Eidgenössische Technische Hochschule Zürich
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Energy Science Center (ESC)

Expert Group Security of Supply

Policy Brief

Steps to Fossil-Fuel Independence for Switzerland

17 June 2022

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Introduction

The Russian invasion of Ukraine in February earlier this year has made clear that reliance on imports of natural gas and other fossil fuels can put countries in a vulnerable position concerning energy security. This reliance also puts European countries, including Switzerland, in the counter-productive position of financially supporting a country against which they are simultaneously imposing economic sanctions, at a cost to their own economies.

Switzerland imported about 131 TWh[1] (or 471 994 TJ[2]) of energy via fossil fuels (oil, natural gas and coal) in 2020[3], which is roughly half of the primary energy demand of the country (SFOE 2021b). Adding the 70 TWh of imported nuclear fuels means that Switzerland sources 72% of its primary energy needs from abroad. The majority of imported natural gas enters Switzerland from Germany via the European transmission lines (Gaznat SA 2020) and until recently Germany sourced about 55% of its natural gas from Russia (BP 2021). If the energy-political conflict continues to change for the worse, or others arise, Switzerland could find itself in a precarious situation with respect to its energy supply.

Recently, and seemingly at odds with decreasing reliance on fossil imports, the Swiss Federal Council decided to plan for two to three gas-fired power plants to cover peak power demand, especially in winter (Swiss Federal Council 2022). Existing gas storage capacity for Switzerland is currently very limited with a total of approximately 1.7 TWh gas. At the same time, rough estimates indicate that gas storage requirements in 2050 could be much higher than today's capacity[4]. Therefore, increasing domestic gas storage and securing the use of foreign storage capacity via regional coordination, storage agreements and appropriate price mechanisms are crucial for this route.

Yet in light of current energy-political developments and also considering Switzerland's climate strategy (Swiss Federal Council 2021) and its aim of reaching net-zero greenhouse gas (GHG) emissions by 2050 (Swiss Federal Council 2019), drastically reducing Switzerland's dependence on foreign oil and gas imports could be the more logical strategy. Indeed, studies show that a net-zero GHG energy system for Switzerland by 2050 is both technically and economically feasible (Kannan et al. 2022; Landis et al. 2019), although there is a large range in the likely distribution of

[1] Values of primary energy demand refer to the amount of imported energy carriers before energy conversion to cover final energy demand for e.g. electricity production or heating. In 2021, e.g. nuclear fuels produced 18.39 TWh of electricity (energy-charts 2022), the difference compared to imported amounts is due to energy conversion losses.

[2] 1 Terawatt hour [TWh] is equal to 3600 Terajoule [TJ]. In this document we give all values for energy in TWh.

[3] We realize that 2020 was a special year due to the COVID-19 pandemic, but the orders of magnitude and trends are similar to previous years.

[4] The additional energy storage requirements in 2050 are estimated to be on the order of 2-10 TWh (Fuchs et al. 2017). If this additional energy storage is entirely provided by gas storage coupled with combined cycle gas-fired power plants (with energy efficiency assumed to be 64%), then the amount of gas storage requirements is on the order of 3.1-15.6 TWh in 2050. Annual import in 2040 could range between 10.3-11.7 TWh (Garrison et al. 2020). If this is entirely replaced by national electric power production via combined cycle gas-fired power plants (with an assumed energy efficiency of 64%) coupled with gas storage with capacity for one entire year (this is an extreme assumption), then the amount of gas storage requirements is on the order of 16.1-18.2 TWh.

costs and benefits depending on the adopted pathways and scenarios. The chosen pathway overlaps strongly with the degree to which Switzerland is or needs to be integrated into the European energy system. The level of resulting integration versus autonomy has its own respective costs and benefits that should be considered. In addition to fulfilling Switzerland's commitment under the Paris Agreement, a net-zero energy system could add significant value in terms of sustainability, health, resilience and enhanced local economies, compared to the energy system of today.

A fossil-free and net-zero energy system will rely on a diverse combination of technical, political and social measures. There is no silver bullet in the form of one technology to solve the problem. The required measures include supply-side low-carbon energy sources, electrification of sectors, such as transport and space heating, and integration of the energy system across energy infrastructures and sectors, such as gas, heat and electric power. Many of these measures are already economical today, for example enhanced building insulation, heat pumps and often electric vehicles (EVs); others need further development and/or policy support, for example in the case of aviation and the decarbonization of industrial processes. Other measures may require political and societal support for technologies that may be controversial such as onshore wind or a CO_2 transport and storage infrastructure. The main challenges in achieving net-zero GHGs are not necessarily technical or economic, but instead social: without society's commitment, these ambitions cannot be achieved. Survey results indicate that Swiss citizens show high levels of support for nearly all of the policies that would eliminate reliance on fossil fuels and promote the development of renewable energy utilization (Patt and Steffen 2022).

In this policy brief, the Expert Group "Security of Supply" of the Energy Science Center at ETH Zurich outlines the most crucial steps in reaching a fossil-fuel independent Swiss energy system, thus reducing the risk of supply shortages arising from political conflicts. At the same time, this will promote a transition to a net-zero GHG energy system. We start with a description of the current energy status-quo to illustrate reduction potentials for the different sectors before elaborating steps to reach fossil-fuel independence both for the demand and supply sides. Finally, we sketch valuable insights on how Swiss citizens view the urgency of fossil independence and goals of climate neutrality.

Energy status-quo in Switzerland

The approximate primary energy demand of Switzerland is 278 TWh (or 1 002 110 TJ), with a final energy demand of about 208 TWh (SFOE 2021b). The required crude oil, natural gas and coal are entirely imported from abroad, approximating 131 TWh (Figure 1). An additional 70 TWh are imported as nuclear fuels (SFOE 2021b).

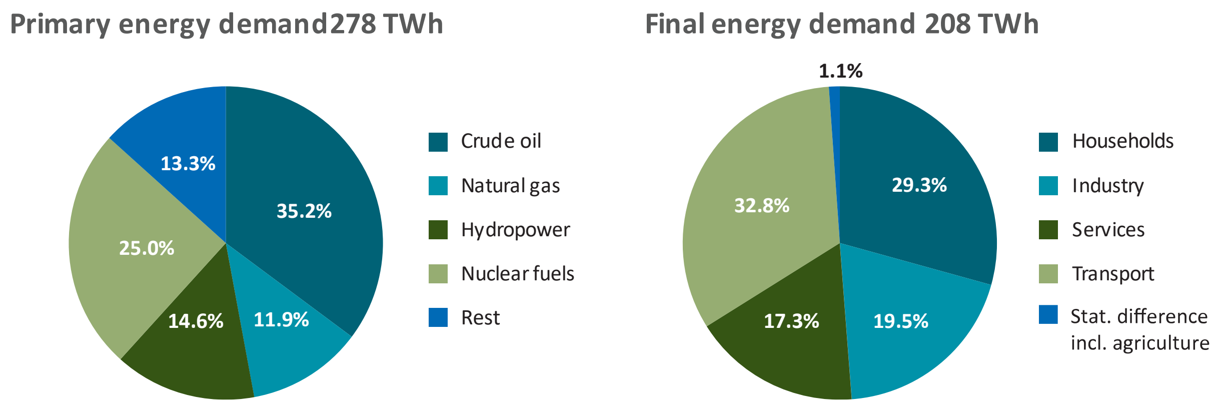

Figure 1. Left panel displays primary energy demand (278 TWh) as percent share of energy sources in Switzerland in 2020. "Rest" includes coal (roughly 0.4% or 1 TWh). On the right panel final energy demand (208 TWh) as percent share of each sector. Adapted from SFOE (2021b), for detailed energy flow diagrams and information, please refer to the SFOE publication.

Based on where energy sources are utilized (Figures 1 & 2), it is obvious that the greatest potential for reducing the demand for fossil energy carriers is in the transport sector (63 TWh of fossil fuels, roughly 70% of all crude oil products) (SFOE 2021b). The Swiss transport sector is also one of the largest emitters of GHGs, totaling 15.66 Mt CO_2eq. annually (this includes international aviation and shipping, total GHG emissions of the country are 43.4 Mt CO_2eq.) (FOEN 2022). For natural gas, the greatest reduction potential is in households/buildings (50% of final use natural gas) and district heating (SFOE 2021b). Households contribute about 16.4% of total GHG emissions (7.12 Mt CO_2eq.) (FOEN 2022).

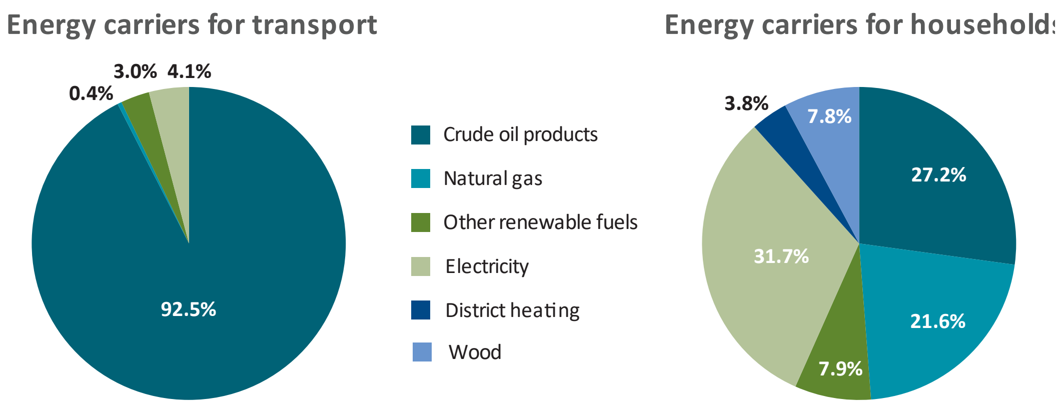

Figure 2. Percent share of energy carriers covering Swiss transport (~68 TWh) and household (~61 TWh) energy demands in 2020. Adapted from SFOE (2021b).

The Swiss industrial sector has a final energy consumption of 40 TWh (SFOE 2021b), of which approximately 10 TWh (26%) are covered by natural gas and 3 TWh (8%) by crude oil products (Figure 3). Fossil fuels are mainly used to produce process heat with a temperature range of up to 1500°C. The largest branches in terms of energy consumption are chemical and pharmaceutical (8 TWh), machinery (6.7 TWh) and food and tobacco (5.8 TWh) industries (IEA 2022). These three subsectors combined account for 66% of the natural gas consumption and 51% of the crude oil consumption by industry. Swiss industries emit GHGs of around 8.3 Mt CO_2eq. per year (UNFCCC 2021). Despite process-related emissions from chemical conversion, mainly in the cement and chemical industries (2.1 Mt, 25%), natural gas and oil constitute a significant contribution on the total CO_2 emissions of the sector (2.2 Mt, 27% from natural gas and 0.8 Mt, 9% from oil).

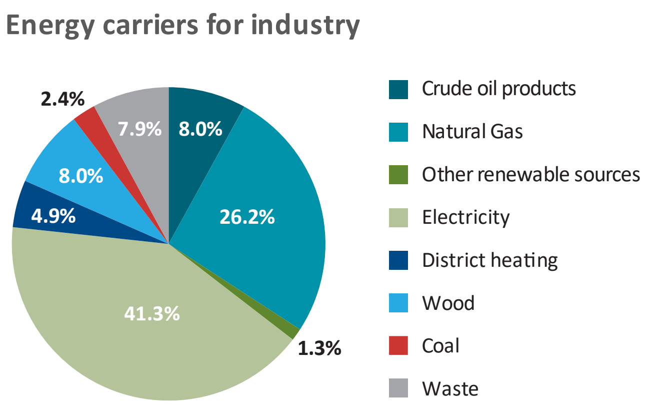

Figure 3. Percent share of energy carriers used in Swiss industry in 2020. The total energy demand of the industrial sector is ~40 TWh. Adapted from SFOE (2021b).

In order to reach fossil-fuel independence and the 2050 net-zero GHG emissions target, it is paramount that all sectors reduce their reliance on fossil fuels and switch to renewable energy sources. In the following, we elaborate the steps that are urgently needed to lay the foundation for such an energy transition. These steps need to be initiated now so that costly investments in infrastructure are sustainable and stranded assets can be avoided as much as possible. Points 1-3 address the demand-side: households and buildings, transport and industry. Points 4-5 the supply-side focusing on renewable energy.

1. Reduce energy demand of buildings and phase-out fossil heating systems

The final energy demand of households and buildings is 61 TWh, of which 16.5 TWh are supplied by crude oil products and 13.2 TWh by natural gas (SFOE 2021b). These are mainly used for space and hot water heating purposes.

A simple and easy way to reduce this demand in the short term is to lower the thermostat for space heating and hot water. Lowering the temperature for space heating by just 1°C reduces natural gas demand by 6% (EnergieSchweiz 2022). Similarly, decreasing warm water temperatures in buildings by 5°C reduces natural gas usage by 10%. Other simple measures are e.g. ventilating heated rooms for a few minutes with windows wide open instead of tilting them for longer periods and replacing domestic appliances with energy-efficient options when necessary.

A more time-consuming option is improving the insulation of existing buildings, which lowers the energy demand and costs for heating. Yet, with the current annual renovation rate of 1-2%, many of today's energy-inefficient buildings are likely to still be in their current condition lacking improved insulation in 2050 and beyond.

Policy needs – building renovation
The main reasons for the low renovation and retrofitting rate include the split incentive problem for landlords and tenants, the high upfront costs of energy-efficiency investments and the pronounced depreciation of future energy savings. Policy conditions and incentives need to be created to address these issues. E.g. for the split incentive problem, laws mandating that the costs for heating be split between landlords and tenants.

In addition to improving the energy quality of a building, replacing space heating provided by oil and natural gas with alternatives such as heat pumps (air and ground-sourced), wood heating (e.g. pellets) and district heating systems (based on biomass, waste or geothermal energy) is another necessary step. Heat pumps are generally cost effective - costing less than fossil systems over their lifetime - for new buildings. In the case of the existing building stock, they are often cost effective, but not always (Cabeza et al. 2022). They are particularly expensive when the existing radiators are sized for higher water temperatures (e.g. 50°C) than heat pumps can efficiently reach.

Policy needs – renewable heating systems
Several cantons already have laws in place banning the installation of new fossil heating systems (either in the case of new buildings or when replacing old systems) or incentives to replace existing fossil heating systems with non-fossil alternatives. At the national level there is a need for similar laws mandating the phase-out of fossil heating systems, which the previous version of the federal CO_2 law would have provided (rejected by voters in 2021). Survey results (see last Section) indicate that voters would now support a Swiss-wide ban on new fossil heating systems starting in 2025. An additional national policy to consider is to require the replacement of existing fossil heating systems that are above a certain age (e.g. 20 years).

In urban settings, where heat pumps or other alternative heating systems may not be suitable, district heating that is based on renewable energy (and not natural gas) is an alternative. District heating can be fed by a number of sources, including waste-to-energy plants, large-scale heat pumps, geothermal energy or waste heat from industrial processes. Waste-to-energy plants and heat pumps can be operated year-round if coupled to large-scale seasonal thermal energy storage and thus help balance a seasonal mismatch between supply and demand (Forum Energiespeicher Schweiz 2022) (see Point 5). Low-temperature heat networks can also serve potential future cooling needs in urban settings.

Policy needs – district heating
District heating is more efficient for heating building clusters and urban neighborhoods than individual heat pumps for each building. Incentives need to be put in place for developing renewable energy-based district heating networks wherever feasible.

2. Reduce energy demand and phase-out fossil fuels for transport

The transport sector takes up about 33% of the final energy demand in Switzerland (SFOE 2021b) and is thus the sector with the highest energy consumption and the highest reliance on fossil fuels

(>90%, see Figure 2). Additionally, about 65% of all trips in Switzerland rely on motorized individual transport (FSO 2015) and account for 60% of transport-related GHG emissions (FOEN 2022).

Options such as working from home, teleconferencing, using public transport and biking and walking when feasible can lower mobility demand considerably and instantaneously (Bach et al. 2021). The COVID-19 pandemic has shown that working from home and teleconferencing are viable and many companies and institutions are continuing to offer this flexibility to their employees.

Drastically reducing the dependence on foreign-imported fossil fuels calls for a phase-out of internal combustion engines vehicles (ICEVs). The European parliament recently approved a set of emissions standards falling to 0 g CO_2 per km by 2035; even if Switzerland chooses to lag behind legally, it is unlikely that new ICEVs will continue to be available for the Swiss market. From a climate-perspective, studies clearly show that EVs charged with renewable electricity are by far superior to any other fuel and powertrain option (Agora Verkehrswende 2019; Jaramillo et al. 2022).

A shift to electrified transportation in the form of light EVs is already occurring in Switzerland as seen by rising new car sales. In 2021, battery electric and plug-in hybrid electric vehicles already accounted for a combined share of 22% of the new car market, up from less than 4% three years earlier (Auto-Schweiz 2022). Provision of public charging infrastructure is crucial for the current trend to continue. Generally, this is proceeding quickly.

However, Switzerland faces a particular challenge with respect to private/residential charging infrastructure, as it has one of the lowest rates of private garage ownership in Europe, meaning most vehicle owners park overnight in communal parking lots (typically belonging to the apartment building) or on the street. Hence, a rapid transition is likely contingent on immediate solutions for charging. Later as the stock of EVs rises, it may also prove necessary to ensure charging flexibility, in particular daytime charging, to match the availability of solar power.

In many use cases, EVs are already an economically viable solution for road freight transport as well, particularly given the current structure of tolls in Switzerland (LSVA) (Noll et al. 2022).

Policy needs – phase-out ICEVs

Charging infrastructure needs to be expanded in residential spaces, company parking lots and along highways. Mandates for cities to install charging infrastructure for residential on-street parking spaces are required to increase charging capacities over the coming years. Furthermore, a legal provision for tenants to be able to install chargers within a short period of request, in residential parking lots and garages where they park their vehicle needs to be provided. An associated mandate for building owners to upgrade wiring and install a load management system where necessary also needs to be in place. Additional policies to supercharge demand can further accelerate the transition include: a faster (e.g. by 2030 rather than 2035) decline to a zero-emissions standard, effectively prohibiting the sale of new ICEVs; financial support for car buyers to install charging stations; financial support, such as tax rebates or limited-duration exemptions from future road-use taxes when purchasing an EV.
To allow for a decarbonization of road freight, potential future changes of the LSVA need to be designed in a way that does not stall the transition to EVs.

A smaller fraction of fossil fuels is used in other transport sectors and modes including road freight and air travel (22.5 TWh aviation fuels in 2019 and 8.5 TWh in 2020) (SFOE 2021c). As these sectors are harder to electrify with current battery technology, energy carriers such as hydrogen and synthetic fuels might play an important role and thus Switzerland might rely on importing these energy carriers in the future.

Policy needs – hydrogen and synthetic fuels
In the transport sectors that will be difficult to electrify, policy conditions need to support a transition away from fossil energy carriers to hydrogen or synthetic fuels produced by renewable sources. This includes developing the appropriate infrastructure.

3. Phase-out fossil fuels in industry

Swiss industrial applications require about 10 TWh natural gas, 3 TWh crude oil products and 1 TWh coal annually (SFOE 2021b). The short-term demand response in industry to high fossil fuel prices is very inelastic. It takes time to adjust and adapt complex manufacturing processes and procedures or to invest in more energy-efficient equipment (Kober et al. 2020).

Long-term measures to reduce the reliance on fossil fuels without compromising the economic competitiveness can be implemented. First, energy efficiency improvements of the production processes are often cost-effective options that are already leveraged to a large extent. Second, low-temperature process heat supply can be electrified. High-temperature heat pumps are a promising option to supply low-temperature heat, which is required in industry sectors like the food and beverage or pulp and paper industries (Obrist et al. 2022). Also, the direct use of geothermal heat is an interesting option for low-temperature industrial processes, especially considering the fact that these run generally throughout the year. A heat pump can be added to match the geothermal source temperature to the requirements of the application.

For many high-temperature processes in the chemical industry, electrification remains a challenge meaning that green hydrogen, synthetic fuels or biofuels could be used instead. However, biofuels have a limited availability and synthetic fuels are rarely cost-effective at this point in time. Green hydrogen can replace natural gas in most applications, but requires a redesign of the production facilities, which has a high upfront capital cost and is often a barrier for deployment. Blend-in of hydrogen to natural gas could be an alternative to reduce its consumption with the advantage of still being able to utilize the existing infrastructure.

For industrial processes (e.g. cement plants) that produce large amounts of CO_2, sequestering this GHG for long-term storage will be necessary for reaching climate goals. The additional space, heat and electricity demand of the capture unit and the subsequent transport and storage have to be considered. Whenever biomass is used as primary energy source, negative emissions can be generated (see Point 6).

Policy needs – industry
The largest CO_2 emitters in Switzerland are already under the CO_2 emission certificate scheme and there is an existing CO_2 tax for the use of fossil fuels in industry. However, as the short-term demand for fossil fuels used in industry is very inelastic, additional measures are needed. Most of these options will rely on a combination of support policies (e.g. tax credits or subsidies), regulatory measures (e.g. emissions standards specific to particular industrial applications), or carbon markets and prices. Additionally, energy-political conditions need to support low-carbon alternatives such as green hydrogen and synthetic fuels, so that their costs are reduced until technological progress makes them competitive.

4. Accelerate deployment of renewables and smart energy systems

Electrifying as many sectors and applications as possible will entail increasing the amount of renewable electricity generation. Speeding up the deployment of renewable energy sources (solar, wind, bioenergy and geothermal) and developing new renewable energy conversion technologies will therefore be key to supply enough renewable electricity and/or heat to replace fossil fuels. At the same time, an increased use of renewables will contribute to Swiss climate-neutrality by 2050 resulting in a win-win strategy.

Policy needs – renewable energy
Policies for renewable energy and supply chain development include e.g. financial support for improving or developing new renewable energy technologies; low-interest financing for supply chain and infrastructure development; streamlining of regulatory approval processes; relaxation of land-use restrictions (e.g. for ground-based solar); reliable remuneration for new projects (e.g. feed-in tariffs, power purchase agreements). This can help accelerate investment in supply chains as well as the supply of renewable energy.

Smart energy systems can serve as the enabler for an efficient integration of renewable generation. On a large scale, this translates into digitalization and automation of the entire electricity system to enable fine-grained monitoring of the system and automated activation of flexible resources. This entails wide-spread measurements at the consumer and system level (e.g. at substations) with smart meters including required communication for real-time monitoring of distribution systems and algorithms for the intelligent actuation of available resources. Automation must extend to the end-user, i.e. the decision of charging EVs has to be incentivized automatically to match optimal grid capacities. Thereby grid capacities and resources can be utilized optimally and the grid can be operated closer to its limits. This will reduce the need for reserves (e.g. hydropower or natural gas) and increase the efficiency of the overall system. Additionally, available but untapped capabilities in the system can be leveraged, e.g. inverters have a high degree of controllability that is currently not used to the extent possible. If inverters are controlled smartly, then renewable resources can provide reserves on a short-term basis to balance daily fluctuations. Data science can be used to further reduce required reserves by employing learning algorithms to predict renewable generation (location specific) more reliably.

Policy needs – smart energy systems
Policies for supporting the buildup of renewable energy also need to include the digitalization and automation of the electricity grid. This will ensure an optimal integration of renewables, which is urgent for electrifying the building, transport and industry sectors.

5. Security of electricity supply

A challenge specific to Switzerland is the possible shortage of electricity in winter. First, Swiss topography means that wind power is generally less productive, and hence relatively uneconomical, compared to wind power outside of Switzerland. Combined with the administrative challenge of permitting new wind installations, this has resulted in an exceptionally small number of wind turbines being built in Switzerland, and the unusual situation of solar photovoltaic (PV) providing more energy annually than wind. Second, Switzerland is not part of the European Union (EU), meaning that the legal frameworks for coordinated power system planning and access to transmission capacity to balance seasonal fluctuations are less secure in Switzerland than in the rest of Europe.

The security of electricity supply – in terms of ensuring complete systems reliability at a cost that maintains the competitiveness of the Swiss economy – can be maximized through international agreements creating a secure legal basis for the continued integration of the Swiss power grid within the European system. This would enable continued and expanded exports of electricity in summer, and imports in winter, addressing the unique Swiss lack of wind power relative to PV and hydropower.

In the event that it is diplomatically impossible, or undesirable, to address the Swiss wind deficit through international cooperation, it will be essential to address it through more costly measures aimed at increasing Swiss domestic production of energy during winter months. A recent study indicates that electricity supply costs in Switzerland rise 50-175% in scenarios where international trade is severely restricted, and in the most extreme case eliminated, compared to a scenario in which such trade is unconstrained (Tröndle et al. 2020).

Policy needs – international cooperation
Policy could best enhance Swiss electricity security by creating a continued secure legal basis for electricity trade, enabling Switzerland to profit from its relative surplus of renewable electricity supply in summer months and relative scarcity in winter months. Options would include a bilateral treaty with the EU, ensuring membership in the EU power market or agreements with neighboring countries and regions ensuring the adequacy of transmission capacity to the Swiss border.

Especially in the absence of a secure legal basis for importing electricity in winter, it is essential to expand domestic winter production. Options include planning for hydropower reserves for the winter months and/or investing in gas-fired power plants, PV at strategic locations or geothermal energy. From a fossil-free and net-zero GHG perspective, operating gas-fired power plants only makes sense if run on synthetic or biogas and equipped with carbon capture and storage (CCS). However, the potential of biogas production is limited in Switzerland and the production of marketable synthetic gas requires a large amount of electricity available throughout the year at low cost. Furthermore, Switzerland has somewhat limited capacity to store synthesized gas temporarily (see introduction) or captured CO_2 permanently or temporarily for subsequent shipment to storage abroad (see Point 6). Thus, such gases will likely have to be stored mostly in neighbouring countries. Careful analysis of possible CO_2 transportation and storage options are therefore needed (Ogland-Hand et al. 2022). As in the case of electricity, there would need to be a secure legal basis for Switzerland to be able to import gas, when it is required, from neighbouring countries.

PV systems in alpine regions could be an important option, as they generate significantly more electricity in winter compared to classic rooftop systems in urban areas (Anderegg, Strebel, and Rohrer 2020). Newest estimates conclude that the technically feasible area for alpine PV amounts to almost 150 km^2, less than 0.4% of the geographical area of Switzerland (Dujardin, Kahl, and Lehning 2021). Covering this area with winter-optimized PV panels could produce more than 40 TWh of electricity annually (Egli et al. 2022). At the moment a large-scale alpine PV pilot project is being discussed in Grengiols (Wallis) with 5 km^2 bifacial PV panels generating 2 TWh of electric energy per year (Hardegger 2022). In any case and at the same time, solar PV should be installed on already existing constructions (e.g., buildings, hydro dam walls and on noise cancellation walls along railways and highways). The estimated potential of rooftop PV ranges between 20 - 50 TWh (Moro et al. 2021) and floating PV on alpine reservoirs (e.g. Lac des Toules (ABB 2020)) might also contribute at appropriate locations.

In principle geothermal electricity generation works year-round and is actually significantly more efficient in the winter. It can be ramped up when needed and thus provide power in e.g. winter or during periods when little to no energy can be generated with the use of wind and solar power (Dunkelflaute) without (much/any) operational CO_2 emissions. However, geothermal energy for electricity generation requires much higher subsurface temperatures than when direct heat usage is only required (e.g. for district heating, see Point 1). At the moment the potential for suitable sites with sufficient subsurface permeability at great depths, where temperatures are high enough, is largely unknown for Switzerland.

Policy needs – winter electricity production

Policy needs to provide support for alpine PV pilot projects as it is important to learn from different projects and the highly different conditions between locations. On the techno-economic side, questions remain about the costs of maintenance and natural hazards including avalanches and mudflows at high altitudes.

In order to assess the potential for deep geothermal electricity generation nationwide field-based investigations and field pilot tests at the canton level need to be facilitated. Additionally, subsurface regulations need to be streamlined and ideally unified at the federal level.

An alternative to generating more electricity in the winter months is to lower electricity use in winter. One option are large scale thermal energy storage systems above and below ground, with or without coupling to heat pumps in district heating systems. When properly sized, heat pumps can operate the full year, harvesting the increased PV electricity generation in summer. In winter, part of the heat demand is then covered by the thermal storage, effectively reducing electricity demand.

Thermal storage can have beneficial effects on the winter electricity demand also when coupled with waste-to-energy plants or by regenerating borehole fields (Forum Energiespeicher Schweiz 2022).

Policy needs – thermal energy storage
Switzerland needs a coordinated spatial planning for energy infrastructure including for large seasonal thermal energy storage. Concrete projects need to be developed and demonstrated. Insights from practical operation need to be shared in the community to foster a wider deployment.

6. Negative emission technologies

Despite all the above options to increase efficiency, decrease the use of fossil fuels and thus lower GHG emissions, completely avoiding them will remain difficult in some cases. This is especially true for high-temperature industrial processes as well as freight transport and aviation. These hard-to-avoid emissions will amount to 12 Mt in 2050 (SFOE 2020). Therefore, negative emission technologies (NET), referring to biological and technical processes that remove CO_2 from the atmosphere and store it permanently, will be necessary. Technical approaches entail capturing CO_2 from concentrated point sources (e.g. cement or waste-to-energy plants), collecting it via a national pipeline network and transporting it to permanent underground storage sites (CCS), which will likely be predominantly abroad. This requires a connection to a European pipeline network so that CO_2 can be shipped to suitable storage sites (e.g. depleted oil and gas fields in the North Sea, Northern Lights project). Other NETs exist and need to be explored and applied (SFOE 2021a) such as direct air capture (DAC), which can also be a source of carbon for producing synthetic fuels.

Policy needs – negative emission technologies
The net-zero climate goal requires to tackle hard or impossible to avoid emissions. The most realistic large-scale option requires deep underground storage of CO_2 that has been separated from point sources such as waste-to-energy or cement plants. To achieve this, subsurface CO_2 storage options need to be investigated and a CO_2 pipeline network has to be put in place – in Switzerland and in neighboring countries – to transport and permanently store all of the captured CO_2 underground. This requires the necessary set of regulations for planning and permitting of geologic CO_2 sequestration sites, pipelines and a strong international collaboration at the European level.

Public acceptance is high

In the final week of April 2022, we conducted a survey of Swiss voters – 600 in German speaking cantons and 400 in French speaking cantons – examining levels of public acceptance for each of the policy measures that we have outlined above, as well as whether acceptance has changed as a consequence of the war in Ukraine (Patt and Steffen 2022). As Figure 4 shows, acceptance levels are generally high, with a majority of respondents supporting eight of the ten policy proposals that we asked survey respondents to consider. The policy proposal with the least support

– and still seeing less than a majority in opposition – would be to prohibit the sale of new ICEVs starting in 2030, five years ahead of the currently proposed EU deadline. Two of the policy proposals we asked respondents to consider – building new gas-fired power plants and solidifying power trading ties with neighbouring countries – address the same issue of seasonal imbalance of renewable energy production in Switzerland. Respondents showed higher levels of support for the solution involving electricity trade, compared with new gas installations.

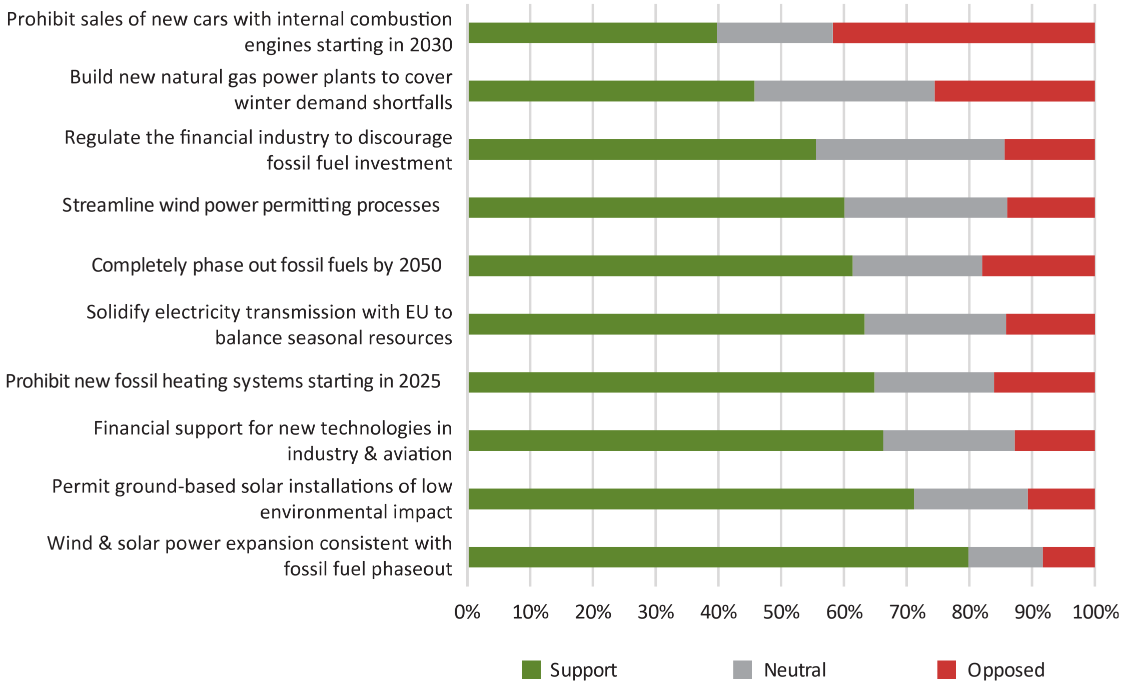

Figure 4. Support for policy proposals. Adapted from Patt and Steffen (2022).

In nearly all cases there was a marked increase in levels of support as a result of the war in Ukraine, across all political parties and with at least twice as many people saying that their support had increased instead of decreased. The one exception was for installing new gas-fired power plants, where support levels rose slightly among those aligned with the conservative parties, but fell slightly among those aligned with the two green parties.

Across nearly all questions, we found political party preferences to correlate highly with support. Figure 5 shows a snapshot of these correlations, showing support levels contingent on political party preferences for three of the policy proposals: phasing out fossil energy by 2050, expanding domestic wind and solar power production to replace fossil energy, and solidifying electricity transmission ties with neighbouring countries to manage seasonal renewable power production.

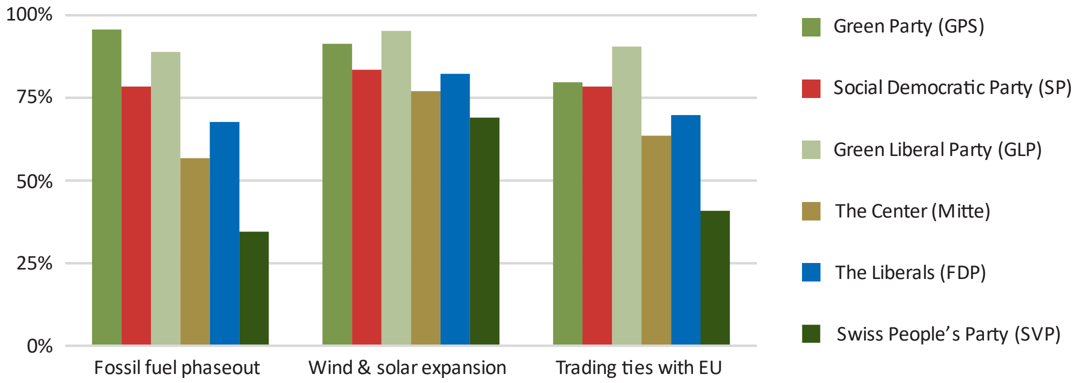

Figure 5. Proportion of respondents supporting three exemplary policies, according to political party preferences. Adapted from Patt and Steffen (2022).

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The Expert Groups is an initiative by the Energy Science Center of ETH Zurich to address current hot topics in the energy sector and consolidate research insights for stakeholders outside academia. The goal is to offer practical, feasible and added-value recommendations for integrating knowledge and know-how into different sectors to promote the energy transition. Expert Groups do not conduct research, but rather gather established findings and synthesize conclusions. Topics are dealt with from a technical, policy, economic (markets and finance) and regulatory perspective. Expert Groups addressing specific issues are convened on demand depending on the developments in the energy sector and in politics.

Security of Supply

The Expert Group “Security of Supply” deals with topics that concern the entire energy system including the electricity grid, energy storage and sector coupling. It is made up of experts that represent the mechanical and electrical engineering sciences as well as climate finance and policy.

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