9 Switzerland

Risks associated with implementing a national energy strategy

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Introduction

In the wake of the disaster in Fukushima, the Swiss government decided in November 2011 that existing nuclear reactors would be used until no longer serviceable and then replaced by renewable sources. One plant has since been shut down and the other three, with a combined capacity of around 3 GW, are to be closed by 2034.

Switzerland already has an almost carbon-free electricity supply because of its many hydropower plants. Hydropower and other sources currently supply some 70% of Swiss electricity, which leaves around 30% of Swiss production to be shifted from nuclear to renewables. This turnaround is part of the latest Swiss Energy Strategy 2050 (ES2050). In addition to a climate target and a nuclear phase out, Switzerland intends to reduce its long-standing reliance on foreign fossil fuels, mostly oil for transportation and heating, as well as some natural gas.

Due to the unique Swiss system of direct democracy, any future expansion of wind, solar, and hydropower requires that utilities, local and regional governments, NGOs, and companies in the renewable sector work together (see *Swiss direct democracy* box and Figure 9.1). Crucially, many of the utilities are publicly and domestically owned. As a result, large amounts of political discussion and academic research have been carried out for the Swiss renewables transition over the last five years, and the process of defining and implementing the ES2050 is still ongoing.

Swiss direct democracy

The Swiss decision-making system is unique in that Switzerland is a confederation with direct democracy. The confederation aspect – the country code CH stands for its Latin name of Confoederatio Helvetica – is reflected in a very devolved government. The municipalities and cantons (analogous to provinces, counties, or states in other countries) retain a great deal of autonomy. For example, public holidays in Switzerland differ between cantons.

This autonomy stretches into the electricity sector in two ways: first, the cantons have considerable discretion when implementing the federal energy law;

and second, most of the utilities operating in the Swiss market are majority-owned by municipalities and cantons.

The direct democracy is exemplified in the Swiss system of *Volksinitiativen* ('People's Initiatives'). With a limited number of signatures (100,000 for a national initiative), any citizen can request a municipal, cantonal, or federal government to consider a specific action. If the government will not implement it out of hand, they can call a referendum on municipal, cantonal, or federal level to change policy. If a referendum passes, it becomes law in the same way as a constitutional change – parliament and the executive have no legal way of overthrowing the results.

The political landscape in Switzerland is strongly influenced by the *Volksinitiativen* as it is effectively impossible for any minority or collection of interest groups to directly impose their will on a majority of the populace. As a result, the entire political culture is strongly disposed towards compromise and consensus building. For example, the top executive decisions are made by a Federal Council of seven, who currently include members from four different parties, instead of having a single head of government.

The current strategy of the Swiss federal government is officially documented in the Energieperspektiven 2050 report (EP2050),[1] which essentially functions as a white paper (BfE, 2013). However, for all its length, the EP2050 report is vague on implementation: its main thrusts are efficiency, especially in buildings, e.g. replacing oil heating with more efficient heat pumps, further electrifying transportation, replacing Swiss nuclear power with Swiss domestic renewables, and a larger role for (existing) hydropower and rooftop solar photovoltaic (PV) panels. This new renewable electricity capacity is to generate 20% of Swiss supply by 2035, or around 12 TWh. The federal government is opting for natural gas power plants and imports of foreign renewables as a stopgap measure in case domestic renewable capacity does not expand fast enough.

The first phase of the Swiss ES2050 was passed into law by parliament in 2016. The Swiss parliament added several changes in the process, including a support package for hydropower, which has been economically less viable due to current low wholesale electricity prices. The new energy law was opposed and immediately challenged by one of the larger parties in parliament (see Überparteiliches Komitee gegen das Energiegesetz, 2016) but the Swiss voted to keep the law in a referendum (Der Bundesrat, 2017). The Bundesamt für Energie (BfE – Ministry for Energy) is currently working on the next phase of the ES2050.

If Switzerland is serious about replacing nuclear, it has four options available. The first is to use domestic renewables, mostly by expanding the number of solar panels and wind turbines. The second is to import renewables from foreign countries. These two seem the most likely and currently enjoy the support of a large majority of Swiss citizens in surveys (see following text). We will explore the risks and challenges that come with these options in detail over the next sections.

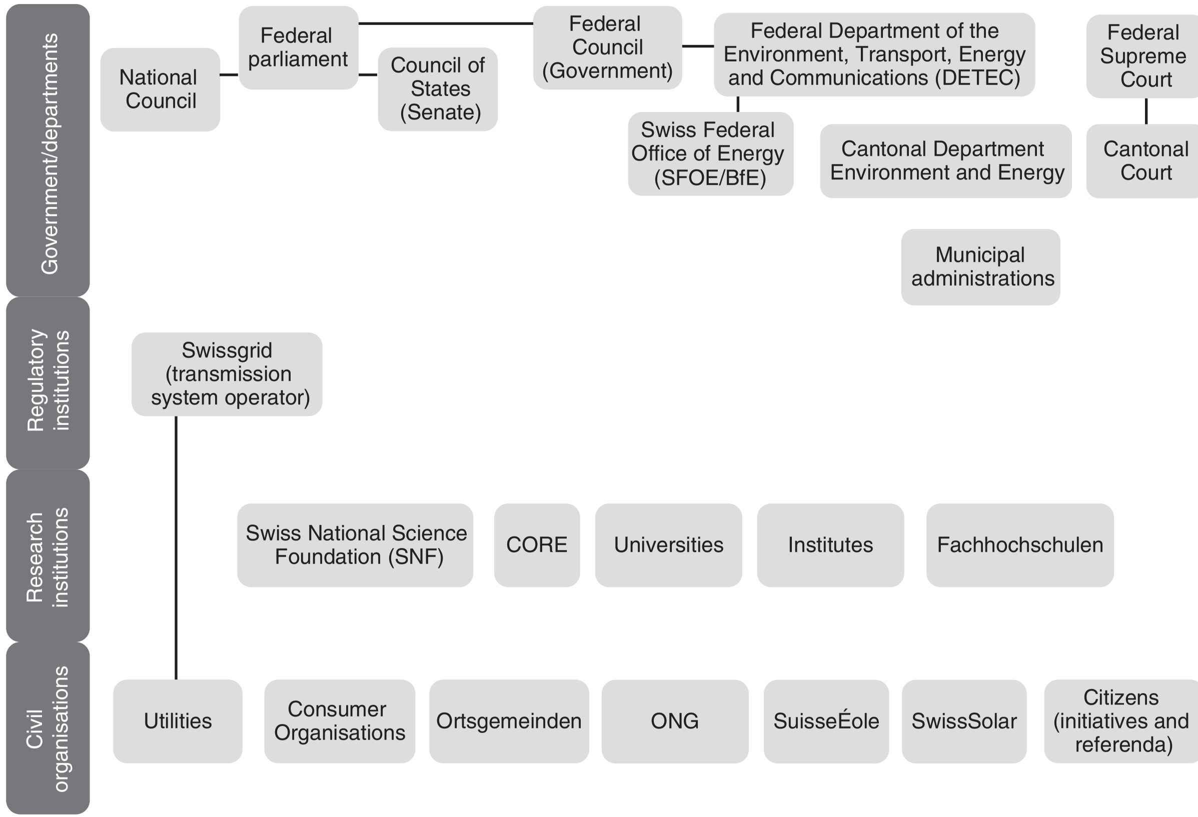

Figure 9.1 Overview of government institutions involved with Swiss renewables transition.

A possible third pathway is to use non-renewable natural gas. Gas is not currently used much for electricity in Switzerland (only for heating and chemical processes) but expanding its use is an option in the ES2050. The main risks for this pathway are that natural gas needs to be imported (e.g. from Russia) and the acceptability of increased air pollution. As we will see in the following sections, natural gas is neither preferred by the public, nor necessary for stability of supply. We therefore will not explore this pathway in depth.

A possible fourth pathway would be based on rapid expansion of (deep)geothermal power. However, earthquakes associated with geothermal tests near St Gallen and Basel seem to have soured the public mood against geothermal for the near future, and we will also not explore this pathway in depth.

The ES2050 emphasises domestic renewables, using natural gas as a bridging fuel until sufficient renewable capacity becomes available. Switzerland therefore has to make a political decision on whether to keep emphasising domestic generation (though using imported fuels like natural gas and nuclear fuel) or to start relying on imported electricity year-round. This is not a binary choice as domestic and imported renewables are potentially complementary pathways.

Domestic renewables

The first pathway is to increase the capacity for renewables production at home. A large number of PV panels could fit on existing rooftops in built-up areas, owned by individuals and companies that also own the buildings. The new energy law includes a feed-in tariff to support expansion of renewables but the Swiss home solar industry is still in its infancy compared to Germany, with a total of 49,000 installations (1.4 GW) completed by 2015.

The expansion of wind power in Switzerland has been even slower than PV because wind is not particularly strong and consistent in most of the country, and also because residents opposed to wind turbines have used spatial planning laws to block their construction. For example, the Kirchleerau–Kulmerau wind project was effectively blocked by a local referendum that ruled that no turbines may be built within 700 m of a residential building in that municipality. As a result, Switzerland had a total of 37 wind turbines in 2015.

The Swiss can also build some additional hydropower but nearly all the best potential sites are already in use. Much of this pathway therefore centres on small-scale renewables: rooftop PV, wind projects with a handful of turbines, and small hydropower plants. In turn, this means that much of the expansion will be in the hands of private citizens, small and medium-sized businesses, and municipalities. Federal and cantonal authorities can support this development, in part through legislation that favours renewables and policies of the utilities they (jointly) own.

The two main risks to the domestic renewables pathway are the intermittency of solar PV and wind power in Switzerland – which does not have a lot of sites with strong and sustained sunshine or winds – and public acceptance of the large number of PV panels and wind turbines necessary to make this work.

Foreign renewables

The second pathway is to import renewable electricity from abroad. This would require a build-up of renewable capacity outside Switzerland to feed into the Swiss grid. There are two general options: wind power, most likely from the west coast of Europe like the North Sea, or concentrating solar power (CSP), from sunny regions like southern Spain or North Africa. This would let the Swiss use the most abundant renewable resources in and near Europe without having to build in populated areas, making for cheaper electricity.

Imports are feasible from a grid perspective: Switzerland already has the transmission lines and interconnections to move large volumes of electricity. These are currently used for three things: exporting excess electricity in summer, importing electricity in winter, and transporting electricity from north-west Europe to Italy. Both imports and exports are equivalent to 75% of gross national electricity production. Despite this trade, Switzerland sees itself as self-sufficient, with a net electricity export just under 2% of its total production in 2015 (BfE, 2016). However, the problem for this pathway is that these power plants are very far from the cities and other demand centres that they are to supply. Building the infrastructure needed requires action from larger utilities and co-ordination between the European grid operators, i.e. the members of the European Network of Transmission System Operators for Electricity (ENTSO-E). Swiss utilities are already investing in foreign renewables projects but this would need to be scaled up. Simultaneously, grid operators are in charge of constructing transmission lines to connect this new supply. This has not always gone smoothly; a major high-voltage line that was to connect wind farms in the Baltic with cities and factories in southern Germany has been opposed by residents and NGOs because of the landscape impacts and alleged health impacts it would have. Furthermore, it runs close to the eastern border and some have alleged it was planned to also carry Czech nuclear power, which seriously undermined the green narrative that supported this transmission line.

The main risks to the foreign renewables pathway are the construction time and vulnerability of the transmission infrastructure – the latter more due to extreme weather than terrorism – and the acceptability to the Swiss public of foreign control over power supply. A further risk is in the acceptability of the power plants and transmissions lines for foreign benefit to the residents of other countries. Assuming we focus on the offshore wind and CSP plants in sparsely populated areas, which are anyway more productive, international transmissions lines face the largest risk of popular resistance.

Research process and methods

Four research methods inform this narrative: energy system modelling, Q-methodology, a choice experiment, and a stakeholder workshop.

The core of energy system modelling is to represent major supply-and-demand technologies in our energy system, and the flows between these, in one single model. The mix of these technologies is constrained by existing real-world circumstances and scenario assumptions, and can be optimised within these constraints, e.g. for lowest total cost given high reliability and low CO_2 emissions. We looked specifically at electricity and included various supply technologies, including run-of-river and dam hydropower, PV and CSP, wind turbines, gas turbine power plants, and pumped storage. Our model, using the Calliope framework (Pfenninger, 2017) represents sources in Switzerland and abroad. We use hourly data for intermittent sources like wind and solar from www.renewables.ninja, a website with open renewable energy potential data (Pfenninger and Staffell, 2016; Staffell and Pfenninger, 2016) to find how intermittency limits the renewable electricity sources we can reliably use together, and how much we would have to use other sources as a backup to balance supply and demand.

The core of Q-methodology is the development of a set of statements expressing potential stakeholders' attitudes and beliefs about a particular issue, ensuring coverage and balance of the topic (Watts and Stenner, 2012). We started by interviewing a diverse range of stakeholders and systematically reviewing mass-media coverage. A sample of participants then ranked the statements according to whether they agree or disagree with their own perspectives. Using factor analysis, we identified patterns in the ranking and identified groups of participants who are likely to rank the various statements differently. In this way, we identified correlations and/or major differences between group perspectives. We could then match these perspectives to any shared institutional and/or demographic attributes of the groups' members. Q-methodology is used to explore perspectives of a small group of individuals that should not be interpreted as representative of a larger populace without further research to confirm it. We used Q-methodology to unravel stakeholder perceptions in three Swiss villages.

The core of a choice experiment is to make explicit what people base their decision on (Alriksson and Öberg, 2008). During the experiment we give respondents a set of different choice tasks, so-called 'choice sets'. Within each choice set, respondents chose their preferred option from three alternatives, one of which was a status quo option. It is assumed that the individual utility of a choice depends (in part) on different observable attributes that characterise the options within the choice sets. In our experimental design, we estimated part-worth utilities of the choice attributes by decomposing respondents' answers as well as other variables. We could also group respondents based on the similarity of their preferences using principal component analysis.

The core use for a stakeholder workshop is to make explicit the viewpoints of the different participants and facilitate an exchange of opinions and arguments between them. This may in turn create a shared vision but a more important goal is to build mutual trust and understanding for different viewpoints. Our workshop used a role-playing format, where we asked stakeholders to reason from the point of view of the voter groupings we found in our survey, to emphasise understanding other viewpoints and stimulate out-of-the-box thinking. We invited representatives of different governments, NGOs, utilities, and consultancies.

Risks and uncertainties

Risks to the Swiss renewables transition emerge at two levels. The first level is the new risks that replacing nuclear with renewables brings: intermittency, when no electricity can be produced as the sun is not shining, the wind is not blowing or rivers are frozen; failures in our electricity grid from extreme weather events such as from storms, icing, and landslides; and public opposition to new energy installations such as solar panels, wind turbines, and power lines.

Any combination of intermittency and grid failure may lead to power losses and blackouts in a country that is used to an extremely reliable supply of electricity. The pathways that we examine trade off these two risks: wind turbines in Switzerland produce less than half of what they do in Denmark (see renewables.ninja) but are close to the Swiss power grid; solar power from North Africa has very predictable output but needs long and vulnerable transmission lines that cross several countries.

For solar farms we find inherent tension between using land for nature or agriculture and infrastructure. This applies especially in Switzerland as much of its mountainous terrain is ill suited to infrastructure and the rest of the country is fairly densely inhabited. Furthermore, the need for permits and grid connections makes solar farms unattractive to utilities at current bulk electricity prices. By contrast, rooftop PV and solar heaters only need to compete with residential electricity prices, which are higher due to inclusion of grid fees and taxes. Installing PV on non-building infrastructure, like avalanche protection barriers, is possible, but such projects are still experimental and expensive.

The second level of risk is in the aggregate, or how the risks for the individual projects and technologies affect the overall Swiss energy strategy. While individual renewable projects may supply intermittent power or get disconnected, combining many different sources and existing Swiss hydropower can lead to a stable supply. However, public support is more difficult at the project level than in aggregate: on the national level, this is just an abstract percentage of supply, while on the cantonal level it is a question of where the infrastructure will be located, and on the local level it is a binary choice of having the infrastructure in your back yard or not. This is particularly fraught because local residents may experience fewer of the benefits and more of the drawbacks of a project that benefits the country as a whole.

Consequential risks (negative impacts)

Switzerland has one of the most reliable electricity supplies in the world right now, and its inhabitants see this as the right and proper natural state of things. Existing proposals implicitly or explicitly commit to operational security of supply, suggesting that the Swiss are unlikely to compromise on reliability for the sake of independence, climate, or a nuclear phase out. This stability can also not come at unlimited cost. We see two risks that would cause renewable electricity to lead to an unstable supply of electricity: intermittency and grid failure.

On intermittency, we find that Switzerland can phase out nuclear and switch to renewables without risk of intermittency as long as we do not rely solely on PV, even though there is sufficient space to put the panels (for more details, see Díaz Redondo, van Vliet, and Patt, 2017). This is because Swiss hydropower can compensate for limited intermittency, but less so in winter when PV output is low and Swiss rivers get limited water. Relying only on PV will require some seasonal electricity storage, which is currently prohibitively expensive due to the staggering volume of electricity it would have to store for every winter. Wind power from the North Sea is especially suited to the Swiss electricity system as it is more stable than solar power and produces more electricity in winter.

Furthermore, both North Sea wind and North African CSP are likely to be cheaper than using natural gas due to the rapid decline in installation cost for renewables electricity. As a measure of this, we use the levelized cost of electricity (LCOE) that is defined as the cost of the entire electricity supply system, including grid and backup plants to guarantee constant supply, divided by the kWh of electricity it supplies (in Swiss francs per kilowatt hour). For example, based on cost projections for wind and CSP from 2011 to 2016, replacing nuclear with a combination of wind and CSP would cause an LCOE ranging from about the same as using natural gas to almost twice as much. However, using commercial costs for wind and CSP contracted in 2017 results in an LCOE below these ranges. This showed that: (a) their model calculations were outdated by the time they were published; and (b) that renewables have reached 'grid parity'. The cost of generation is no longer a reason to avoid a switch to renewables.

If Swiss utilities can invest in, buy a majority stake, or otherwise gain control over one or two dozen wind farms and/or CSP plants abroad, this system would insulate Swiss electricity supply from the intermittency of individual renewable power plants and the resulting fluctuations in prices on power markets. This would be a shift in policy for Swiss utilities: they already own stakes in power plants in foreign countries (overwhelmingly in EU member states) but the electricity is sold on local markets, not imported back to Switzerland.

However, the second risk is that long power lines come with increased chance of outages due to extreme weather, which currently accounts for almost half of all grid outages. The magnitude of this risk depends on the grid: for a future with a large share of imports, sufficient redundancy in transmission corridors, high-quality equipment, and best practices in grid management can minimise the risk. Quantitative analysis and interviews with grid experts have shown that grids can almost always be built to withstand the harshest conditions in any given country. For example, the Finnish grid suffers more outages in the comparatively mild summer than in the harsh Nordic winter. Exchanging best practices would help transmission system operators (TSOs) prepare for changes in weather conditions brought on by climate change. This can be organised through existing organisations like ENTSO-E or Eurelectric. Furthermore, even if the transmission grid breaks down due to weather or for other reasons, Switzerland has a large capacity for hydropower to provide some short-term buffer.

Our exploration of these two consequential risks shows that both can be mostly avoided and a fully renewable electricity supply for Switzerland can be realised at reasonable costs without an increased risk of supply interruptions. The only option that does not work is to rely on PV only. Without overwhelming technical or economic constraints, this means the choice between pathways is essentially a matter of public preference. And here we find that it is not immediately clear that any of these supply options can be realised.

Implementation risks (barriers)

The implementation barriers we find for the Swiss ES2050 are of a social and political nature rather than, for example, lack of access to financing. For example, some legal bottlenecks need to be sorted out, such as cost-sharing or compensation for people who rent and wish to install PV on the roof of the building they live in. This particular problem of agency is especially acute in Switzerland as 80% of the population live in rented houses and apartments, and it requires a legal solution.

However, the largest perceived barrier to renewables in Switzerland is public acceptance. The prevailing view is that the high attachment of the Swiss to their traditional landscape, and the large number of landscape and nature NGOs, make the construction of power lines, wind turbines, PV farms, and conspicuous rooftop PV in historic centres likely to attract opposition. Several research projects are underway to address this directly, and most of the projects in NFP70, a research programme about electricity supply options for Switzerland, include an 'acceptance' component in addition to the technical research at the heart of these projects.

We could obviate acceptance issues in Switzerland in theory by outsourcing electricity supply to other (neighbouring) countries and the Swiss transmission grid could most likely handle the import load. However, this leads to two potential problems.

First, citizens in these countries may be equally or even more unhappy to have energy infrastructure in their environment to supply someone else, though this might be offset by the business opportunity of selling the electricity. Moreover, if all of Europe follows in the footsteps of a renewable Switzerland, the required international interconnect capacity would need to grow by a factor of 6 to 12 (Rodríguez *et al.*, 2014). Expansion of transmission lines would especially be needed in areas where renewable electricity is generated, which are usually peripheral areas.

Second, this creates a reliance on other countries. The Swiss have a strong interest and desire for energy independence, often expressed as a desire for electric autarky (Trutnevyte, 2014). This has some dissonance with the fact that Switzerland currently imports 75% of its energy in the form of natural gas, oil, and uranium to fuel nuclear plants (BfE, 2016), and also with recent efforts by utilities to invest in renewable electricity generation abroad. Regardless of the current realities of energy use, independence is an aspiration that makes imports, renewable or fossil, less politically attractive.

Swiss citizens consistently prefer solar electricity and, to a lesser degree, wind (for more details, see Plum *et al*., n.d.). These should be built in existing industrial and commercial areas, including ski resorts, rather than in areas of natural beauty. However, the Swiss do not agree on all aspects of their energy strategy. We find five distinct groups of voters: the largest two groups are 'Moderates' and a group that is specifically 'Contra status quo' to using nuclear power but otherwise also moderate. Three groups have a very specific profile: 'Pro renewables', 'Pro Switzerland', and 'Pro landscape'. All groups except 'Pro landscape' (95% of respondents) prefer electricity from Switzerland, and all groups except 'Pro Switzerland' (84% of respondents) accept imports of renewable electricity, preferably from plants operated by Swiss utilities. Unlike domestic or imported renewables, Swiss generally dislike natural gas and non-renewable imported electricity. Furthermore, our survey results show that the Swiss public find 'the construction of high-voltage transmission lines abroad for supplying Switzerland with electricity problematic' just as much as having power lines or wind turbines in their own living environment.

Local perspectives

Three local renewable energy projects in Switzerland illustrate the perspectives of different stakeholder groups on the process and negotiations involved in actually implementing a renewable energy project and show approaches to manage the risks involved: a small hydropower project in the canton of St Gallen (examined in Díaz Redondo, Adler, and Patt, 2017), solar PV on avalanche barriers in the canton of Graubünden (examined in Díaz Redondo and Van Vliet, 2018) and a solar farm project in the canton of Vaud (examined in Späth, 2018).

The small hydropower project in Breschnerbach (canton St Gallen) was led by a local utility, consultants, and pro-hydropower members of local and cantonal governments. The main challenge noted by these proponents was that the decision-making process, including permitting, took a very long time to complete. In the event, NGOs in favour of reducing energy demand were in conflict with local proponents who saw the hydropower plant as benefiting the local economy and community. After the utility received the concession in 2011, four years were spent negotiating a nature compensation scheme, with some 40 stakeholders represented in the process, including national NGOs. One NGO complained to the cantonal court but this was rejected, and the construction permit was granted in 2016. The project was eventually seen as 'win–win'. All perspectives showed consensus on the need for fair, inclusive, and democratic decision making, though the local proponents felt that participatory decision making limits infrastructure development.

In St Antoniën (canton Graubünden), a project aimed to install solar PV on avalanche protection barriers. This would generate more electricity than PV in lowlands as the solar input is up to 50% higher in the mountains. Moreover, suitable foundations were already present, and foundations make up a significant share of the installation costs for most PV projects. However, building PV on avalanche barriers in a remote village had never been done on a commercial scale. Everyone involved thought the project could contribute to the regional and local economy and benefit the environment. We found this to be the major driver for stakeholders to engage in the implementation process. Furthermore, the project was strongly driven by the idea that this could be a model for PV systems on avalanche defences. Most of the funding required for the project was crowd-sourced, with some contribution from the cantonal government. However, the federal government refused to fund the project as an innovation pilot and the municipal assembly ultimately voted against a loan to cover the funding shortfall. Residents, NGOs, and government officials suggested this was due to doubt over whether sales of electricity could cover investment costs, as well as their worries about estimates of technical difficulties, rising costs during the decision process, and unsuccessful fundraising activities. This seems to have increased doubts about and opposition to the project, and eventually led to an opposing vote in the municipal assembly. Some of the stakeholders who were opposed also felt that they did not receive the information they wanted from the proponents of the project, and that this created a lack of trust. Better communication might have removed this risk. Furthermore, the decision of the federal government not to fund this rural PV project was seen as inconsistent with the national policy to promote rural development and renewable energy.

In Payerne (canton Vaud), the local utility proposed a solar farm on a plot of agricultural land that had already been designated as an industrial area. This project was part of a greater plan to make the village largely self-sufficient in electricity. Local stakeholders and NGOs were involved in the planning process and, while one NGO formally opposed the project, it did not take the project to the courts. The project was completed in 2015 and produces around 40% of the electricity used in the village. Stakeholders generally agreed that large roof surfaces should be used first to install solar panels, but there was a gap between traditionalists who wanted to reserve farmland for agriculture and pragmatists who will use it for solar PV if that is more profitable. Others emphasised energy efficiency, much like in Breschnerbach, and citizens' role in decision making, much like in St Antoniën.

Broader implications

The potential for utility scale PV is likely quite limited in Switzerland, given the value put on rural landscapes and agriculture, but fortunately the available rooftop area for PV seems sufficient for Swiss purposes in several estimates (see Gutschner *et al.*, 2002; Compagnon, 2004). Furthermore, permitting for any energy infrastructure is known to be a long process both inside and outside Switzerland. One utility noted that they only invest in foreign renewables projects that have already obtained permits in order to reduce their exposure to acceptance risk.

Utilities and renewable plant developers are particularly concerned about the current low price of electricity in Switzerland and the EU power market, as a result of the ongoing expansion of renewables in Germany and elsewhere. The 'merit order effect' reduces prices when renewable electricity is abundant (i.e. sunny weather and high winds across the EU) and drives up prices of balancing power when renewable electricity is scarce, making renewable electricity a victim of its own success (see Cludius *et al.*, 2014). This has reduced enthusiasm for installing renewable electricity by utilities. Consumer-owned rooftop PV has not been affected as much, as domestic production reduces electricity bills that include taxes and grid fees (electricity cost is only half the total) and the Swiss feed-in tariff policy.

Across the three projects, stakeholder perspectives suggested a risk to the overall Swiss ES2050: stakeholders feel disengaged with the ES2050 process because they disagree on the overarching framework, i.e. the pillars of the energy strategy. It seems that the federal, cantonal, and local stakeholders have different interpretations of the ES2050 and its major objectives of energy efficiency, supply diversity, deployment of investments, and environmental protection. Each of these levels of government prioritises the ES2050 objectives differently, and all of them seem to think their approach is best for everyone. However, these authorities lack a forum to resolve these differences. Furthermore, these interpretations differ in turn from the preferences of the Swiss public. This is a risk to the general political process that carries the ES2050 forward.

This is separate from the 'usual' political risk where different interest groups want different things. This is also present in Switzerland, and some of the lobby groups have very close ties to political parties.

Comparing pathways

Unsurprisingly, we cannot have an energy system that is reliable, climate friendly, gives us independence, keeps the landscape intact, and phases out nuclear all at the same time. However, it is possible to replace the existing nuclear plants in Switzerland with a combination of domestic and imported renewables without infringing on reliability. The cost for this would be no higher than using natural gas, as suggested in the ES2050, or replacing the ageing Swiss nuclear plants. Good management by the TSOs that carry the imported power would minimise the risk of weather-induced grid failures. Both pathways, domestic renewables and the foreign renewables, are therefore possible in principle, though rooftop PV would have to be supplemented with Swiss wind power in strictly domestic pathways. Due to the low potential for wind power in Switzerland (i.e. wind blows slowly, infrequently, and/or erratically), this would also have highest cost. Natural gas is technically feasible but a non-starter in the opinion of the Swiss public.

While both pathways are technically feasible and broadly socially acceptable, there are still issues with individual projects (see Table 9.1). As long as renewables partially depend on subsidies to be competitive, financing remains difficult and the projects will be seen as risky by investors. This is especially the case if

Table 9.1 Risks to successful expansion of renewable sources of electricity in Switzerland (CH)

Barriers	*Hydropower in CH*	*Rooftop PV in CH*	*Utility scale wind/ PV in CH*	*Offshore wind*	*Mediterranean CSP*
High investment costs	Compounded by low prices	Ameliorated by FIT and fees	Compounded by low prices	Compounded by low prices	Compounded by low prices
Landscape/visual impact	Only for large hydro	Minor	Unwanted	Low population if far offshore	Low population in desert
Permitting	Nature compensation done	Building owner's permission needed	Challenges expected	Transmission line may be challenged	Transmission line may be challenged
Intermittency	Base load and dispatchable	Diurnal, weather, and seasonal	Diurnal, weather, and seasonal	Relatively stable, better in winter	Thermal storage reduces
Energy independence	Swiss source	Swiss source, need balancing	Swiss source, need balancing	Contributes to diversification	Contributes to diversification

nature compensation adds to the cost. Delays in permitting and constructing all of the necessary power plants and transmission lines are also very likely. This is not necessarily a problem to either pathway in the long run, as the Swiss nuclear plants are scheduled to remain in service for as long as they are deemed safe to operate. As the two youngest and largest plants (built in 1979 and 1984, with a combined capacity of 2.2 GW) have recently received extensive safety upgrades in the wake of Fukushima, we can expect their lifespan to be extended to 60 years (World Nuclear Association, 2018). If these nuclear plants remain in service until 2039 and 2044, the Swiss have some 25 years to construct their replacements.

Some uncertainties remain in the Swiss transition to renewable electricity, although they are not threatening: For example, the political winds may shift over the next 25 years to be more or less open to international co-operation. However, the structure of the Swiss Confederation's executive makes dramatic shifts in policy – like in countries with two-party systems (e.g. the USA) – unlikely. Overall, we may expect Switzerland to remain rhetorically independent and autarkic, but practically integrated in Europe. Likewise, the Swiss economy has been relatively stable, with a largest annual drop of 3.4% of GDP in the last financial crisis, despite being known for international banking. The effects of climate change are also uncertain but the effects on hydropower are expected to be small over most of this century (SGH and CHy, 2011). Finally, it is unclear how far the costs of PV and wind will decrease in the future, but grid parity has now effectively been achieved and any further drops can only be in favour of the wider adoption of renewable electricity sources.

Conclusions

Overall, the Swiss prefer domestic production of renewable electricity, but a majority share of imported renewable electricity will likely be cheaper overall and cause fewer issues with intermittency. However, the renewable imports pathway would face more problems with acceptance of new infrastructure, especially long-distance transmission lines. (See Figures 9.2 and 9.3.)

The most recommended option would be to combine the domestic renewable pathway with the imported renewable pathway. The most favourable combination seems to be Swiss rooftop PV, offshore wind from the North Sea, and Swiss hydropower. Such a mix would also be acceptable to the Swiss public. This is especially important given the Swiss political system in which policies and projects can be challenged in local, cantonal, or national referenda.

However, depending on the demand for renewables in EU countries, this may require expansion of transmission capacity in the Dutch, Belgian, Danish, and German grids. Both the needs for grid expansion, and ways that this could be done in a manner acceptable to residents around the new transmission lines, should be researched further.

This narrative has two major implications for the Swiss energy strategy. First, the ES2050 can be broadened to include imports of wind and/or CSP, but Swiss

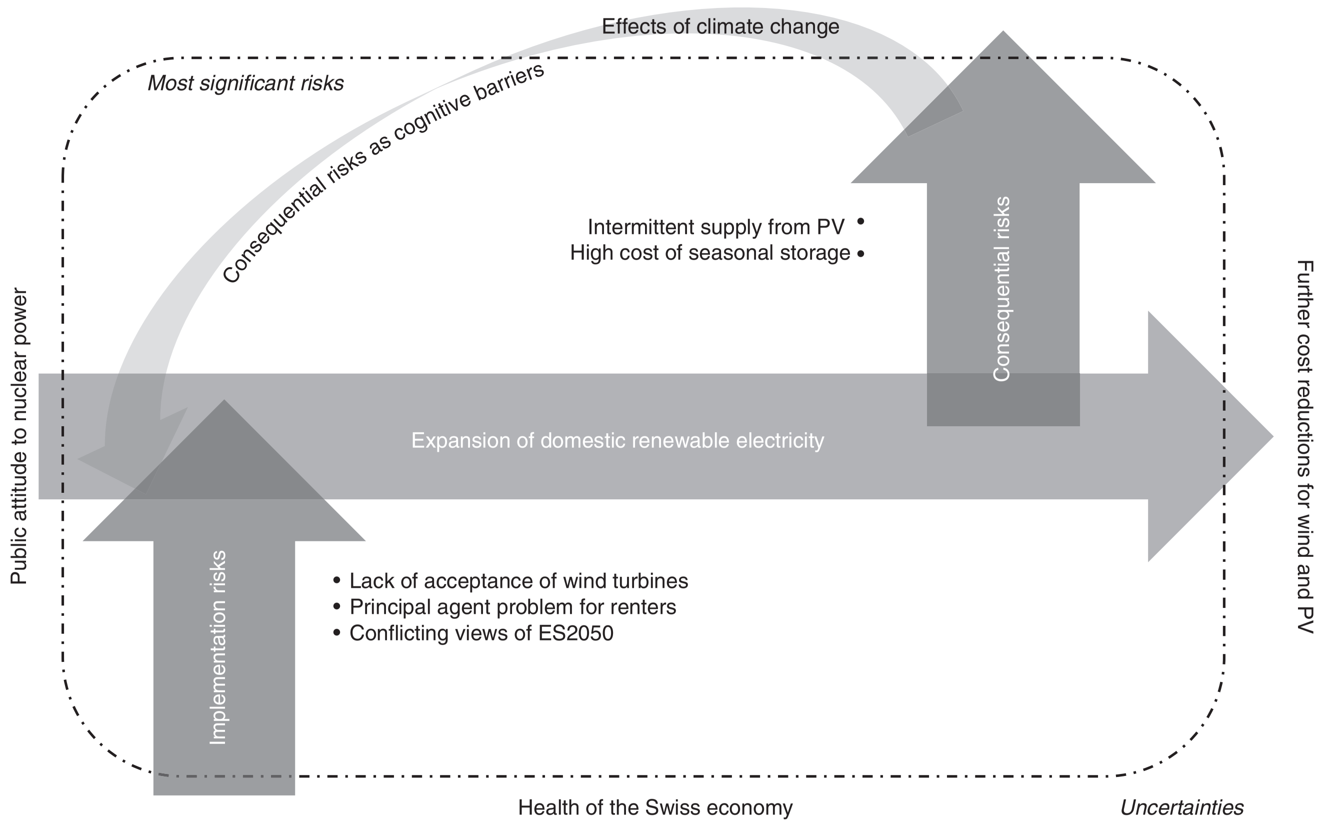

Figure 9.2 Main risks associated with expansion of domestic renewables in Switzerland.

Note

Assumes no significant changes in public attitudes to nuclear power, effects of climate change, downturn in the Swiss economy, and ongoing gradual reductions in costs of wind and PV installations.

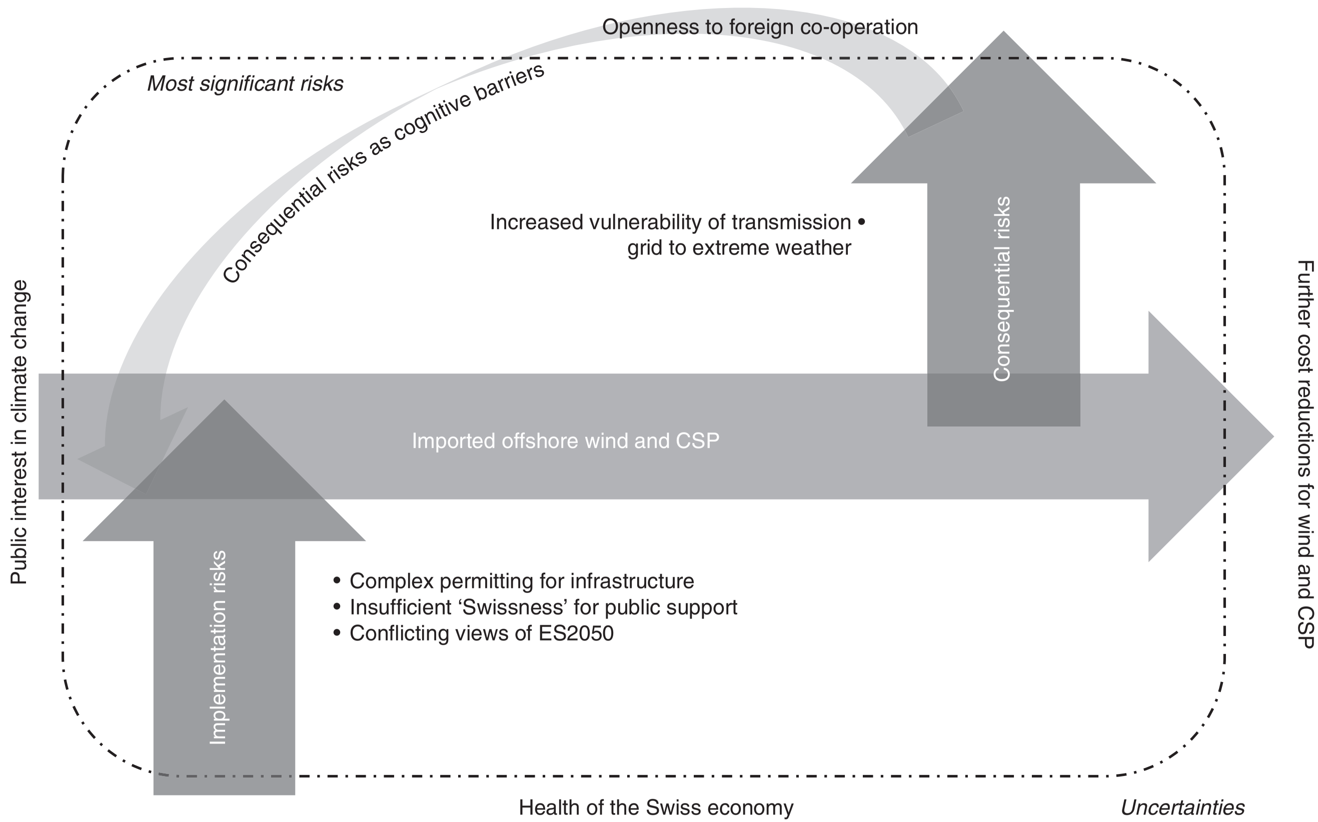

Figure 9.3 Main risks associated with expansion of imported renewables for Switzerland.

Note

Assumes no significant changes in public interest in climate change, openness to imported electricity, downturn in the Swiss economy, and ongoing slow reductions in costs of wind and CSP plants.

ownership and operational control would be preferable to the Swiss people. Second, as long as there is no forum to resolve the diverging interpretations of ES2050 among local, cantonal, and national stakeholders, we can expect conflicts and delays.

The risks we examined were of a political, technical, and economic nature. The political risks were mostly barriers to implementing one of the pathways, and the technical and economic risks were mostly about the consequences of these pathways. This follows a pattern we have observed in general in the literature about the Swiss energy transition.

The most pressing risk seems to be delay or outright failure to obtain permits, and more generally how to plan and build energy infrastructure without provoking opposition and legal challenges from nearby residents. This has been done successfully in Switzerland, for example for the Linth–Limmern pumped storage plant and its connection to the grid, where residents raised no objections. It would be worthwhile to investigate successful processes for energy infrastructure and determine how these can be mainstreamed.

Note

1 The EP2050 was written by Prognos AG, the consultancy firm that also wrote Energiekonzept 2050, a similar document, for the German government.

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