production, transport, and storage facilities and to harmonize authorization practices. Cantons are further urged to amend their structure plans to facilitate the planning and development of hydrogen infrastructure.

Overall, Switzerland’s regulatory, planning, and funding framework provides a structured approach to ensure hydrogen projects are safe, environmentally compliant, and strategically integrated with renewable energy systems. Clear guidance and harmonization across cantons will be crucial to accelerate hydrogen deployment while maintaining environmental and safety standards.

Hydrogen production

Switzerland provides several legal mechanisms to support hydrogen and Power-to-X (PtX) projects.

Article 14a, paragraph 1 of the Electricity Act (RS 734.7) exempts all storage facilities from grid fees if they have no end electricity consumption. Starting from 1 January 2026, Article 14a, paragraphs 4(a) and 4(b) of the Electricity Act extend this exemption to storage facilities with end electricity consumption, as well as to conversion plants that transform electricity into hydrogen, gas, or other renewable fuels, but only to the extent of electricity fed back into the grid. Additionally, Article 14a, paragraph 4(c) of the



Electricity Act provides exemptions for pilot and demonstration plants that convert renewable energy into hydrogen, gas, or other renewable fuels, up to a total national capacity of 200 MW.

Funding opportunities are further defined under Article 6 of the Federal Act on Climate Protection Targets, Innovation and the Strengthening of Energy Security (RS 814.310), which allows the use of innovative technologies and procedures in implementing roadmaps pursuant to Article 5 of the same law. This makes hydrogen and PtX production and storage via innovative technologies eligible for financial support (see Art. 11 ff. of the Ordinance on Climate Protection Targets, Innovation and the Strengthening of Energy Security [814.310.1] for the details).

Finally, hydrogen and PtX produced from renewable energy can be recognized as compensation measures under Article 26 of the CO₂ Act, providing additional incentives for their deployment and integration into Switzerland's climate and energy strategy.

The ecological requirements for placing on the market renewable or low-emissions fuels are defined by the Ordinance on the market distribution of renewable or low-emission fuels (IBTV, RS 814.311.1), based on Articles 35d (paragraphs 3–6) and 39 (paragraph 1) of the Environmental Protection Act (RS 814.01). These requirements include: (i) a reduction of greenhouse gas (GHG) emissions by at least 40% over the entire life cycle compared to conventional fossil fuels, (ii) a maximum increase of environmental pollutants by 25% over the entire life cycle compared to conventional fossil fuel, (iii) no use of land that previously had high carbon stocks or high biodiversity (e.g., forests, peat bogs, wetlands). Hence, to comply with the environmental requirements, set out in Art. 3 IBTV, the electricity used in the production of hydrogen must originate from non-fossil sources.

The new certificates of origin (CoO) system entered into force on the 1st of January 2025 and tracks renewable gases in a database from the point of production or import. The system enables the ecological added value to be clearly allocated to a specific actor and to the chosen climate or energy policy instruments. This prevents the resulting emission reductions from being counted twice. The details of the system are regulated in the DETEC Ordinance on the Certificate of Origin for Thermal and Motor Fuels (RS 730.010.2). Certificates of origin will now be issued for renewable liquid and gaseous thermal and motor fuels of biogenic and non-biogenic origin, non-renewable hydrogen and low-emission aviation fuels.

Hydrogen transport

Hydrogen can be transported by rail, road, waterway or pipeline, with relevant safety and security provisions applying depending on the mode of transport. For road transport, the Ordinance on the Carriage of Dangerous Goods by Road (RS 741.621) and the Agreement concerning the International Carriage of Dangerous Goods by Road (0.741.621) are applicable. Rail and cableway transport is regulated under the Ordinance on the Carriage of Dangerous Goods with Railways and Cableways (RS 742.412). In addition, the Ordinance on Protection against Major Accidents (RS 814.012) sets requirements for facilities handling large quantities of hydrogen (above 5'000 kg).

For pipeline transport, the Federal Act on Pipeline Transport (RS 746.1) applies if the hydrogen pipeline operates with a maximum authorized operating pressure greater than 30 bar and an external diameter greater than 6 cm or with a maximum authorized operating pressure greater than 5 bar but less than or equal to 30 bar and an external diameter greater than 12 cm. The Federal Pipeline Act and related ordinances namely establish heightened safety standards, and federal authorities are responsible for supervising construction, maintenance, and operation of such pipelines. Hence a pipeline with an operating pressure between 0 and 5 bar falls under the jurisdiction of the cantons, regardless of its external diameter; the same goes for a pipeline with an operating pressure between 5 and 30 bar and an external diameter of less than 12 cm as well as for a pipeline with an operating pressure greater than 30 bar if the external diameter is less than 6 cm (Art. 3 Ordinance on Pipeline Transport Installations for Liquid or Gaseous Fuels [RS 746.11]).

Because of corrosion, embrittlement, leak tightness, as well as component compatibility, existing natural gas pipelines are generally unsuitable for transporting pure hydrogen only after specific technical assessment, material compatibility checks, and compliance with hydrogen-specific additional requirements (for further details, refer to the SVGW guideline H1000 d Empfehlung zu Planung, Bau und Betrieb von



Rohrleitungsanlagen für den Transport von Wasserstoff – April 2023). However, hydrogen can be blended into the natural gas network at low concentrations, currently up to approximately 10% by volume in Switzerland (for further details, refer to the SVGW guideline G18 d Gasbeschaffenheit – June 2022).

The connection of Switzerland's hydrogen infrastructure to the European hydrogen network is expected to be primarily financed by the private sector, which remains responsible for the energy supply. The Confederation is, however, assessing the potential need for financial guarantees to support the construction of hydrogen pipelines linking to the European network.

Regarding the right to feed hydrogen into pipelines and the obligation to transport it, Article 13 of the Pipeline Act establishes that network operators must, by contract, transport goods for third parties within the limits of their technical capabilities and the economic requirements of the service, provided the third party offers adequate compensation. While this provision creates a legal basis for access, its formulation remains relatively vague.

Access to gas networks can also be supported under competition law, for example in cases of abuse of dominance, which can grant producers the right to network access. However, such procedures are typically costly and lengthy. On 19 September 2025, the Federal Council submitted for consultation a new preliminary draft of the Gas Supply Act. This draft namely provides for a right of access to the gas market for all consumers. However, the scope of application of the draft is limited to gas networks that primarily transport methane (natural gas, biomethane and synthetic methane). In accordance with the Hydrogen Strategy adopted by the Federal Council in December 2024, the regulation of the hydrogen market will be incorporated into the Gas Supply Act (LAGas) only once the need to construct hydrogen pipelines has been demonstrated.

Storage

Planning and building regulations apply to hydrogen storage facilities throughout Switzerland. Several Cantons have additional legislation governing the use of underground spaces, and the federal government has launched a program to explore subterranean areas for potential storage sites.

Under Article 6 of the Climate and Innovation Act, innovative technologies and procedures used to implement roadmaps pursuant to Article 5 of the Climate and Innovation Act are eligible for funding, providing financial support for hydrogen and PtX production and storage using advanced methods.

Until 2035, hydrogen storage is expected to take place primarily at or near production and consumption sites, forming regional hydrogen clusters. Concurrently, efforts are being made to secure storage capacity abroad to complement domestic capabilities. Under the Swiss Energy Strategy 2024, it is envisaged that the issue of storage be taken on, among others, in the context of a roundtable organized by the SFOE in collaboration with other federal offices, the cantons, and the energy sector, with a view to examine the contribution that hydrogen and PtX derivatives can make to energy storage, and consequently to the security of energy supply in Switzerland. Based on available information, this initiative is aimed at identifying possible solutions and locations for seasonal underground and above-ground storage facilities in Switzerland—such as converted existing caverns or tank farms—as well as storage options abroad (Hydrogen Strategy 2024 N. 5.8).

Consumption

Vehicle importers and manufacturers are subject to targets aimed at limiting the average CO₂ emissions of vehicles entering into use during the reference year. Under Article 26b of the CO₂ Ordinance, if a vehicle importer is contractually allocated a certain quantity of renewable synthetic fuel, they may request that the CO₂ emission reductions achieved through the use of this fuel be factored into the calculation of their new vehicle fleet's average emissions. In general, the new Certificate of Origin (CoO) system allows the ecological added value to be clearly attributed to a particular stakeholder and the chosen climate or energy policy instruments.

Article 28f of the CO₂ Act establishes blending quotas for renewable aviation fuels, supporting the decarbonization of the aviation sector.



Additionally, heavy-duty vehicles powered by hydrogen fuel cell trucks are exempted from the heavy vehicle tax, providing a financial incentive for low-emission transport. However, hydrogen combustion engines are not exempt from the heavy vehicle tax.

General security norms & technical standards

Hydrogen has long been used by the chemical industry, and a detailed legal framework focused on safety and security is well established. Key regulations include the Ordinance on Protection against Dangerous Substances and Preparations (RS 813.11) and the Ordinance on Protection against Major Accidents (RS 814.012), which are particularly relevant for plants exceeding the 5'000 kg threshold and for larger hydrogen production facilities. Safety requirements for transport are governed by the Ordinance on Safety Requirements for Pipeline Transport Systems (RS 746.12).

Additionally, Switzerland aligns with European chemical regulations. The Classification, Labelling, and Packaging (CLP) EU Regulation is referenced in Article 2(f) of the Swiss Chemical Ordinance, while the REACH Regulation on the registration, evaluation, authorization, and restriction of chemicals is incorporated through Article 5, paragraph 1, and Annex 2, number 3.1 of the Swiss Chemical Ordinance, which requires a REACH-compliant safety data sheet (Schreiber, 2021).

Technical standards for hydrogen handling and transport are primarily determined by private entities, complementing the legal framework. The ordinances governing pipelines and pipeline safety requirements are under revision, with the consultation period having ended in December 2024. The revision aims to clarify rules concerning competence and safety requirements specific to hydrogen pipelines and facilities.

2.2.2.2. The policy and regulatory framework relevant for renewable energy in Switzerland

Targets

In support of its commitment to a sustainable energy future, Switzerland has set out objectives for the development of renewable energy production. These targets, established under the Energy Act and the revised Energy Ordinance, provide a concrete roadmap for the transition away from nuclear power and fossil fuels, towards a resilient, low-carbon energy system in line with the Energy Strategy 2050.

Binding Targets Under Article 2 of the Energy Act

Art. 2 of the Energy Act (RS 730.0) outlines specific, binding targets for electricity generation from renewable energy sources, both including and excluding hydropower. These targets are set for the years 2035 and 2050: (i) Electricity from renewable sources (excluding hydropower): at least 35'000 GWh by 2035; At least 45'000 GWh by 2050; (ii) Net electricity production from hydropower: at least 37'900 GWh by 2035; at least 39'200 GWh by 2050; (iii) Winter electricity imports: Net electricity imports during the winter half-year must not exceed 5 TWh. This aims to strengthen domestic energy resilience and reduce dependence on foreign energy supply during peak seasonal demand.

Interim Targets Under Article 1a of the Revised Energy Ordinance

The revised Energy Ordinance (Art. 1a; RS 730.01), for which the consultation period lasted until the 21st of July 2025, proposes interim targets for the year 2030, with a specific breakdown of expected contributions by technology. The general intermediate target for 2030 shall be a total production of electricity from renewable sources of no less than 23'000 GWh; while the intermediate target for the expansion of electricity generation from renewable energies shall be a total production of no less than 18'700 GWh for photovoltaic installations and a total production of no less than 2'300 GWh for wind power installations. These interim milestones are considered to be essential to ensure the country stays on track to meet the longer-term targets of 2035 and 2050. They also provide guidance for planning, investment, and the expansion of energy infrastructure (DATEC, 2025).

Incentives



Switzerland offers a variety of regulatory incentives and economic and fiscal support schemes to promote the development and integration of renewable energies. These incentives are part of the broader framework of the Energy Strategy 2050 and are both implemented at federal and cantonal levels.

The Swiss Energy Act provides several important legal provisions that directly support the development, use, and fair market integration of renewable energy sources. Key articles relevant to renewable energy producers and operators can be summarized as follows. Pursuant to Article 15 on the Grid Access and Compensation for Renewable Energy Producers, grid operators are legally obligated to accept electricity produced from renewable sources and biogas within their designated grid areas. They must also provide appropriate compensation to producers, provided the production plant does not exceed a maximum power capacity of 3 MW. This ensures that small and medium-sized producers can reliably feed their energy into the national grid and be fairly remunerated.

Pursuant to Article 16 on the Rights of Self-Consumption and On-Site Energy Use, any individual or entity generating energy for their own use has the legal right to consume and/or sell this energy (either in full or in part) at the location of production. Furthermore, when an electrolyser is installed on-site at the production facility, no grid usage fees are charged. This incentivizes local and decentralized energy production, particularly for facilities involved in hydrogen production or similar applications.

According to Article 24 ff., on Investment Contributions for Renewable Installation, the Energy Act allows operators of installations based on photovoltaic, hydropower, biomass, wind, or geothermal energy to apply for investment contributions, typically in the form of one-off payments. These financial incentives are designed to offset high initial capital costs and promote the rapid deployment of renewable energy infrastructure.

Considering Article 29a, on floating market premium for the feed-in of electricity from renewable energies, with the introduction of the sliding market premium, a new support instrument for hydropower, photovoltaics, wind energy, and biomass is being established (Art. 29a ff. EnG). This instrument is designed to compensate the difference between a fixed remuneration rate and the actual market revenues obtained from electricity sales. In this way, a stable return is ensured throughout the entire remuneration period, providing plant operators with protection against market risks. The idea behind the sliding market premium is to secure the annual costs resulting from the investment and thereby guarantee a consistent return for the plant operator.

Furthermore, according to Article 30 on Market Premium for Large Hydropower Operators, operators of large hydropower plants (with a capacity exceeding 10 MW) are eligible to apply for a market premium in situations where the market price of electricity is lower than production costs. This premium serves as partial compensation for financial shortfalls but is capped at a maximum of one centime per kilowatt-hour. This mechanism helps to ensure the continued viability of large-scale hydropower operations in volatile energy markets.

Further incentives

Further incentives can be provided at cantonal and municipal level. They may take the form of **tax deductions**. For instance, investments in renewable energy installations (e.g., solar panels, heat pumps) can be deducted from taxable income, for both private individuals and businesses. A second form of incentive consist of subsidies for energy-efficient renovations. In this case, if a homeowner renovates a building to improve energy efficiency and installs a renewable energy system, they may qualify for combined subsidies. This scheme is often tied to the Building Program (Gebäudeprogramm), which supports: Thermal insulation upgrades or the replacement of fossil heating systems with renewable alternatives (e.g., heat pumps, solar thermal). Additional support is provided through solar and biomass incentives. Specifically, some cantons and municipalities provide additional funding or rebates for solar panel installations, biomass heating systems and small wind turbines. It should, however, be noted that, during its meeting of 19 September 2025, the Federal Council adopted the dispatch on the 2027 Budget Relief Program, which includes measures aimed at reducing or eliminating incentives under climate policy.



2.2.3. Comparative analysis of legal and policy landscapes in European countries

2.2.3.1. Policy and regulatory measures to support the development and scaling of green hydrogen

Targets

All the countries analyzed prioritize green hydrogen as a key pathway for their energy transition, thereby aligning with the EU policy and regulatory framework. The RED III Directive (Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652), in particular, establishes targets for green hydrogen, which is expected to account for 42% of all hydrogen used in industry, rising to 60% by 2035 (Article 22a). At the same time, countries recognize the importance of low-carbon hydrogen alternatives, not only to reduce emissions and support market decarbonization but also to accelerate the development of the hydrogen market as a whole. It should be kept in mind that, pursuant to the Hydrogen and Gas Market Directive (Directive (EU) 2024/1788), Article 2(11), “low-carbon hydrogen” is derived from non-renewable sources and must meet a 70% Greenhouse Gas (GHG) emissions threshold. It has been clarified that this definition may also apply to hydrogen produced through nuclear derived power (European Parliamentary Research Services, 2025).

National strategies are not aligned in this regard. Different types of low-carbon hydrogen are deemed eligible at the national level, as summarized in the following table:

Table 1: Definition of low-carbon hydrogen by country

Country	Green Hydrogen	Low-carbon hydrogen
Germany	x	Blue, turquoise, and orange hydrogen (National Hydrogen Strategy 2023, p. 4)
France	x	Nuclear hydrogen (Article L. 811-1 <i>Code de l’Energie</i>)
Italy	x	Blue hydrogen (National Hydrogen Strategy 2024, p. 8) ²
Austria	x	Blue and turquoise hydrogen (National Hydrogen Strategy 2022, p. 2)

For the purposes of this report, it is worth noticing that France is the only country among those analyzed that relies on nuclear-based hydrogen alongside green hydrogen. By contrast, Austria does not consider this type of hydrogen to be sustainable (National Hydrogen Strategy, 2022) while Italy, although recognizing its potential for decarbonization, currently lacks the nuclear capacity to develop it (National Hydrogen Strategy, 2024).

Overall, this overview confirms that the targeted EU Member States have chosen a pragmatic approach that reflects a broader trend observed in jurisdictions worldwide (Wenting Cheng and Sora Lee, 2022): prioritizing decarbonization as an initial step (and thus target other forms of low-carbon hydrogen alongside green hydrogen), and moving toward full greening over time. This approach is further reflected in the strategic adjustments occurred at the national level. In this perspective, France has revised its green hydrogen targets downward (National Hydrogen Strategy 2025, p. 15), while Germany, in subsequent revisions of its National Hydrogen Strategy, has expanded the range of eligible hydrogen types beyond green hydrogen (National Hydrogen Strategy 2022, p. 4).

While a detailed examination of the EU legal framework applicable to green hydrogen falls outside the scope of this report, it is important to note that the methodology established under the RED III Directive and the related Delegated Acts (Commission Delegated Regulation (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by



establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin and Commission Delegated Regulation (EU) 2023/1185 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a minimum threshold for greenhouse gas emissions savings of recycled carbon fuels and by specifying a methodology for assessing greenhouse gas emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels) seeks to harmonize green hydrogen production and its integration into the EU market. This is particularly evident given the choice of legal instruments: the Delegated Acts were adopted in the form of EU Regulations, which, under EU law, are binding in their entirety and directly applicable in all Member States. As Regulations set minimum harmonisation standards, Member States retain the discretion to adopt more stringent conditions should they deem this appropriate. In a similar vein, the proposed Commission Delegated Regulation specifying the methodology for assessing greenhouse gas emissions savings from low-carbon fuels aims at bringing further clarity on what qualifies as low-carbon hydrogen in the EU without, however, setting EU-wide targets on the production. As a result, Member States will retain discretion to develop their own national targets to low-carbon hydrogen production, provided that those could be met exclusively by fuels that comply with the GHG emissions saving thresholds resulting from the EU regulatory framework on hydrogen production.

Regarding green hydrogen specifically, the four countries analyzed display differing levels of ambition in their targeted electrolyzer capacities. In this context, Germany has set the most ambitious target, aiming for 10 GW of electrolyzer capacity by 2030, alongside a projected hydrogen demand of 95–130 TWh within the same period (National Hydrogen Strategy 2023, p. 2). The country has therefore doubled its objectives compared to the targets originally established in the 2020 National Hydrogen Strategy. France has set a target of 4.5 GW by 2030, to become 8 GW by 2035, with a projected hydrogen demand of 20-30 TWh (National Hydrogen Strategy, 2025). Compared to plans announced in the 2020 version of the French National Hydrogen Strategy, electrolysis power objectives have been revised downward from 6.5 GW by 2030. Italy adopts a flexible scenario-based approach, with targets ranging between 3 GW by 2030 (National Energy and Climate Plan, 2024) and 4-9 or 15-30 GW by 2050, depending on the interplay between domestic production and imports, with a projected annual demand for hydrogen of 0.252 Mton/year (National Hydrogen Strategy, 2024). Austria features the least ambitious target, aiming to 1 GW electrolytic power by 2030, with a projected demand of climate-neutral gases of 138 TWh (National Hydrogen Strategy, 2022).

Investment and budget allocations for green hydrogen

Countries support their green hydrogen related objectives through investment and budget allocations.

Germany has allocated €7 billion to support the development of the green hydrogen sector, and €2 billion for international partnerships (Germany National Hydrogen Strategy, 2020). The federal budget for 2026 also allocated approximately €3 billion for the development of green hydrogen import strategy via H2Global auctions (see *infra*). Additionally, The Climate and Transformation Fund, a key tool in Germany to advance the energy transition, will receive additional resources for a total of €100 billion by means of an annual allocation of €10 billion between 2025-2029 from the Special Fund for Infrastructure and Climate Neutrality (2025 Federal Budget).

France commits €9 billion for hydrogen development by 2030, of which €4 billion are planned to support the development of 1 GW electrolysis within 15 years (French National Hydrogen Strategy 2025).

Italy, for the period 2021-2026, allocates approximately €2.5 billion to projects related to hydrogen valleys and the decarbonization of the industry sector (PNRR, 2021).

Austria dedicates € 400 million to green hydrogen production in the form of auction-as-a-service from its national budget (EU Commission, 2025). Additionally, based on the Hydrogen Promotion Act, a €400 million subsidy scheme has been announced, channelled through the EU's European Hydrogen Bank, starting with an annual allocation of €40 million and rising to €100 million per year from 2027 onwards to boost green hydrogen production.

Economic and regulatory incentive schemes



As already mentioned, analyzed countries must follow the regulatory framework of the RED III Directive and the Delegated Acts to ensure that synthetic hydrogen produced can be labelled as green hydrogen. These requirements are additionality, temporal and geographical correlation. Indeed, based on the current regulatory framework, green hydrogen producers may comply with the additionality requirement in two ways: (i) they produce renewable energy in their own installations; (ii) they purchase renewable energy from newly established, unsubsidized renewable energy plants (Art. 5 of the Commission Delegated Regulation 2023/1184).

Accordingly, the measures analyzed in the following paragraphs addressing renewable energy production, the energy grid, and hydrogen infrastructure are to be examined as measures designed to implement EU law at the domestic level, although not without struggle. Indeed, Germany has advocated for a postponement and ease of the application of the stringent requirements set out under the Delegated Acts, especially additionality, arguing that it increases costs for hydrogen production (Letter of the Federal Minister Robert Habeck to the European Commissioner for Energy, 16 September 2024). This position has been backed up by other EU countries (HydrogenInsight, 2024). Beyond the EU framework, issues also arise with reference to imported green hydrogen, which is expected to comply as well with the requirements set out by the Delegated Acts.

Moreover, and more broadly, domestic approaches analyzed *infra* also align with the RED III objective, which aims for at least 42.5% of total energy consumed in the EU to come from renewable sources by 2030 (Art. 3). The rationale is, *inter alia*, to reduce the EU's reliance on imported fossil fuels, and ensure a reliable and affordable energy supply.

Analyzed countries have established several schemes to meet their targets and ensure the economic viability of green hydrogen production. In this regard, it should be noted that some of the schemes analyzed have been adopted under the Temporary Crisis and Transition Framework network, replaced on 25 June 2025 by the new Clean Industrial Deal State Aid Framework. Such schemes can be divided into the following categories: (i) tax incentives, including advantageous tax schemes; (iii) economic incentives, such as subsidies, grants and loans; (iii) regulatory incentives.

Considering **tax schemes**, all countries offer some form of targeted tax relief to support green hydrogen production, most commonly in the form of tax exemptions, reimbursements, or tax credits. The following examples may be considered: a) Germany provides reimbursement of taxed electricity when used for electrolysis (§9a, Electricity Duty Act, *Stromsteuergesetz*); The country has also introduced an exemption from electricity taxes for electrolysis facilities connected to the grid through a dedicated metering point and using grid electricity for the production of green hydrogen, provided the facility is commissioned before 2030 (§25, Energy Financing Act), up to 20 years (§118(6) Energy Industry Act); b) France has introduced a tax exemption from the payment of electricity duties for electrolysis facilities (*Taxe intérieure sur la consommation finale d'électricité* (TICFE)); c) Italy has introduced an exemption from the payment of general electricity system charges for electrolysis plants producing green hydrogen, where the electricity consumed originates from renewable sources (Art 23, Decree-Law No. 36 of April 30, 2022, converted by Law No. 79 of June 29, 2022); d) Austria exempts hydrogen producing plants from grid fees payment provided that they maintain a minimum capacity of 1MW, operate solely on renewable energy resources, and do not feed into the gas network (§55(10) EIWOG). The country also exempts green hydrogen from hydrogen tax that would normally apply to grey hydrogen (Austria, Natural Gas Tax Act).

Considering **economic incentives**, schemes generally focus on innovative technology or equipment for green hydrogen production. For example: a) Germany's strategy promotes innovation in green hydrogen technologies, including their derivatives and fuel cells. The *National Innovation Programme for Fuel Cell and Hydrogen Technology* specifically funds diverse projects that span from developing and qualifying materials, components, and systems to piloting plants that produce green hydrogen and its derivatives for various applications (NIP, phase II, 2016-2026). The program also supports essential equipment including valves, safety devices, compressors, and gas purification units, alongside innovative solutions for hydrogen storage and transport; b) France has provided support through direct grants (approximately €1.5 million per project) to promote the production of components and equipment essential for green hydrogen production, transport, and fuel cells (ADEME, *Appel à projet Briques technologiques et*



démonstrateur hydrogène); c) Italy, with the aim of promoting environmental protection projects and energy efficiency measures, provides grants to enterprises through programs that support green hydrogen development. These grants cover various costs including patents, raw materials, know-how, and real estate (Support to Sustainability of Production Processes, PNRR, *Sportello sostenibilità dei processi produttivi*); d) Additionally, all the countries under consideration participate in the IPCEI Hy2Tech initiative, which is specifically dedicated to scaling up green hydrogen production.

Looking at **regulatory incentives**, schemes are designed to streamline administrative procedures, arguably in accordance with the EU's Commission recommendation to remove unnecessary obstacles to renewable energy production (EU Commission, 2022). Accordingly, support for green hydrogen production plants is usually granted in two forms: (i) qualification of establishment projects as of "national interest", to streamline authorization and urban planning procedures (Germany, Hydrogen Acceleration Act; France, ICPE 3420 Production d'hydrogène); (ii) streamline of administrative procedures (urban planning, project authorization) for the construction and operation of green hydrogen plants (Italy, art. 6 and art. 38, L. 199, November 2021).

Transport of green hydrogen

The regulation of green hydrogen transport in the countries analyzed centers on two main areas: (i) the construction or repurposing of physical infrastructure, and (ii) safety considerations.

Regarding physical infrastructures, national laws cover authorization procedures, technical standards, and methods for developing pipeline projects. However, a comprehensive regulatory framework specifically dedicated to green hydrogen has not yet emerged. Existing provisions indeed typically address individual aspects, such as the determination of pipelines suitable for repurposing or allowable blending ratios (see *infra*). As a result, regulatory frameworks applicable to natural gas or hydrocarbons often apply. It is likely, however, that, as the hydrogen sector develops, specifically dedicated regulatory frameworks will be shaped based on the EU Hydrogen and Decarbonized Market Package.

The analysis shows that the regulatory frameworks analyzed converge around at least one of three key priorities: (i) repurposing existing pipelines to reduce costs, (ii) establishing dual-use transport systems, and (iii) constructing new networks. Moreover, all countries discipline blending ratios for green hydrogen, although differently: Germany applies a 10% threshold; in France, hydrogen can be blended into the natural gas network for pipeline distribution at a proportion set by the main energy providers (GRDF, GRTgaz, and Téréga) currently limited to 6%, with GRDF conducting trials to raise this limit to 20%. Providers are required to ensure interoperability between the different networks (R433-14 Code de l'énergie); Italy specifies that low-carbon hydrogen can be blended for transport in natural gas pipelines up to 2%, with a planned increase up to 10% (DM 139, June 2022); Austria, despite not yet having a comprehensive regulation applicable to pipelines (Monsberger and others, 2025) can practically apply a 4% blending ratio (Gas Connect Austria, 2021).. Such diverse approaches may have important impacts on international trade flows (K. Kanellopoulos et al., 2022).

Concerning safety, hydrogen is classified as a dangerous substance. Consequently, regulations governing the transport, storage, and environmental protection of hazardous materials apply. These are designed to comply with international instruments such as, for example, the UN Agreement on the International Carriage of Dangerous Goods by Road (ADR) and, at the EU level, the Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of Member States' laws relating to equipment and protective systems intended for use in potentially explosive atmospheres (the ATEX Directive) and the SEVESO III Directive on the control of major-accident hazards involving dangerous substances.

- More in detail, Germany aims to have 1,800 km of pipelines for green hydrogen transportation deployed, either new or repurposed. In line with this objective, the government has approved €18.9 billion investment for a 9,040-kilometer hydrogen network to be completed by 2032 (pursuant to §28(q)8 EnWG). From a legal perspective, the repurposing of existing infrastructures is prioritized. Accordingly, Transmission System Operators (TSOs) are expected to identify the natural gas pipelines that are suitable to be repurposed for hydrogen transport (§113b EnWG). Also, to ensure the economic feasibility of capital-intensive infrastructure projects, the German



government has established depreciation mechanisms, both to support economic expectations of investors of infrastructures that will be decommissioned in the coming years and investments in hydrogen related projects. Such mechanisms support the development of a hydrogen framework by allowing depreciation of hydrogen network assets to be included as recoverable costs through regulated network tariffs, providing investors with predictable cost recovery and returns (§8, 9, 10 WasserstoffNEV).

- France targets to develop 500 km of hydrogen pipelines by 2030. The Energy Regulatory Commission (CRE) is tasked with the supervision of the hydrogen infrastructure. The country also aims to concentrate low-carbon hydrogen production and consumption in clusters in pre-determined areas, namely Dunkerque, the Seine Valley, Le Havre, Lyon, Lacq and Marseille. Such an approach is deemed to facilitate logistics of production and consumption between producers and most important consumers of hydrogen. Considering the applicable legal framework, the French system applies to hydrogen transportation via pipelines the same discipline that is applicable to natural gas, namely concerning construction, authorization and operation of the network. A regulatory framework for projects concerning pure hydrogen pipelines has not yet been established.
- Italy targets the establishment of 2.300 km, with an import daily capacity of 448/GWh and an export capacity of 168 GWh/d, within the context of the SouthH2 Corridor project (qualified as a Project of Common Interest (PCI)) positioning it as a hydrogen import hub by 2030. The country also projects to transform Italian ports in strategic import assets. Considering short-length transportation, similarly to France, Italy is also considering the establishment of clusters for green hydrogen production by repurposing existing brownfield industrial sites. From a legal perspective, a specifically dedicated regulatory framework for the transport of green hydrogen has not yet emerged. At present, green hydrogen is disciplined as any other dangerous substance and the related regular regulatory framework applies. However, a dedicated framework is currently under development (See Draft law on “Delegation to the Government for the definition of a legislative framework for the carbon capture and storage (CCS) supply chain, as well as for the regulation of hydrogen development, the regulatory framework for the sector and related network infrastructure, and the governance system for compliance with methane emission reduction obligations in the energy sector” - Schema di legge recante “Delega al Governo per la definizione di un quadro legislativo di riferimento per la filiera carbon capture and storage (CCS), nonché per la disciplina dello sviluppo dell'idrogeno, dell'assetto regolatorio del settore e delle relative infrastrutture di rete, e del sistema di governo per l'adempimento agli obblighi di riduzione delle emissioni di metano nel settore dell'energia”).
- Austria is focusing on developing pure hydrogen infrastructure to supply industrial clusters and other large consumers, with a particular emphasis on repurposing existing natural gas pipelines. The country has announced plans to implement dual-function pipelines capable of carrying both natural gas and hydrogen within the same corridor (Enerbgi AG). Several repurposing projects have been announced with a regional focus. For example, in Upper Austria, projects aim to establish dual-function pipelines, allowing one pipe to transport natural gas and the other to transport green hydrogen. Netz Oberösterreich has also launched projects to repurpose sections of pipeline between Linz and Sattledt. These initiatives are consistent with Austria's broader objective of prioritizing pure hydrogen infrastructure.

International trade of green hydrogen

The countries analyzed – which have all Transmission System Operators (TSOs) that adhere to the European Hydrogen Backbone – adopt different strategies for the international trade of hydrogen, reflecting their respective local conditions and specific circumstances.

- Germany is the only European country featuring a comprehensive hydrogen import strategy (Import Strategy for Hydrogen and Derivatives, 2024), reflecting its ambitions to become a global hydrogen import hub (Rainer Quitzow et al., 2024). This objective is supported through several strategies. First, the country aims to establish international trans-European connections, through pipelines acting as import corridors. This is done through IPCEIs projects (such as the



H2Infra). The federal government has clarified in the import strategy that it will provide support to infrastructure projects through, *inter alia*, state guarantees, also inspired by coordination with other EU Members (German Hydrogen Import Strategy, p. 23). Other projects considered for implementation by Germany include the South-West Corridor to connect Spain, Portugal and Morocco with Germany as a transit country and the SouthH2 Corridor, also including Austria and Italy (see *infra*). At the European level, Germany also considers the Baltic Sea region as a possible H2 import source, due to the important presence of renewable energy in the region. Considering projects outside Europe, the key tool implemented by Germany is the H2Global programme, designed to facilitate the import of green hydrogen and derivatives at competitive prices. The programme is modeled on the tool of Contracts for Difference (CfD). Hence, through international auctions, the lowest bidder secure long-term contracts backed by the German government. The delivered hydrogen is then auctioned to EU buyers, and the H2Global mechanism covers the gap between supply and demand prices. The funding envisaged for the program amounts to €3.5 billion. Moreover, the German government is pursuing bilateral cooperation with non-EU countries, particularly with developing economies. Established partnerships include Algeria, Oman, Saudi Arabia, Egypt, India, Turkey (German Hydrogen Import Strategy). According to WTO estimates, in 2021 Germany was among the top importers of green hydrogen globally for a total of USD 5.9 million. Main imports sources include the Netherlands (65%); France (19%) and Belgium (6%) (WTO, International Trade and Green Hydrogen, 2023).

- France's strategy aims to strengthen domestic hydrogen production, ranking sixth among European hydrogen producers with approximately 800 kilotonnes of output equivalent to 26 terawatt-hours as of 2019. By 2024, France achieved a sufficient decarbonized hydrogen production capabilities to export up to 0.7 Mt and import 0.5 Mt of hydrogen annually by 2050 (World Energy Council, 2021). The country's strategy centers on major infrastructure investments to boost imports, including the €1.6 billion hydrogen import terminal project at the Port of Le Havre involving Air Products, Qair Group, and Livista (Marché Publique, Site OUEST A29-Le Havre). France also aims to reinforce its global position through strategic partnerships such as the Joint Roadmap on Green Hydrogen with India (French Embassy in New Dehli, Press, 18 October 2022). According to WTO estimates, in 2021 France was among the top importers of green hydrogen globally for a total of USD 4.1 million. Main import sources include Germany (36%); the Netherlands (36%) and Belgium (13%) (WTO, International Trade and Green Hydrogen, 2023).
- Italy aims to be a strategic transit, import, and distribution hub within the European hydrogen market, leveraging its geographical location. The country has a high energy import dependency rate (J. Heredia Yzquierdo, A. Sánchez-Bayón, 2020). Italian ports serve as crucial entry points for hydrogen imports, with capabilities for converting hydrogen derivatives including green ammonia, green methanol, and sustainable aviation fuels. For the development of the green hydrogen network, the country appears to mainly rely on IPCEIs (H2Infra in particular) and on private sector and SOEs initiatives, such as ENI and SNAM for the establishment of the H2 South Corridor related projects, through the development of projects abroad as well as at the domestic level. Considering the latter, projects have been announced by SNAM, endorsed by the Italian government, to establish four main networks spanning from Southern to Northern Italy prioritizing the repurposing of existing frameworks, with the objective to import from domestic consumption and export purposes (*Scheda 1, Piano Decennale SNAM Rete Gas 2022-2031*).
- Austria too leverages its central European geographical position to function as a transit country for green hydrogen at the EU level, developing infrastructure projects that connect with neighboring countries through initiatives like the H2 Backbone WAG and Penta-West project, including repurposing existing methane pipelines for hydrogen compatibility through the H2 Readiness program. Moreover, in collaboration with Italy within the context of the SouthH2Corridor project, the country aims to repurpose one of the three existing CH4 pipelines of the TAG system, for a total of 380 KM, for the transport of pure hydrogen, with a bi-directional design. The project is currently at the level of feasibility studies (TAG, Ready for hydrogen. An Ambitious



project. 16.6.2025). Moreover, Austria is implementing a second hydrogen transport project, the “H2 Backbone WAG + Penta-West” project aims to supplement the West Austria Gas Pipeline (WAG) and the Penta- West Pipeline (PW) with a parallel line for hydrogen transport. The project is part of the Repower EU initiative as a PCI, and it aims to support domestic industrial clusters projected to be the highest consumers of green hydrogen, with cross-border implications with Germany and Slovakia.

2.2.4. The policy and regulatory framework to support the renewable energy sector

Targets

In addition to direct support to green hydrogen production, countries have established economic and regulatory incentives to develop their renewable energy sector, thereby indirectly supporting green hydrogen production in accordance with the relevant EU regulatory framework.

- In this perspective, Germany, consistent with its ambitious electrolyzer capacity target, has established the most comprehensive, legally binding trajectory to expand electricity generation from renewable resources and foster green hydrogen production. It aims to achieve 80% of electricity supply from renewables by 2030, supported by detailed sector-specific targets for solar and wind energy (EEG 2023 §1–4).
- France aims to reach 40% renewable energy production by 2030 for, *inter alia*, green hydrogen production (Article L100-4 (10) *code de l'énergie*). By 2035, electricity from renewable sources is expected to increase by 177 TWh compared to 2022 levels, with an interim objective of 120 GW by 2030 and 160–190 GW by 2035 (National Energy and Climate Plan 2024, p. 69). To support this goal, installed offshore wind capacity is targeted to reach 3.6 GW by 2030 and 18 GW by 2035 (National Energy and Climate Plan 2024, p. 70). It can also be noted that the country may be exempted from the additionality requirement ex Article 4(2) Delegated Act, exempting bidding zones where the emission intensity of electricity is lower than 18 gCO₂eq/MJ (HydrogenInsight, 2023).
- Italy aims to produce 237 TWh of renewable energy by 2030, 10 TWh of which destined to green hydrogen production (National Energy and Climate Plan 2024, p. 101). The country also aims to achieve 39.4% of total energy consumption from renewable sources by 2030, with 63% of electricity generation from renewables, especially PV and onshore wind (National Energy and Climate Plan, 2024).
- Austria aims at a minimum threshold of 57% of increase of energy from renewables by 2030, with the aim to replace 80% of fossil hydrogen with climate-neutral hydrogen by 2030 (National Energy and Climate Plan, 2024, pp. 26-27). This framework is accompanied by a legally binding target to reach 25 GWh of annual energy output (Energy Efficiency Act).

Incentives

To support the expansion of the renewable energy sector, countries have established several support schemes. Similarly to what has been observed for green hydrogen support, countries provide tax incentives for renewable energy production and consumption. A few examples are provided below.

- Germany has established tax exemptions for renewable energy plants with an output of at least 2 MW if withdrawn for own consumption or to produce electricity. Eligible technologies include wind, solar, biomass, biogas, geothermal and hydropower (§9, Electricity Duty Act, *Stromsteuergesetz*).
- France designed a tax credit system to favor investment in the production of critical equipment for renewable energy production (C3IV), covering a predetermined percentage of the investment ranging from 20% to 60%, which varies by company size and investment location. Eligible expenses include buildings, facilities, equipment, machinery, and land essential for equipment operation, as well as patent rights, licenses, know-how, and intellectual property rights. (France, C3IV tax credit).
- Italy applies VAT reduction for selected renewable energy products (Italy, DPR 166/1972).



Other forms of support concern the **tariff regime applicable to the use of the grid by renewable energy producers and consumers**. Examined national approaches related to the integration of renewable energy within the grid differ. A few examples are provided below.

- Germany has established an asymmetrical tariff system that applies charges to energy withdrawal rather than injection, though this system is not exclusively applied to renewable energy (§5 Electricity Duty Act).
- France, under the TURPE 7 framework, has introduced an experimental tariff option for energy storage sites that can both withdraw from and inject into the grid, to prompt such sites to operate counter to grid demand, therefore consuming during surplus and injecting during peaks, helping stabilize the system. Accordingly, TURPE 7 offers temporary, favorable pricing for eligible sites, such as batteries in areas with high solar production or heavy consumption. The goal is to financially reward flexibility that eases strain on the most constrained parts of the network. This optional mechanism will be rolled out gradually between 2025 and 2028, focusing first on high-impact areas. It marks a first step toward more dynamic, local-based grid pricing.
- Italy has recently abolished the national price (*Prezzo Unico Nazionale*) in favor of a regional pricing system for energy, better reflecting regional and local conditions and providing flexibility to the system, supporting renewable energy producers (D.Lgs. 181/2023).
- Austria establishes grid fee reductions or exemptions to hydrogen production facilities that meet specific conditions, such as a minimum capacity requirement, exclusive use of renewable inputs, and compliance with defined grid connection ratios (Section 54(6) and 55 EIWOG).

Considering direct economic and financial incentives to boost the renewable energy sector, these include feed-in tariffs (FITs) and market premiums schemes (Germany, Art.19-21 EEG 2023; France, *Loi relative à la transition énergétique pour la croissance verte*; Italy, FER 2 Decree; Austria, Renewable Gas Act). Additionally, aid may be provided in the form of grants (Germany, BIK funding; France, DE-CARB IND25). In this case, funds are typically allocated through public calls for interest or tendering procedures, which may also allow participation to non-EU economic operators. Examples of such public procedures include:

- Germany through its Renewable energy programme (KfW) aims to promote the production of electricity and heat from renewable resources with long-term and low-interest loans (from 3.76% interest rate) with a fixed interest period of 5 or 10 years including a repayment-free start-up period. Applications are open also to non-German economic operators.
- France, within the context of France 2030, has established several projects to boost both the production and integration of renewable energy into the grid and to promote innovative projects for renewable energy production, including equipment. For example, through the DE-CARB IND 25 scheme, France has accelerated the decarbonization of the industrial sector by granting up to €30 million per project to industrial sites and projects that enable a reduction in GHG emissions of more than 1,000 tCO₂eq per year. Moreover, under the *Aide à l'investissement de l'offre industrielle des énergies renouvelables*, the French government has supported innovative projects for infrastructure and renewable energy production equipment.
- Italy promotes the development of renewable energy through simplified purchase agreements (DLG 387/2003, art. 13 c.3 seq; L 239/2004, Art. 1, c.41). Under this scheme, RE producers can either sell their energy on the free market or enter into a contract with the *Gestore dei Servizi Energetici* (GSE) who will resell the energy on their behalf for a guaranteed minimum price. In other words, the GSE pays the producer a certain fixed price for each kWh fed into the grid.
- Austria has established several schemes to support innovative solutions, especially for PV energy, and the construction or revitalization of existing renewable energy plants (§24 and 27a 24 ÖSG 2025).

Alongside economic incentives analyzed countries also adopt **regulatory incentives** to boost renewable energy growth. Generally, such measures are inspired by the need to simplify procedures concerning the renewable energy sector, as envisaged by the Commission. Accordingly, support in this category



takes four main forms: (i) priority access to the grid for renewable energy suppliers (Germany, § 8 Renewable Energy Act; Italy, Art. 3, c.3, - art. 11, c.4, D.Lgs. 79/99 and art. 13, D. Lgs. 387/03); (ii) purchase obligations on network operators (Germany, §11 EEG 2023; France, L.341-1 Code de l'énergie; Austria, §12 ÖSG); (iii) streamlining of administrative processes related to the establishment and operation of renewable energy plants (Italy, Article 4, DL 3 March 2011, No. 28); (iv) qualification of renewable energy plant projects as of "national interest", to streamline authorization and urban planning procedures (Austria, §12(2) EIWOG).

2.2.5. The policy and regulatory measures to support the development and scaling of biomethane

At the EU level, the RePowerEU sets a target of 35 bcm/year of biomethane production by 2030. Within this framework, selected countries display different strategies for the development of the biomethane sector. It should be noted that not all have established targets for biomethane production, and sometimes analyzed measures target the category of biogas more generally.

- Germany, while not specifically identifying an overarching target for biomethane production, aims at putting 600 MW capacity out for tender (National Energy and Climate Plan, 2024).
- France aims to reach 50 TWh of biogas production by 2030, 44 TWh of which to be injected into the gas grid (National Energy and Climate Plan, PPE 2025-2030; 2031-2035). This objective has therefore been revised upward compared to the previous PPE, due to the growth of the sector, allowing France to hold a leading position in biomethane production in Europe (Margarita De Gregorio and others, 2024; *Plan Énergétique Pluriannuel*, 2018-2028).
- Italy is among the countries that adopted an overarching target for biomethane. The country aims to reach an annual production of 5.7 bcm by 2030, backed by EUR 1.7 billion for production and infrastructure (National Energy and Climate Plan, 2024).
- Austria has not established a specific target yet, although the draft Renewable Gas Act sets an annual target of biogas production of 7.5 terawatt hours by 2030 (Erneuerbare-Gase-Gesetz - EGG).

The countries analyzed promote the biomethane sector through a range of economic and regulatory incentives, many of which overlap with those used to support the development of low-carbon and green hydrogen and therefore the same considerations apply. In terms of **economic support measures**, and consistent with what was observed in the hydrogen sector, the analyzed states rely primarily on FIT schemes (Germany, EEG 2023; Austria, §12 and §17 ÖSG 2025; Italy, DM 15/9/22, Decreto Biometano); market premiums (Germany, EEG 2023) competitive mechanisms, such as tenders (Germany, EEG 2023; Italy, FER 2 Decree); contracts for difference (France, recent aid scheme approved by the EU COM); direct capital grants (Italy, DM 15/9/22, *Decreto Biometano*; Germany, KfW Renewable Energy Standard program); tax-based incentives, in the form of tax exemption (Germany, §9 electricity duty act).

Considering **regulatory incentives**, two key measures are worth noting: guarantees of origin and biogas quotas. Regarding guarantees of origin (GOs), national legislation is based on EU law, specifically the RED Directive. As for quotas, Austria is aiming at implementing a green gas quota system (Austria, *Erneuerbaren-Gase-Gesetz*, EGG). Under this scheme, natural gas network operators would be required to ensure that their networks contain a minimum proportion of biomethane by 2030. Similarly, France has introduced biogas production certificates (BPCs), which will take effect starting in January 2026. Under this scheme, national gas suppliers must submit BPCs to national authorities, either by producing biomethane themselves or by purchasing certificates from biogas producers, with costs ultimately passed to end customers (*Décret n° 2024-718 du 6 juillet 2024 relatif à l'obligation de restitution de certificats de production de biogaz*).

International trade

Selected countries do not appear to rely on dedicated international trade strategies for biomethane. However, key elements affecting international trade flows of biomethane are instruments that track its



renewable origin, such as GOs and Certificates of Origin (COs). Given the relevance of these tools and their specific impact on international trade with non-EU countries, they will be further explored in the following phases of the research (see *infra*).

2.2.6. Preliminary results and policy inputs for Switzerland

The analysis shows that the current regulatory framework governing carbon-neutral fuels in Switzerland is complex, fragmented and operates at multiple levels, lacking a coherent and unified approach. There is no specific legislation dedicated to hydrogen and its associated value chain. Instead, relevant provisions are dispersed across a variety of laws and ordinances. This fragmentation can result in legal uncertainty, coordination challenges among authorities, and potential obstacles for stakeholders seeking to develop or invest in hydrogen-related activities.

The approach adopted by Switzerland is pragmatic: hydrogen is intended to be utilized only in contexts where it is economically advantageous. Moreover, financing is expected to adhere to the polluter-pays principle, positioning the public sector in a subsidiary role. This implies that private actors are primarily responsible for investment costs, with the state intervening only where necessary. Moreover, there is currently no dedicated funding mechanism for hydrogen projects, which may limit the development of essential infrastructure and slow market adoption. While this strategy may ensure cost-effectiveness, it runs the risk of not providing a clear policy signal for long-term development or scaling of the hydrogen sector.

Although the green hydrogen technology is partially considered mature (namely electrolysis), involved actors estimate the framework conditions for planning and investment security to be lacking or insufficient (e.g. *Einschätzung des VSE zur nationalen Wasserstoffstrategie*, Januar 2025 or *Wasserstoffstrategie des Bundesrates – 3 Blickwinkel* in <https://wasserstoff-politik.ch/wasserstoffstrategie-des-bundesrates-3-blickwinkel/>).

In this context, recent studies have identified *carbon contracts for difference* (CCfD) as a promising support tool within the Swiss framework, particularly in the field of CCS, but such instruments are not yet implemented in Switzerland (*Investitionsbedarf und Finanzierungsmöglichkeiten von CCS-Technologien in Sonderabfallverbrennungsanlagen*). However, certain new measures tend to adopt a similar financial approach, see e.g. the Floating market premium for the feed-in of electricity from renewable energies under Article 29a of the Energy Act.

Another key tool may be *State guarantees*, which in Switzerland are only available for heating networks and thermal storage systems. According to Art. 7 of the Climate and Innovation Act, the Confederation covers the risks associated with investments in public infrastructure that are necessary to achieve the net-zero target. The original idea included the possibility of applying for state guarantees for thermal networks, as well as other public infrastructure requiring significant investment and long amortisation periods, such as CO₂ pipelines and CCS/NET technologies (*Iniziativa parlamentare – controprogetto indiretto all'Iniziativa per I ghiacciai. Saldo netto delle emission di gas serra pari a zero entro il 2050. Rapporto della Commissione dell'ambiente, della pianificazione del territorio e dell'energia del Consiglio nazionale del 25 aprile 2022*, N. 2.3.4.). However, the Federal Council considers that only market-ready infrastructure projects are eligible for risk coverage by the State. In this sense, it assumes that the expansion or underground CO₂ storage facilities by 2030 is better promoted through incentives under Article 6 of the Climate and Innovation Act. Conversely, the Federal Council will consider specific proposals regarding climate policy to enhance CCS and NET technologies, as well as the necessary infrastructure for the period beyond 2030 and for the development of the hydrogen infrastructure, namely the need for a financial guarantee for the construction of hydrogen pipelines connected to the European network, in particular for the conversion of the Transgas pipeline to hydrogen transport (Swiss Hydrogen Strategy). For now, the Climate and Innovation Ordinance limits such measures to: (a) new or upgraded district heating networks whose thermal energy is derived from renewable sources or unavoidable waste heat and supplied to decentralised end users; and (b) new long-term thermal storage systems integrated with a district heating network (Art. 21 ff. of the Climate and Innovation Ordinance). In



conclusion, a legal basis is in place; however, its scope of application has been significantly restricted by the executive.

Against this background, the results of the comparative analysis can inform Switzerland's future strategy on carbon-neutral fuels at two levels. First, at the national level, the analysis is useful to identify best practices used in neighboring countries to address issues that are similar to those experienced in Switzerland; such insights could inform policy discussions at the domestic level even though there is no one-size-fits-all approach and Switzerland's specific needs and interests would need to be properly taken into account when evaluating alternative policy options and scenarios. Second, the analysis can guide the establishment of strategic partnerships, depending on competitive advantages and strategies pursued by potential partners at the domestic level. Ultimately such partnerships could provide Swiss operators enhanced access to additional funding, technology transfer opportunities, and expanded market reach through access to European hydrogen and renewable energy markets. For instance, Italy's support scheme under the PNRR Investment 3.2 initiative (allocating €2 billion budget for promoting hydrogen use in hard-to-abate sectors) already permits non-resident entities, including Swiss operators, to participate in tendering procedures. On the other hand, the analysis will further investigate best practices implemented in other countries for the purposes of evaluating whether and under which conditions they could serve Switzerland's needs and interests. For example, to improve grid resilience and adaptability, Switzerland could consider adopting Germany's flexibility surcharge mechanisms; to support investor confidence in capital-intensive pipeline projects, Germany's depreciation mechanisms may offer a useful model; Austria's quota system for biomethane could provide a relevant example to incentivize sustainable fuel production.

Although best practices and regulatory tools from neighboring countries may provide valuable insights for Switzerland, they must be carefully adapted to its distinct legal, economic, and energy context. The importance of context-specific adaptation and continued alignment with both domestic reforms and European developments was also consistently stressed during the Reg4Fuels kick-off meeting by several participants.

In this perspective, subsequent steps in the regulatory analysis will aim at identifying, on the one hand, areas where the similarities in the approach adopted by Switzerland and its neighboring countries may present market access and/or collaboration opportunities. For example, interesting parallels exist between the Swiss and French frameworks, particularly concerning the deployment of hydrogen clusters to overcome logistical and production hurdles for green hydrogen. This might facilitate the establishment of cross-border partnerships focused on hydrogen clusters near the French-Swiss border, which in turn requires the development of shared infrastructure and the alignment of technical regulations to enable cross-border hydrogen trade.

Further efforts will focus on instruments and approaches that have emerged as of particular interest based on the preliminary findings from the analysis of the Swiss regulatory framework, the feedback gathered at the Reg4Fuels kick-off meeting and the iterations with the technical and modelling work packages (WPs). These include design options for State guarantees, contracts for difference, and flexibility surcharge mechanisms.

The list may be further refined based on additional insights derived from the modelling WPs and/or subsequent analytical findings reflecting further normative and regulatory developments. Over the coming months, the focus will be on examining the regulatory details of existing schemes and their requirements with a view to assess whether, and under which conditions, they can be adapted to the Swiss framework. This would allow to formulate tailored policy recommendations for Switzerland.



2.3 Energy system models

2.3.1. Methodological approach

The study uses a multi-step modelling approach linking two energy system models with different spatial, temporal, and sectoral scopes (Figure 1). The first model, ZEN-garden, is a European model which identifies pathways toward net-zero carbon emissions in 2050. This model sets the boundary conditions for subsequent Swiss modelling. The Swiss modelling is done using the Nexus-e platform. This platform contains a collection of models that describe the Swiss energy transition with high fidelity and spatial resolution.

The European model, ZEN-garden, optimizes the development of all economic sectors with large carbon emissions. These include sectors for the supply of electricity, heat, transportation, steel, cement, and chemicals. ZEN-garden captures the general trends in these sectors at a national level; however, it is unable to provide information at a sub-national resolution due to computational limitations and insufficient data availability. As a result, a more detailed Swiss modelling is required to refine the European findings.

The Swiss modelling is done using the CentIV (Raycheva et al., 2023) and GasNet (Akbari et al., 2024) modules of the Nexus-e platform. CentIV focuses on future developments in the Swiss electricity system. It uses data-driven and physics-based representations of the high-voltage transmission system to ensure that the modelled developments are feasible and realistic in the Swiss context. Next, GasNet optimizes the Swiss gas system. It uses physics-based representations of gas flow through pipes in Switzerland, thereby ensuring realism in the representation of gas infrastructure. Results from ZEN-garden are used to set boundary conditions for both CentIV and GasNet. ZEN-garden determines the demand for electricity (including for heat provision), and hydrogen in Switzerland as well as the production capacities in the rest of Europe.

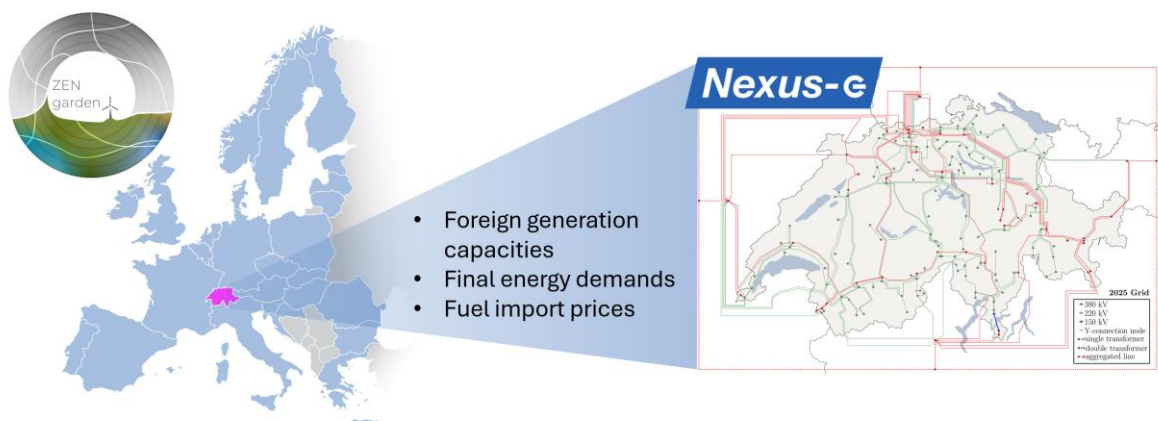


Figure 1: Schematic diagram of the two models used in the study. ZEN-garden simulates all carbon-intensive sectors in Europe. Results from ZEN-garden then set boundary conditions for the detailed Swiss modelling using Nexus-e.



2.3.2. ZEN-garden in detail

ZEN-garden is a linear energy system optimization model which minimizes the future cost of the energy supply subject to constraints on energy demand and carbon emissions (Mannhardt et al., 2025). The model determines optimal investments in new energy infrastructure (e.g. power plants, pipelines, heating technologies, etc.) required to meet future energy demands while also achieving net-zero energy emissions in 2050. It takes a central planner perspective, meaning decisions are made in a way that minimizes European costs without any consideration of national objectives or interests. In theory, the result of a cost-minimizing model can be interpreted as the result of a perfectly competitive market outcomes characterized by rational behaviour, and perfect information about the future (see e.g. Finke et al. (2024) and Brown and L. Reichenberg (2021)).

In this study, ZEN-garden models energy supply in the years 2022, 2036, and 2050. Perfect foresight is used, which means that decisions of all years are optimized jointly. Initial energy infrastructure is set in 2022 using a brownfield approach. Therefore, all existing European energy infrastructure is included in the model and is assumed at the beginning of the first simulation year. The model uses a national spatial resolution, where each country (EU 27 + CH + UK + NO – CY – MT) is represented as a single node. As a boundary condition, the model must meet an exogenous final demand for electricity, heat, transportation, ammonia, clinker, kerosene, methanol, steel, shipping, and olefins. Imports are allowed for crude oil, diesel, gasoline, coal, hydrogen, natural gas, and uranium. Furthermore, carbon dioxide, electricity, hydrogen, natural gas, and oil (fossil or synthetic) can be transported between countries via pipelines or transmission lines.

Capacity factors for renewable electricity sources are derived using hourly data from the year 2009. For investment planning, time series aggregation is used to reduce the computational complexity of the problem. The time series aggregation reduces the full annual time series of 8760 hours to 100 representative hours. The capacity planning model is then run using only these 100 representative hours. Subsequently, the optimal capacity values are transferred to an operation-only model in which in the full hourly time resolution of 8760 is considered.

Sustainable fuels are represented in ZEN-garden primarily via hydrogen and biomethane. Green hydrogen can be produced either from electricity via electrolysis, from dry biomass via gasification, or from methane (fossil or renewable) via steam methane reforming. Similarly, biomethane can be produced from hydrogen via methanation or from wet biomass via anaerobic digestion. Both hydrogen and methane can then be used for to meet industry, transport, or power demands. For example, hydrogen can be used to create synthetic hydrocarbons (via the fisher tropsh process), ammonia (via the haber bosh process), methanol, steel, or fuel. Similarly, methane can be used to produce power in natural gas

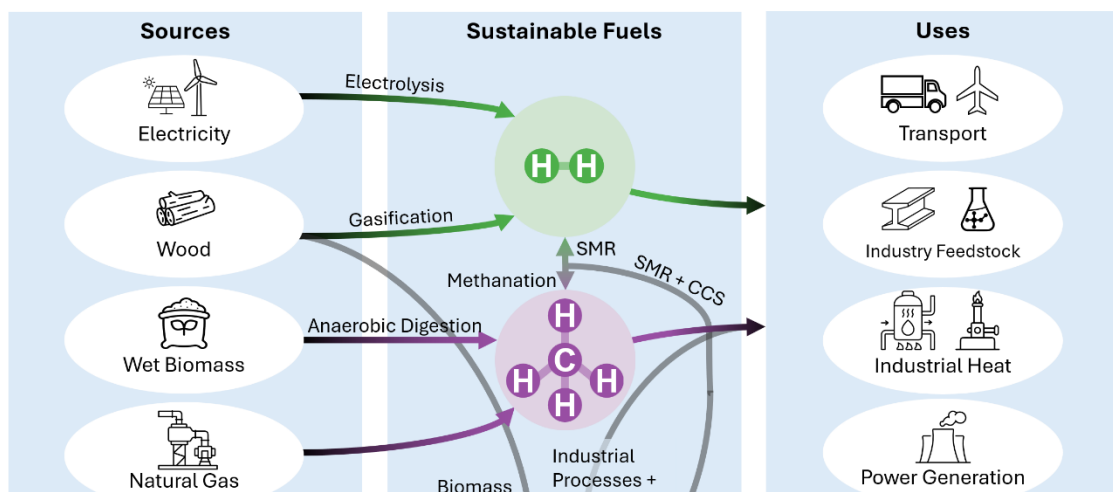


Figure 2: Schematic diagram showing conversion processes for hydrogen and biomethane in ZEN-garden. All arrows indicate processes which are included in the modelling



turbines, meet industry heating demands, produce steel, or produce methanol. Figure 2 below shows a flow chart of the different conversion processes which produce or consume hydrogen and methane.

2.3.3. Nexus-e in detail

The Centlv module from the Nexus-e platform formulates and solves an optimization problem to determine the optimal design and operation of the Swiss electricity system as well as other European countries – in this case based on outputs by ZenGarden. It includes hydroelectric power plants (run-of-river power plants, dams and open and closed pumped storage plants), renewable energies (wind and photovoltaics), large-scale thermal power plants (nuclear, gas, biomass, etc.), battery storage systems as well as other flexibility options through e-mobility (flexible and bidirectional charging), heat pumps and P2X. In addition, the model can provide negative emissions in the power sector via Carbon Capture and Storage (CCS) and Direct Air Capture.

The model simultaneously determines the optimal use of all power generators and flexibility options (pumped storage power plants,) as well as the optimal capacity expansion. The objective function has the aim to minimize the total cost of the system. The cost-minimization is subject to a set of constraints that specify operating limits for the power plant fleet and its expansion, international trade restrictions (NTCs), grid limits of the Swiss transmission grid and other policy instruments such as climate targets or target values for the expansion of new renewable generation. The resulting hourly electricity prices result from the shadow price of the energy balance equation between electricity supply and demand at the nodes.

Centlv minimizes the sum of annualized capital costs and operating costs of all existing and potential generation and storage technologies over the planning horizon T (one year with hourly resolution):

$$\begin{aligned} \min \sum_{i \in G_I} a_i c_i^{inv} X_i + \sum_{j \in G_J} \sum_{t \in T} (c_j^{vom} + c_j^{fuel} + c_j^{emi}) P_{j,t} \\ + \sum_{s \in G_S} \sum_{t \in T} c_s^{vom} P_{s,t} + \sum_{r \in G_R} \sum_{t \in T} c_r^{vom} P_{r,t} + \sum_{n \in N} \sum_{t \in T} c_{ls} L_{n,t} \end{aligned}$$

Where investment cost for construction of a candidate generator or storage i with the capacity X_i are determined by the annuity factor a_i and the specific overnight capital cost c_i^{inv} of unit i . Operation costs of every thermal unit j , every storage technology s and every renewable generator r are determined for each time step t . Furthermore, load shedding at each transmission grid node n is priced at c_{ls} for each unit of shed load $L_{n,t}$ at node n at time t .

Each technology belongs to a subset of the total set of all units $j \in G$ (i.e. $i \in G_I$, $j \in G_J$, $s \in G_S$, $r \in G_R$). To calculate the operating costs, variable operation and maintenance costs c^{vom} are multiplied with the power generated by thermal units $P_{j,t}$, of the power delivered by hydropower or battery storage systems $P_{s,t}$ and the power generated by renewable producers $P_{r,t}$. Generation volumes by all technologies are decision variables of the optimization problem.

For thermal generators, the fuel costs c_j^{fuel} and the cost of CO2 emissions c_j^{emi} is taken into account. The cost of load shedding, c_{ls} , vary between 1,000 and 10,000 €/MWh. The capital cost (including fixed operating and maintenance costs) for a unit i from the set of all candidate units $i \in G_I$ are c_i^{inv} . The investment decision variable is X_i , i.e. the installed capacity of a potential technology. New technologies can be installed at different hubs based on real availability (e.g. wind) or official expert estimates (e.g. waste and gas power plants).

The following describes the most relevant constraints of the optimization problem. Detailed explanations can be found in Gjorgiev et al. 2022 and Raycheva et al. 2022.



Input data

Centlv simulates the European electricity system with a focus on Switzerland. Therefore, the simulated system includes a detailed representation of the Swiss electricity system as well as an aggregated representation of other European countries. The capacity expansion paths, hourly load profiles, generation volumes from renewable energies and fuel prices for non-Swiss regions are provided by ZenGarden. In Nexus-e, every country in Europe is mapped as a node, so the entire European electricity market can be mapped. The data for Europe include demand profiles (conventional load, heat pump load and electrolyser load), installed capacities (power generation and demand side response (DSM), storage capacities), production profiles (solar and wind power plants), water inflow profiles (pumped storage plants, reservoirs) and net transmission capacities (NTC). For the representation of Switzerland, we build on the existing Nexus-e database.

Electricity demand profiles, including the electrification of mobility and heat in Switzerland, are input variables of the optimisation problem and are based on data from Swissgrid in the current version of Nexus-e and, for future years, on data from the Swiss Energy Perspectives 2050+. Flexibility usage from electric vehicles and heat pumps is endogenous to the model.

The Swiss power plant fleet comprises all currently existing generation plants with a capacity of more than 5 MW. For hydropower, WASTA data is used and the detailed cascade structures of hydropower are mapped (see also Figure 3). A cascade is defined by a network of waterways between reservoirs and generators. These connections and water flows are critical to the operation of the generators in a cascade and therefore need to be modelled in detail to predict operating behaviour. We model a cascade as a directed graph consisting of water nodes (reservoirs) with a specific storage capacity and direction-specific connections (pressure tunnels/rivers). Each hydroelectric generator is connected to a specific pressure line, and the power generated or consumed by a generator determines the flow of water through that particular pressure line. The cascades are considered to have ended when the run-off flows into a river without a power plant downstream in close proximity. Since the pressure tunnels are always filled with water, there is no delay between inflow and outflow. The water is tracked and the water loss is modelled.

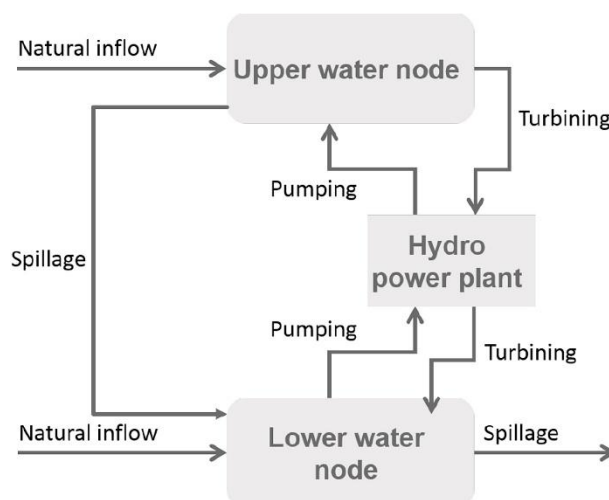


Figure 3: Stylized example of a hydro cascade

While the capacity expansion path is predetermined for the non-Swiss regions based on ZenGarden outputs, the path for Switzerland is based on endogenously optimized investment decisions that determine when further new generation capacity should be built.

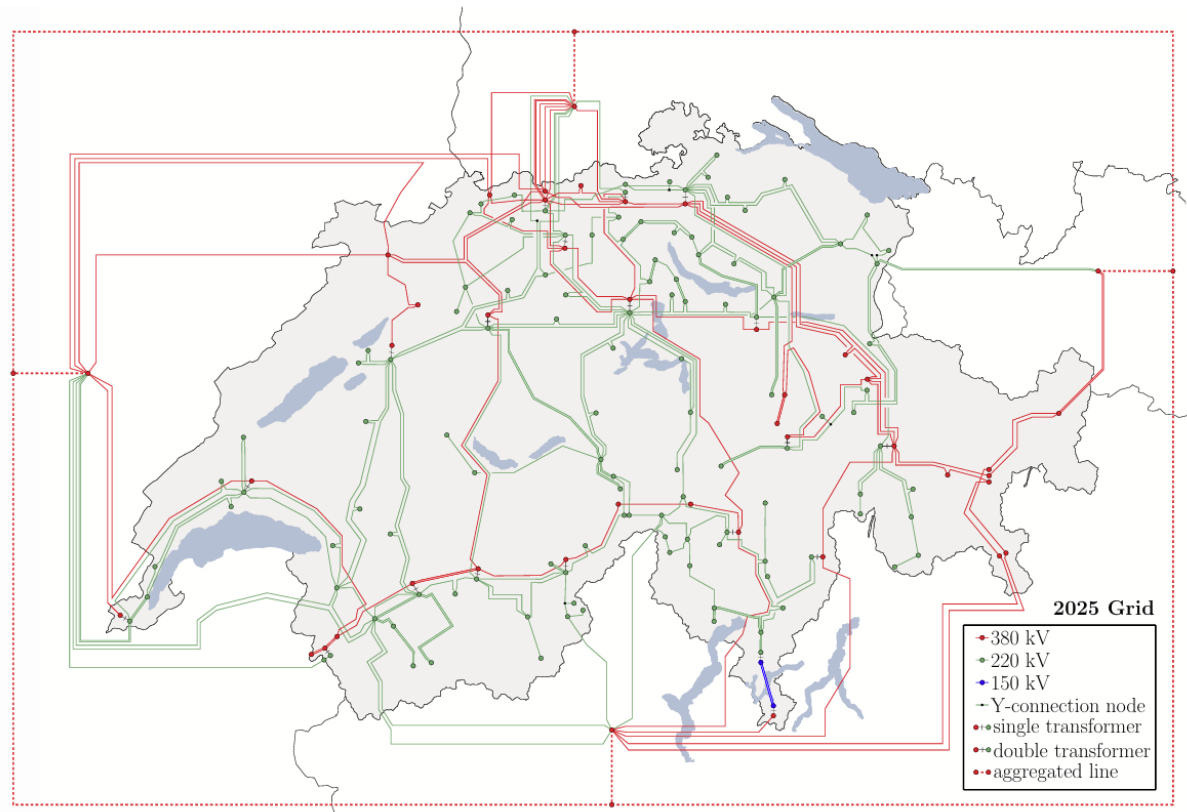


Figure 4: Swiss transmission grid used in Nexus-e

The model of the Swiss electricity grid consists of 170 nodes and 318 lines based on data from Swissgrid (see Figure 4). Transmission lines to neighbouring countries as well as between EU countries are modelled as NTCs. This enables a detailed mapping of the grid situation in Switzerland as well as a good representation of electricity trading in Europe.



2.4 Scenarios to investigate

2.4.1. European Scenarios

The European scenarios set the background conditions. They are selected with two goals: (1) to capture the most relevant European factors that shape future hydrogen demand and production in Switzerland, and (2) to minimize the number of scenarios. The latter is important since each European scenario must be simulated with all Swiss scenarios. The number of model runs thus increases exponentially with the number of European scenarios.

To select the European scenarios, a literature review of past hydrogen studies is conducted. Past studies have investigated the impact of several factors on European hydrogen deployment. These include: (i) the price and availability fuel imports (Neumann et al., 2023; Greevenbroek et al., 2025; Akbari et al., 2024), (ii) technology cost and performance assumptions (Neumann et al., 2023; Greevenbroek et al., 2025; Wallinger et al., 2025; Langer et al., 2024), (iii) transmission expansion and energy carriers available for transportation (Neumann et al., 2023), (iv) availability of complement or substitute technologies such as carbon storage, biomass, and wind (Neumann et al., 2023; Wallinger et al., 2025; Greevenbroek et al., 2025), and climate policies (van der Zwaan et al., 2025).

For the European scenarios, we selected a small subset of these, namely the price of hydrogen imports and the availability of hydrogen substitute technologies. The price of hydrogen imports affects the value of producing hydrogen domestically, whereas the availability of substitutes influences the overall demand for hydrogen. For hydrogen substitutes, we include the biomass production potential and the carbon storage potential, both of which are uncertain.

The scenarios follow a 2 x 2 design, where one dimension relates to the fuel price and the other to the availabilities of substitutes. The four scenarios are:

1. **Cheap imports, scarce substitutes** (CISS) – hydrogen can be imported from outside Europe at a low cost. The European potential for biomass production and carbon storage is at the low end of current estimates.
2. **Cheap imports, abundant substitutes** (CIAS) - hydrogen can be imported from outside Europe at a low cost. The European potential for biomass production and carbon storage is at the high end of current estimates.
3. **Expensive imports, scarce substitutes** (EISS) - hydrogen imports from outside Europe remain expensive. The European potential for biomass production and carbon storage is at the low end of current estimates.
4. **Expensive imports, abundant substitutes** (EIAS) - hydrogen imports from outside Europe remain expensive. The European potential for biomass production and carbon storage is at the high end of current estimates.

Table 2 shows the detailed assumptions behind each of the four scenarios in the European modelling. Hydrogen price assumptions are derived from the highest and lowest hydrogen price estimates in Neumann et al. (2025). Neumann et al. (2025) use a supply chain model to estimate hydrogen import prices from various global regions into Europe. The supply chain model analyses 53 possible exporting regions and estimates the cost of European hydrogen imports from each region using information about solar and wind potentials, storage costs, and transportation costs. Next, potential biomass production values are taken from the “ENS_High” and “ENS_Low” scenarios of the ENSPRESSO database (Ruiz et al., 2019). This database provides transparent estimates for wind, solar, and biomass potentials in Europe. Finally, carbon storage potentials are taken from the sensitivities in Greevenbroek et al. (2025). Greevenbroek et al. (2025) review carbon storage potentials used in current energy system modelling studies on hydrogen, and the values captured in their scenarios capture the range of existing studies.



Table 2: Assumptions of the four European scenarios in 2050. The scenarios follow a 2 x 2 design, varying the price of hydrogen imports and the potential of hydrogen substitute technologies.

Scenario name	Hydrogen import price (Eur/kg)	Dry biomass potential (GW)	Wet biomass potential (GW)	Carbon storage potential (MT CO ₂ e/yr)
cheap imports, scarce substitutes	2.46	20.7	49.9	275
cheap imports, abundant substitutes	2.46	61.4	151	1100
expensive imports, scarce substitutes	5.47	20.7	49.9	275
expensive imports, abundant substitutes	5.47	61.4	151	1100

2.4.2. Swiss scenarios

The Swiss scenarios cover four dimensions that will have a major impact on the deployment of carbon neutral fuel infrastructure. First, we consider cases with and without a renewable target for Switzerland. While resulting in overall higher system costs, a high renewable target will lower electricity prices, making electrolysis and the production of hydrogen derivatives in Switzerland more attractive. Second, we look into co-location incentives. Under current grid tariff designs with per MWh tariffs, it is attractive to locate electrolyzers next to large generators such as Run of river or nuclear power plants to avoid paying grid fees while still keeping the option of drawing electricity from the grid in times where the generator is not available, e.g. during maintenance cycles. However, from an overall systems perspective, the cost of providing grid capacity and electricity generation in times where the electrolyser draws electricity from the grid is mostly fixed cost driven and hence per MWh tariffs do not reflect the true cost. This can be adjusted by introducing time varying or capacity based tariffs, which in turn affects the attractiveness of co-location. Third, potential winter net-import constraints will have a strong impact on both capacity investments into new electricity generation and on electricity prices which directly determine the attractiveness of domestic hydrogen production. Fourth, time matching requirements will have a strong impact on both renewable and hydrogen infrastructure deployment.

Renewable targets and renewable subsidies

Representation of the **renewable target** in the model as follows:

$$\sum_{res \in G, t \in T} GEN_{res,t} + CURT_{res,t} \geq target_{res}$$

In this formulation, curtailed renewable energy counts towards the target. This means that a potential subsidy is paid for the potential of generation and not only for generation that is actually being used in the system. The target is a simplified representation of different potential support mechanisms for RES generation which will be discussed in more detail in the chapter on regulatory settings.

Grid tariffs and co-location incentives

For the representation of grid tariffs and co-location incentives, the objective function of Centlv is expanded by adding a grid fee c^{grid} that is applied to the $NETFLOW_{n,pn,t}$ between system level nodes n and prosumer nodes pn . c^{grid} can be adjusted to reflect different time varying tariff designs c_t^{grid} . Electrolysers are located at prosumer nodes to analyze the co-location incentives stemming from different tariff designs.

$$\begin{aligned} \min \sum_{i \in G} a_i c_i^{inv} CAP_i + \sum_{g \in G, t \in T} (c_g^{vom} + c_g^{fuel} + c_g^{emi}) GEN_{g,t} \\ + \sum_{n \in N, t \in T} c^{ls} LL_{n,t} \end{aligned}$$



$$+ \sum_{n \in N, pn \in N, t \in T} c^{grid} NETFLOW_{n,pn,t}$$

Furthermore, investment cost are represented by the total capacity CAP_i for investment technology i , at given capital cost c_i^{inv} and specific annuity factor a_i . Operation are determined by the generation $GEN_{g,t}$ of each generator g in time t and the plant specific variable operation and maintenance cost c_g^{vom} and in the case of thermal generators fuel c_g^{fuel} and emission costs c_g^{emi} . Load shedding $LL_{n,t}$ is possible at a cost of c^{ls} .

Winter net-import constraint

Furthermore, we model a winter net-import constraint that is based on generation potential. For all hours in winter with w in t

$$\sum_{i \in G, w \in T} CAP_i * avail_{i,w} + \sum_{s \in G} E_{s,0} + \sum_{s \in G, w \in T} inflow_{s,w} \geq \sum_{w \in T} load_w - winterlimit - backuppotential$$

Where CAP_i and $avail_{i,w}$ determine the production potential of thermal and renewable generators during winter, $E_{s,0}$ is the energy content of hydro storage at the beginning of winter and $inflow_{s,w}$ is the hydrological inflow in MWh to hydro storages. All the available energy combined has to be sufficient to satisfy domestic load $load_w$ while taking into account the height of the $winterlimit$ and the potential for generation by backup power plants $backuppotential$. In the Swiss case, the latter is determined by the currently contracted backup capacity of 500 MW and the intended fuel storage duration of 2 weeks.

Implementing a winter net-import constraint in this way avoids the negative impact on arbitrage by storage units that a generation based constraint would cause. Furthermore, it reflects an internal capacity market rather than an import tax, which would violate current EU-level regulation.

Time-matching requirements

In this study, we model both hourly and annual time-matching requirements. Annual matching is enforced by defining that annual generation from wind and solar resources must equal annual electricity consumption of all electrolyzers e :

$$\sum_{res,t} GEN_{res,t} + CURT_{res,t} \geq \sum_{e \in G, t \in T} LOAD_{e,t}^{electrolysis}$$

Analogous to the renewable target constraint, we consider generation potential rather than generation fed into the system by including curtailment. Hourly time matching is implemented by requiring hourly output of renewable generators to be at least equal to the hourly electricity consumption of electrolyzers.

$$GEN_{res,t} + CURT_{res,t} \geq LOAD_{e,t}^{electrolysis}$$

Furthermore, we are exploring to include additionality requirements of renewable generation.

3 Conclusions and outlook

The project is currently well on track to deliver novel results on the future role of hydrogen and electric fuels in the Swiss energy system while considering the interaction with the European energy system in high detail. The scenario development is mostly completed and first model calibration runs have been executed. Detailed results will be added to the next annual report.



4 National and international cooperation

To assess the value of hydrogen and methane in the Swiss energy system, we rigorously quantify the transition to net zero in Switzerland and Europe by 2050, leveraging our expertise in studying net-zero scenarios in previous research and ongoing projects like SWEET PATHFINDER, EDGE, and CoSi/CROSS. Activities within this project are regularly discussed with experts from these projects.

To accomplish the assessment of the legal and regulatory framework, we rely on our past project experiences as part of the DemoupCARMA project (carbon capture and storage technologies) as well as ongoing work as part of SWEET re-Fuel.ch (sustainable fuels and platform chemicals) for the purposes of informing findings and recommendations by the legal theory of multi-layered governance. As part of these projects, we are in regular contact with a multidisciplinary group of experts informing the work on this project.

Furthermore, we are in regular contact with the HYPATH project and the SusTec group at ETH Zürich.

5 Publications and other communications

We are currently developing two scientific publications out of the project. The first paper will provide an overview of the results for the different Swiss scenarios and their interaction with the European scenarios described above combined with a discussion of the regulatory framework. The second paper will focus on the role of national import constraints on different carriers in the European energy system. In particular, this study will compare different formulations of policy driven import constraints that are formulated as binding targets based either on actual generation or on potential generation.



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7 Appendix

Appendix 1 – Centlv constraints

Constraints

Constraints for Centlv can be divided into the following categories:

- **Investment constraints** ensure that the newly built capacities for conversion and storage technologies remain within their maximum defined potentials. All investment decisions are linearized so that the built candidate capacity X_i can be any value between zero and the maximum potential X_i^{max} .
- **Operational constraints** are defined for all conversion technologies $g \in G$ and reflect their physical generation and reserve provision capacities. These operational constraints include ramp rate limits ζ_g , which limit the changes in production levels between time steps. It uses linear approximations that assume constant conversion efficiency and do not take unit commitment decisions into account. Likewise, constant emission rates are used to quantify and limit the allowable amount of CO₂.
- **Maximum power limits** ensure that the combination of energy generated $P_{g,t}$ and procured (upward) reserve $R_{g,t}^{up}$ do not exceed maximum power capacity X_i . The minimum power limit (since no unit commitment is taken into account here, the minimum electricity generation for all generators is zero) is also used to constrain the combination of energy generated and procured (downward) reserve $R_{g,t}^{dn}$. In addition, the planned maintenance of certain technologies is determined in advance by assigning availability values.

For all storage technologies $s \in G_s$ all limitations of the conversion technologies remain in place (e.g. the maximum power limit (2) and the ramp rate limit (3)) and are complemented by additional constraints on the modelling of the charging and storage operations. Storage technologies consist of various components that together form a storage unit. For example:

- The combination of turbine, pump and storage reservoir forms a pumped storage power plant.
- The combination of turbine and reservoir is considered a dam.
- The combination of electrolyser, fuel cell and hydrogen tank forms a hydrogen storage technology.

During the charging process, the electricity consumption in each hour is limited by the existing or newly built charging power, which in turn is limited by the maximum installable charging power (4). The ramp rate constraint (ζ in MW per hour) limits the change in charging consumption between successive time increments (5).

Additional restrictions are introduced for storage technologies:

- State of charge is tracked, including self-discharge (λ_s), Charging inflow ($Q_{s,t}$), discharge ($P_{s,t}$), natural inflow ($\xi_{s,t}$) and excess, unstored energy ($W_{s,t}$) (6).
- State of charge at the beginning and end of the simulation period is matched to ensure sustainable operation of the storage unit over time (7).

The state of charge must always be between the minimum permissible energy level and the maximum installed energy volume, the latter being less than the maximum permissible capacity limit (8).



Depending on the type of storage technology, natural energy inflows and energy losses due to overflow can be zero. Only hydroelectric storage, such as dams and pumped storage, have natural energy inflows (water) into their reservoirs and the ability to drain excess energy (water) when needed.

$$0 \leq P_{s,t} \leq X_s \leq X_{\max,s} \quad (2)$$

$$P_{s,t-1} - \zeta_s \leq P_{s,t} \leq P_{s,t-1} + \zeta_s \quad (3)$$

$$0 \leq Q_{s,t} \leq Y_s \leq Y_{\max,s} \quad (4)$$

$$Q_{s,t-1} - \zeta_s \leq Q_{s,t} \leq Q_{s,t-1} + \zeta_s \quad (5)$$

$$E_{s,t} = (1 - \lambda_s \Delta t) E_{s,t-1} + \eta_{c,s} Q_{s,t} - \frac{P_{s,t}}{\eta_{d,s}} + \xi_{s,t} - W_{s,t} \quad (6)$$

$$E_{s,0} = E_{s,T} \quad (7)$$

$$Z_{\min,s} \leq E_{s,t} \leq Z_s \leq Z_{\max,s} \quad (8)$$

Energy balances define that in all time intervals and for all energy carriers considered, the sum of imported and generated power corresponds to the sum of exported, demanded and consumed power.

The constraints for the transmission system include the active electrical power balance at each grid node, so that at each time interval, demand, consumed charging demand, and outflows are balanced with generation, inflows, and load shedding. Load shedding is allowed at each node, but is limited to a maximum of the hourly node load and is sanctioned by the cost of load shedding. The shadow price of the energy balance yields wholesale electricity prices as a result.

The active power flow on each line is calculated according to the DC load flow approach, taking into account the defined line reactance, and is constrained by a maximum thermal limit.



Appendix 2 - Legal references consulted and reviewed for the analysis of national and international regulatory frameworks relevant for carbon neutral fuels

EUROPEAN UNION (EU)

Directives

- Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen, amending Directive (EU) 2023/1791 and repealing Directive 2009/73/EC (recast)
- Commission Delegated Directive (EU) 2024/1405 of 14 March 2024 amending Annex IX to Directive (EU) 2018/2001 of the European Parliament and of the Council as regards adding feedstock for the production of biofuels and biogas
- Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) (Text with EEA relevance.)
- Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)
- Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast)
- Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC

Regulations

- Regulation (EU) 2024/1789 of the European Parliament and of the Council of 13 June 2024 on the internal markets for renewable gas, natural gas and hydrogen, amending Regulations (EU) No 1227/2011, (EU) 2017/1938, (EU) 2019/942 and (EU) 2022/869 and Decision (EU) 2017/684 and repealing Regulation (EC) No 715/2009 (recast)
- Commission Delegated Regulation (EU) 2023/1185 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a minimum threshold for greenhouse gas emissions savings of recycled carbon fuels and by specifying a methodology for assessing greenhouse gas emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels
- Commission Delegated Regulation (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin
- Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast)
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SWITZERLAND

Laws

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- Energy Act (RS 730.0)
- Electricity Act (RS 734.7)
- Federal Act on Nature Protection
- CO₂ Act (RS 641.71)
- Federal Act on Climate Protection Targets, Innovation and the Strengthening of Energy Security (RS 814.310)
- Federal Act on Pipeline Transport (RS 746.1)
- Spatial Planning Act (RS 700)

Ordinances

- Ordinance on Spatial Planning (RS 700.1)
- Revised Energy Ordinance (Art. 1a; RS 730.01)
- CO₂ Ordinance (RS 641.711)
- Ordinance on Climate Protection Targets, Innovation and the Strengthening of Energy Security [RS 814.310.1]
- DETEC Ordinance on the Certificate of Origin for Thermal and Motor Fuels (RS 730.010.2)
- Ordinance on the Carriage of Dangerous Goods by Road (RS 741.621)
- Agreement concerning the International Carriage of Dangerous Goods by Road (0.741.621)
- Ordinance on the Carriage of Dangerous Goods with Railways and Cableways (RS 742.412)
- Ordinance on Protection against Major Accidents (RS 814.012)
- Ordinance on Protection against Dangerous Substances and Preparations (RS 813.11)
- Ordinance on Safety Requirements for Pipeline Transport Systems (RS 746.12)



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ITALY

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- DM 224/2024 recante "Attuazione dell'articolo 46 del decreto legislativo 8 novembre 2021, n. 199 in materia di garanzie di origine"
- Decreto direttoriale 11 aprile 2024 – contratti di sviluppo. Apertura Sportello semiconduttori
- DM 347/2022 Condizioni per l'accesso alle agevolazioni sul consumo di energia rinnovabile in impianti di elettrolisi per la produzione di idrogeno verde
- DM 15 settembre 2022 (decreto biometano)
- DM 3 giugno 2022 - Aggiornamento al decreto del Ministero dello sviluppo economico 18 maggio 2018 - Regola tecnica sulle caratteristiche chimico fisiche e sulla presenza di altri componenti nel gas combustibile
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Laws

- Legge n. 11 del 2 febbraio 2024 (conversione Decreto Energia) - pubblicata sulla Gazzetta Ufficiale del 7 febbraio 2024
- Legge 145/2018 Bilancio di previsione dello Stato per l'anno finanziario 2019 e bilancio pluriennale per il triennio 2019-2021
- Decreto del Presidente della Repubblica del 26/10/1972 No. 633, istituzione e discipline dell'imposta sul valore aggiunto (VAT discipline)

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- D.Lgs. 25 novembre 2024, n. 190 "Disciplina dei regimi amministrativi per la produzione di energia da fonti rinnovabili"
- Decreto direttoriale del Ministero dell'ambiente e della sicurezza energetica recante "Approvazione delle Regole operative del DM 19 giugno 2023 (c.d. FER 2)"
- DL 181/2023 - Disposizioni urgenti per la sicurezza energetica del Paese, la promozione del ricorso alle fonti rinnovabili di energia, il sostegno alle imprese a forte consumo di energia e in materia di ricostruzione nei territori colpiti dagli eccezionali eventi alluvionali verificatisi a partire dal 1° maggio 2023
- DL 36/2022, recante: «Ulteriori misure urgenti per l'attuazione del Piano nazionale di ripresa e resilienza (PNRR)»
- DL 21/2022 Misure urgenti per contrastare gli effetti economici e umanitari della crisi ucraina



- DL 210/2021 Attuazione della direttiva UE 2019/944, del Parlamento europeo e del Consiglio, del 5 giugno 2019, relativa a norme comuni per il mercato interno dell'energia elettrica e che modifica la direttiva 2012/27/UE, nonché recante disposizioni per l'adeguamento della normativa nazionale alle disposizioni del regolamento UE 943/2019 sul mercato interno dell'energia elettrica e del regolamento UE 941/2019 sulla preparazione ai rischi nel settore dell'energia elettrica e che abroga la direttiva 2005/89/CE
- DL 199/2021 Attuazione della direttiva (UE) 2018/2001 del Parlamento europeo e del Consiglio, dell'11 dicembre 2018, sulla promozione dell'uso dell'energia da fonti rinnovabili
- D.Lgs. 104/2017 Attuazione della direttiva 2014/52/UE del Parlamento europeo e del Consiglio, del 16 aprile 2014, che modifica la direttiva 2011/92/UE, concernente la valutazione dell'impatto ambientale di determinati progetti pubblici e privati, ai sensi degli articoli 1 e 14 della legge 9 luglio 2015, n. 114
- DL 28/2011 Attuazione della direttiva 2009/28/CE sulla promozione dell'uso dell'energia da fonti rinnovabili, recante modifica e successiva abrogazione delle direttive 2001/77/CE e 2003/30/CE
- D. Lgs. 162/2011 Attuazione della direttiva 2009/31/CE in materia di stoccaggio geologico del biossido di carbonio, nonché modifica delle direttive 85/337/CEE, 2000/60/CE, 2001/80/CE, 2004/35/CE, 2006/12/CE, 2008/1/CE e del Regolamento (CE) n. 1013/2006
- DL 239/04. Legge 23 agosto 2004, n. 239. Riordino del settore energetico, nonché delega al Governo per il riassetto delle disposizioni vigenti in materia di energia
- DL 387/03. Decreto Legislativo 29 dicembre 2003, n. 387. Attuazione della direttiva 2001/77/CE relativa alla promozione dell'energia elettrica prodotta da fonti energetiche rinnovabili nel mercato interno dell'elettricità
- DL 79/99. Decreto Legislativo 16 marzo 1999, n. 79. Attuazione della direttiva 96/92/CE recante norme comuni per il mercato interno dell'energia elettrica, "Decreto Bersani"

Strategy and policy plans

- National Hydrogen Strategy (2024)
- Piano Nazionale Integrato per l'Energia e il Clima (2024)
- Piano nazionale di ripresa e resilienza (PNRR, 2021, updated 2024)
- Circolare 18 ottobre 2024 No 42927, about PNRR implementation
- SNAM, Piano Decennale SNAM Rete gas, 2022-2023 (2022)

GERMANY

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- Erneuerbare-Energien-Gesetz - EEG 2023 (Act on the Development of Renewable Energy Sources (Renewable Energy Sources Act))
- Wasserstoffbeschleunigungsgesetz (Hydrogen Acceleration Act), 2024
- Windenergie-auf-See-Gesetz - WindSeeG 2023 (Act on the Development and Promotion of Off-shore Wind Energy)
- Energieeffizienzgesetz - EnEfG (Energy Efficiency Act) 2023
- Gebäudeenergiegesetz - GEG (Building Energy Act) 2020
- Kohleausstiegsgesetz (Act to Reduce and End Coal-Fired Power Generation) 2020
- Stromsteuergesetz (Electricity Tax Act) 1999



- Bundes-Immissionsschutzgesetz – BimSchG (Federal Immission Control Act - Act on Protection Against Harmful Environmental Effects Caused by Air Pollution, Noise, Vibrations and Similar Processes) 1974
- Wasserhaushaltsgesetz – WHG (Water resources act) 1957

Ordinances

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- Gasnetzzugangsverordnung - GasNZV (Ordinance on Access to Gas Supply Networks) 2010
- Gasnetzentgeltverordnung - GasNEV (Ordinance on Charges for Access to Gas Supply Networks) 2006
- Biomasseverordnung - BiomasseV (Biomass Ordinance) 2001

Strategy and policy documents

- Federal budget 2026 (Renewable energy program KfW)
- National Hydrogen import strategy (2024)
- Updated National Energy and Climate Plan (2024)
- National hydrogen strategy update (Fortschreibung der Nationalen Wasserstoffstrategie) - published on July 26, 2023
- National hydrogen strategy (Nationale Wasserstoffstrategie) - published in June 2020
- National Energy and Climate Plan 2020
- Special Climate and Transformation Fund (KTF) framework
- H2Global Framework

FRANCE

Laws

- Loi n° 2023-1322 du 29 décembre 2023 de finances pour 2024
- Loi n° 2023-973 du 23 octobre 2023 relative à l'industrie verte
- Loi n° 2019-1147 du 8 novembre 2019 relative à l'énergie et au climat
- Loi n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte
- Loi n° 2005-781 du 13 juillet 2005 de programme fixant les orientations de la politique énergétique
- Code de l'énergie
- Code des douanes, cadre pour la taxe intérieure de consommation sur le charbon (TICC) et la taxe intérieure de consommation sur les produits énergétiques (TICPE)

Decrees/ordinances

- Arrêté du 6 juillet 2024 relatif au dispositif des certificats de production de biogaz
- Arrêté du 10 juin 2023 fixant les conditions d'achat du biométhane injecté dans les réseaux de gaz naturel
- Décret n° 2022-640 du 25 avril 2022 relatif au dispositif de certificats de production de biogaz



- Arrêté du 6 octobre 2021 fixant les conditions d'achat de l'électricité produite par les installations implantées sur bâtiment, hangar ou ombrière utilisant l'énergie solaire photovoltaïque ≤ 500 kilowatts
- Ordonnance n° 2021-167 du 17 février 2021 relative à l'hydrogène
- Arrêté du 9 avril 2020 fixant les conditions du tarif d'achat de l'électricité produite par les installations flottantes utilisant l'énergie mécanique du vent en mer, de 4 aérogénérateurs au maximum
- Arrêté du 13 décembre 2016 fixant les conditions d'achat pour l'électricité produite par les installations utilisant à titre principal le biogaz produit par méthanisation de déchets non dangereux et de matière végétale brute implantées sur le territoire métropolitain continental d'une puissance installée strictement inférieure à 500 kW

Strategy and policy documents

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- Plan national intégré énergie-climat 2024
- Stratégie nationale pour l'hydrogène 2023
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- France 2030, 2021
- Rubrique ICPE 3420 Production d'hydrogène
- Plan national intégré énergie-climat 2020
- Stratégie nationale pour l'hydrogène 2020

AUSTRIA

Federal laws

- Gesamte Rechtsvorschrift für Ökostromgesetz 2012 (2025) (Green Electricity Act 2012 – updated 2025)
- Wasserstoffförderungsgesetz (WFöG) (Hydrogen Promotion Act) 2024
- Umweltverträglichkeitsprüfungsgesetz 2000, BGBl. I Nr. 26/2023 (Environmental Impact Assessment Act 2000 – 2023 amendment)
- Raus aus Öl und Gas (“Get Out of Oil and Gas” programme – decarbonisation initiative)
- Renewable Energy Expansion Act (EAG) (Renewable Energy Expansion Act)
- Gesamte Rechtsvorschrift für Gaswirtschaftsgesetz 2011 (Natural Gas Industry Act 2011)
- Gesamte Rechtsvorschrift für Elektrizitätswirtschafts- und -organisationsgesetz 2010 (Electricity Industry and Organisation Act 2010)
- Gesamte Rechtsvorschrift für Biomasseförderung-Grundsatzgesetz (Basic Federal Act on the Promotion of Biomass)
- Gesamte Rechtsvorschrift für Gewerbeordnung 1994 (Trade, Commerce and Industry Regulation Act 1994)
- Gesamte Rechtsvorschrift für Mineralrohstoffgesetz (Mineral Resources Act)
- Gesamte Rechtsvorschrift für Rohrleitungsgesetz (Pipeline Act)



- Gesamte Rechtsvorschrift für Erdgasabgabegesetz / Erdgasabgabegesetz (Natural Gas Levy Act)

Other laws

- Bundes-Energieeffizienzgesetz BGBl. I No 72/2014 (EEffG) (Federal Energy Efficiency Act 2014)
- Kraftstoffverordnung 2012 (Fuel Ordinance 2012)
- UPV-G (Environmental Impact Assessment Act – abbreviated framework law)
- Emissionenschutzgesetz für Kesselanlagen (EG-K) (Emission Protection Act for Boiler Installations)

Strategy and policy documents

- Integrated National Energy and Climate Plan for Austria, 2024
- National Hydrogen Strategy, 2022