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Conceptualizing energy transitions in Austria and Switzerland: A historical comparative analysis of different electricity use paths

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:

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Switzerland and Austria share significant commonalities, which predestines for similar developments with regard to the use of resources for electricity production: Both countries are economically wealthy, show a similar development of electricity use and share similar topographical conditions not only for the use of hydropower, but also wind power. However, today, the share of wind power in Switzerland's primary electricity supply is only 0.2 percent, while in Austria, the share converges already towards 10 percent. At the same time, Switzerland operates five nuclear reactors, whereas Austria decided not to put its already constructed nuclear power plant into operation. The study at hand aims to explore the reasons for these striking differences by analyzing the historical development of electricity use from the beginning of the 21st century, taking into account important aspects from the economic, socio-technical and political perspectives on energy transitions. Thereby, the aim is to contribute to the existing research body on energy transitions, whereby comparative country historical analyses have remained rare. In this regard, it is assumed that analyzing transitions while integrating the time aspect helps to identify path dependencies which might be neglected in short-time analyses. The insights thereby gained are useful in order to predict future developments with regard to countries' energy transitions.

Keywords: Energy transition, electricity use, climate change, nuclear power, wind power, hydropower, policy development

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1. Introduction

The way civilization is using energy is significantly contributing to greenhouse gas emissions (GHG) whose impact on global warming is widely recognized by the scientist community. Today, more than two thirds of GHG-emissions are related to fossil fuel combustion and therefore to energy generation foremost for heating, cooling and transport, but also for electricity. On the other hand, the temperature rise and the changing climate we are currently experiencing already have an impact on how and when energy is generated and used. Inter alia, global warming already affects water systems and therefore electricity generation with hydropower. Furthermore, droughts have an impact on the operation of fossil power plants and energy demand tends to increase in the summer while it is gradually decreasing in the winter (Cherp et *al* 2011; EEA 2017).

Against this background and as demonstrated by IPCC (International Panel on Climate Change) reports, decision-making entities – namely nation states or international mergers – have to reconsider their plant portfolio, the related infrastructure and fuel usage significantly. On the one hand, to adjust to these changing conditions and on the other in favor of low emissions and mitigation of temperature rise if global warming is aimed at being kept below 2°C until the end of the century (Cherp et *al* 2011). In order to support this goal, 195 states have committed themselves to the legally binding Paris Agreement in 2015 that requires action in every single signatory state. Concerning the energy sector, a decrease in GHG-emissions can be inter alia achieved through the enhanced use of renewable energy technologies (RET), Carbon Capture and Storage (CCS) and the reduction of demand through energy efficiency measures (Cherp et *al* 2011; EEA 2017).

However, this new type of necessity-driven energy transition is influenced by unpreceded factors like increasing resource scarcity and simultaneous population growth as well as new questions of energy security which arise due to the geographic concentration of shrinking fossil fuel deposits (Cherp et *al* 2011). Although climate change is clearly a global problem, these challenges are predominantly analyzed and addressed with the aim to find self-tailored solutions within this complex interwoven system, depending on the examined entity's energy use path which evolved in a certain geographical and societal context (ibid.). In that respect, specific patterns based on long-term investment decisions of the past and the related issue of incumbency have a crucial influence on how energy is used today, which can result in a certain lock-in with an impact on present choices (EEA 2017).

Although wealthy countries like Switzerland or Austria are likely to suffer less from the impacts of climate change compared to developing countries, decarbonization and 'clean' energy play an outstandingly important role in their current national energy strategies. In the Austrian example's preamble it is declared that the world needed "nothing more than an energy revolution" to remain future-proof, while, in particular for Austria, it explicitly stresses on the importance of further developing renewable energies in order to become self-sufficient (energy security), ensure job creation (economic competitiveness) and to reach climate and energy goals (BMDW 2009). Also the completely revised Swiss energy law of 2018 states that "the use of renewable energy and its expansion are of national interest", which grants these energy technologies a special legal status thereby creating a convenient regulatory environment for them (Energiegesetz 2018).

The mentioned examples show that, in order to address the challenges of today's energy systems which should guarantee for energy access, energy security and mitigation of climate change at the same time, it is crucial not only to strive for low-carbon, but also for a sustainable energy transition. In this respect, the increased use of electricity will play a significant role as it is considered a backbone of a sustainable energy future in several energy strategies due to its potential as substitute for fossil fuels in the heating and transport sectors (e.g. Andersson et *al* 2011). However, nuclear power is less and less seen as a reliable low-carbon electricity source in terms of energy security (e.g. Cherp and Jewell 2011). This is demonstrated by the (planned) nuclear bail-out in several countries, reflecting the strive for (an anticipated) independence and security as integral components of sustainable energy systems. Furthermore, investing into conventional sources is becoming less and less economically viable in the light of shrinking electricity prices, making the consideration of alternatives even more urgent.

This research's aim is to create an in-depth comparative analysis framework for the electricity use paths of two European countries, with Austria being a Member State of the European Union (EU) and Switzerland an independent nation state in the center of Europe. The main focus will lie on the question of nuclear power use, as the way these countries have dealt with this technology certainly had an effect on their electricity generation paths. Inter alia, the objective is to reveal the reasons why Switzerland still relies on 40% of nuclear power for its energy mix but has widely ignored other renewables besides hydropower or biomass and to a lesser extent solar (Markard et *al* 2016). On the other hand, Austria at least never used domestic nuclear capacities but has been deploying a variety of (renewable) sources for decades. In this regard, the objective is to analyze the development of wind power use in both countries as an example of how electricity transitions are handled today.

In general, country comparisons of energy transitions are considered important to understand the evolvement of different energy use paths (Cherp et *al* 2017). However, internationally comparative analyses of energy transitions remain rare (ibid; Geels et *al* 2016). In this regard, the focus of the study at hand will lie on the long-term evolvement of the electricity system as in several cases, transition processes of today can be traced back over decades (Cherp et *al* 2017).

The conceptualization will comprise the following elements in line with Cherp (2018) and his colleagues meta-theoretical framework according to Elinor Ostrom's approach, provided that the co-evolution and a certain interdependence of the different domains is kept in mind. However, the listed strands can certainly evolve independently as one factor might change and influence the whole system, which makes a distinct analysis indispensable of:

Techno-economic perspectives – in this context, the physical availability of resources and the trends of electricity usage will be examined. Can the anticipated demand and supply gap be compensated with 'sustainable technologies'?

Socio-technical perspectives – how did certain technologies evolve in these countries? How and why was a market created? Is there a technological lock-in in any case? Are innovations embraced or rejected?

Political perspectives – where there paradigm shifts that influenced national energy policy? What is the role of external actors on decision making, like international organizations, society and vested interests of the industry? How can (sudden) policy change be explained?

In order to answer these questions, an analytical framework will be provided which will build on the literature review that is presented in the following chapter. However, comparative analyses that deal with long-term processes represent a methodological challenge (Cherp et *al* 2017). Similar to Cherp and his colleagues' (2017) comparative analysis of electricity transitions in Japan and Germany, the study at hand will deploy the "comparable case – most similar system" study design due to the fact that Austria and Switzerland share many commonalities relevant to the research's focus. Thereby, the aim is to find the explaining variable that led to the countries' divergent electricity use paths.

Finally, the comparative analysis' aim is to reveal current problems with transitions to sustainable energy generation and energy use in high-income countries that have evolved in different institutional, societal and economic contexts. The conclusions will be additionally backed by analysis of data and information mainly obtained from the International Energy Agency (IEA), national statistics, scholarly literature as well as Swiss and Austrian documents.

2. Theoretical background and literature review

2.1 How to define energy transitions?

In this chapter firstly a definition of energy transitions should be formulated. Finding a definition should support the researcher in assessing past and ongoing changes in energy systems in the target countries.

According to Grubler et *al* (2016), who also represent the mainstream view, energy transition processes are complex, evolve on many levels and find complete expression solely after decades. In consequence, energy transitions are likely to result in a long process and create a path dependency which can „suppress threatening innovations", due to – to name one of many – infrastructural issues. However, they simultaneously state that external shocks, like climate change (resource scarcity) or movements can lead to technical or social disruptive transformations.

Sovacool (2016) tries to contest the mainstream view of transitions, arguing that future transitions would be triggered by other factors than before. As far as climate change and the pace innovations are introduced with today are concerned, he goes even further by saying that these factors are so striking that they are even likely to change the nature of those transformant processes. In conclusion, he contests to describe future energy transitions by existing theories, since they would have other main drivers and (policy) instruments at hand than before. Accordingly, he suggests to rethink the framing of energy transitions in terms of definitional assumptions and demarcations, or by „one magic formula".

However, Grubler and his colleagues (2016) suggest to keep consistent on defining an energy transition which is a „change in the state of an energy system as opposed to a change in an individual energy technology or fuel source" in order to avoid comparing processes that happen on different levels. Inter alia, different stages of spatial and temporal technology diffusion, a (regulatory) basis where innovations can evolve and the argument of „scale matters“ are important to make changes comparable. According to the authors, when listing his examples, Sovacool (2016) misses to distinguish between those diffusion stages of an innovation’s lifecycle which was considered crucial for comparisons.

Furthermore, they argue that the efficiency of transitions depended on the pervasion of the technologies and infrastructures used before: Already established paths can lead to „lock in“, meaning that the system can absorb new technologies fast as long as a complex change is not required. The systemic nature of energy transitions is also recognized by Cherp et *al* (2018), who add that besides scale and depth, also the co-evolutionary nature of energy transitions had to be borne in mind. This is in line with Elinor Ostrom and her colleagues’ approach that multiple theories were “necessary to describe the evolution of a complex socio-ecological system”. By emphasizing on systemic change which is needed for sustainable energy production, Grubler et *al* (2016) state that energy transition might „take many decades to implement fully“. However, the authors agree with Sovacool (2016) when he raises the problem-oriented question of how to achieve rapid transitions rather than examining how long it takes.

All in all, scholars widely agree to define energy transitions as a systemic change that can be seen as a “holistic transformation of energy systems triggered by different factors which change over time and space, depending on the priorities of the agenda setter.” This is a definition the author of the study at hand has formulated for herself where the single elements should be explained as follows:

(1) Holistic. Energy transition has to be understood and combined on different levels: as a sociological, technological and economic process. Furthermore, the aspect of scale has to be taken into consideration, referring to one of the most influential frameworks in socio-technical transition: the concept of the multi-level perspective. In this study, the researcher analyses national electricity transitions which is the most appropriate scope since nation states still are the main decision-making entities (Cherp et *al* 2018).

(2) Factors. As Sovacool (2016) states in his article on 10 fast transitions, energy transitions can be evoked by different factors which can be a catalyst for a high-level (holistic) transformation, even if they seem small or as a partial change in the first place. For example, a change from conventional fuels to ethanol does not necessarily lead to a holistic energy transition. However, it shows that rethinking of existing structures is possible, for whatever reason.

(3) Temporal aspect. It is important to include the temporal criterion since the catalyst for energy transitions changes as well, depending on environmental factors. As Sovacool

(2016) states, former energy transitions were based on economic opportunities and the abundance of resources, unlike today, as they are driven by scarcity and global concerns (climate change).

(4) Spatial aspect. Spatial aspects can also be a determining factor for energy transitions. Inter alia, one governing entity (e.g. a nation state) might be naturally more rich in resources than another. This can hold true for conventional fuels (e.g. coal deposits) as well as for renewables given geographical opportunities that influence the disposability of geothermal energy, high solar radiation, good wind conditions for offshore utilization, et cetera. According to Coenen et *al* (2012), the "geography of transitions" has been widely neglected in the socio-technical transition research.

(5) Priorities of the agenda setter. An agenda setter can be understood as the entity which is in charge for deciding on an area's priorities, e.g. a country or a country conglomerate or, in a rather decentralized system, even smaller entities like cantons or federal states. In general, these priorities are driven by different factors due to economic, environmental, (geo-) political or societal pressure. In the EU, the main agenda setter in the environment sector is the European Commission, whereas the competence in several questions on energy use is in a regulatory grey area due to the increasing market integration. For example concerning renewables, the EU sets obligatory targets while the national states decide on their energy mix (De Jong and Egenhofer 2014). Coenen et *al* (2012) argue that the embeddedness into existing framework, named "institutional thickness" by Markard et *al* (2016), but also the significance of global networks have to be integrated into empirical analyses.

2.2. Framework for analyzing energy transitions

In this subsection, the theoretical background to the above formulated definition and the respective derived questions shall be given in order to design the analysis framework for the comparative study at hand. Theories and variables from the economic, socio-technical and political perspectives will be considered to create a profound reflection of the co-evolutionary and asynchronous nature of national energy transitions (see *fig. 1*).

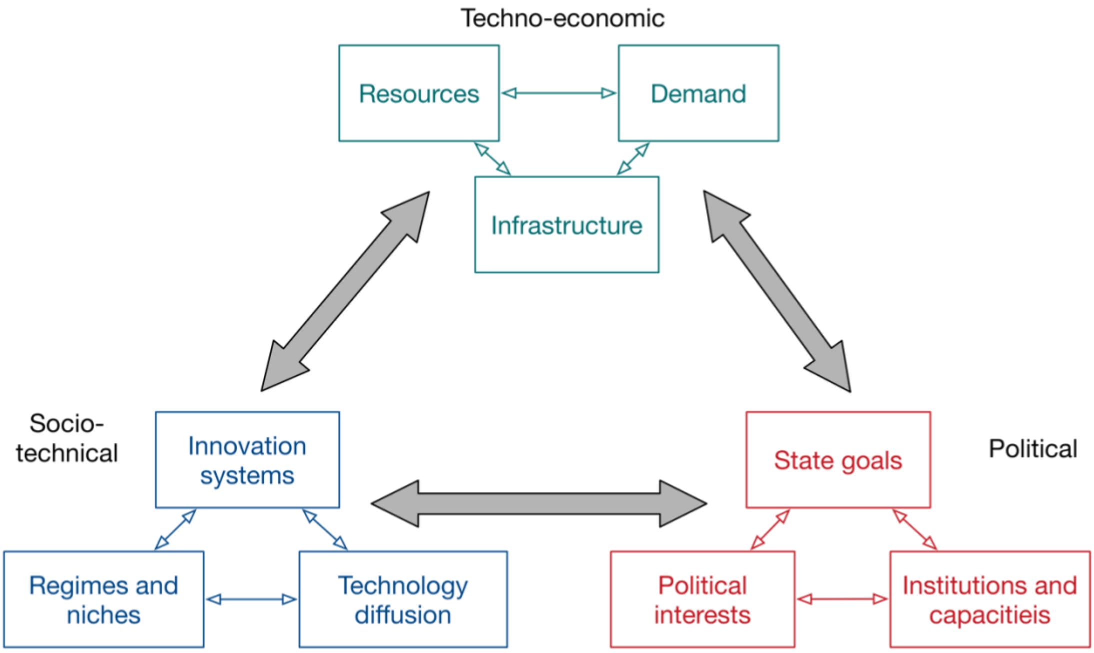


Fig. 1: Different perspectives on energy transitions. A meta-theoretical framework developed by Cherp et *al* (2018)

In doing so, it is recognized that transitions can have divergent drivers at different times which is why at a certain stage of transition, one perspective might dominate over another. For example, Cherp et *al* (2018) anticipate that shaping sustainable energy transitions – which is the necessity-driven global challenge of the 21st century – could be rather explained by political science approaches than the transitions experienced before inter alia due to the role of policy-making in implementing measures that do not trigger immediately obvious positive (economic) outcomes. According to Markard et *al* (2016), the importance of power and politics in transition research has only been recognized recently which should be compensated for by striving for a better understanding of long-term effects of sustainability policies.

This analysis uses the meta-theoretical framework proposed by A. Cherp (2018) and his colleagues who combine the three perspectives which they illustrate on the comparison of electricity transitions in Germany and Japan. In this regard, however, it has to be acknowledged that the approach formulated and concepts mentioned in the upcoming subchapters are not exhaustive, whereby alternative explanations for the differences in electricity transitions remain possible (Cherp et *al* 2017). Therefore, as a next step, the present study will give an overview on existing theories and concepts in the different disciplines to reveal important indicators for cross-country comparison. As a result, the researcher aims to have a "tool-box" at hand that should serve as backbone for the analysis of energy transitions in Austria and Switzerland.

2.2.1. The techno-economic perspective

Especially until the mid-1970s, the focus did not lie on sustainable or low-carbon aspects, but rather heavily on domestic growth that mostly neglected environmental factors, implying that the techno-economic considerations were dominating when debating the nature of energy transitions. However, this does not mean that this perspective should now be ignored but rather that this discourse is increasingly influenced by resource scarcity and a competition for "high quality" fuels at the same time as the aspect of low-carbon becomes more and more crucial and valuable. "Value" is an important keyword also against the background that energy transitions' feasibility is still significantly viewed through the lens of the prospect of economic growth that can be subsumed under the fashionable term "sustainable growth". This shows how important economics are when assessing the feasibility of energy transitions since it usually constitutes the foundation of decision-making and its legitimacy is only questioned by a few (Hall et *al* 2001).

Notwithstanding the envisioned cross-cutting nature of the analysis, a distinct reflection on the techno-economic perspective should be provided in order to understand its origins and future implications. Main aspects of this perspective originate in various strands of economic theory, but mainly neoclassical – "mainstream" – economics that imply a general strive for equilibrium of supply and demand in the framework of a closed system. Within an energy system, "the concept of supply-demand balance means that a change in any particular type of energy supply or use must be balanced by corresponding changes in other types of supply or uses (e.g. expansion of electricity generation from renewable sources must be accompanied by increasing use of electricity, or phasing out conventional sources, or increasing electricity exports (Cherp et *al* 2018)". In this regard, prices are considered the most important drivers while assuming rational decision-making and a limited influence of non-economic determinants (Geels et *al* 2018). However, Hall and his colleagues (2001) criticize that neoclassical economics do not consider the finite character of natural resources thus exclude aspects related to the geosphere or biosphere. For example, the emission-absorption capacity of the biosphere was entirely ignored when valuing goods and the energy needed for their production which runs against the increasing need for the integration of sustainability factors in economic models. This is one of the aspects why the authors claim that biophysical economics have to be considered when examining "physical production, where energy and material stocks and flows are important […]. It must complement the social sphere perspective (ibid.)". According to Hill et *al* (2001) this was vital for the validation of economic concepts in the real world, which were often based on arbitrary assumptions. In this regard, they argue that sustainability aspects of fuels were excluded in calculations due to the systematic neglect of the role of energy for production in neoclassical economic models. Thus, these were myopic due to the focus on short-term availability while being ignorant of long-term assessment of scarcity. This is especially vital when considering that the current economy is built on the assumption that resources were abundant and cheap (Hall et *al* 2001).

Conclusion

At first, this subsection might seem too detail-oriented for a simple reflection on the techno-economic perspective. However, the criticism provided by Hall et *al* (2001) reflects how neoclassical economics still dominate when it comes to analyses and models, which is also recognized by Geels et *al* (2018), who generally consider a socio-technical transition perspective more suitable to address the complex patterns and challenges of energy systems and transitions. The provided description of neoclassical economics shows that the logic used is not reconcilable with a change in energy systems (e.g. by integrating more cost-intensive renewables) while resources are still available, abundant and cheap. Then again, this approach cannot be simply ignored as it is the only perspective that highlights price mechanisms and thereby forms the basis of the free market's logic and that of a myriad of policy implications (e.g. van den Bergh 2006).

Economic models that include biophysical aspects acknowledge limits to growth and enable future economists to deal with integrating aspects of resource depletion that, according to Hall et *al* (2001) has to be treated as fundamental component of economic models. This is also the reason why Hall et *al* (2001) claim that nations should attribute more importance to their natural resources than they do under the current economic system that is based on neoclassical models. When analyzing sustainability of transitions, the aspect of including long-term scarcity of resources becomes vital. Bearing that in mind will be useful for the assessment of how energy strategy in Austria and Switzerland evolved and if a paradigm change has taken place and if so, when. For example, some analysts report a "paradigm shift turning away from supply security" concerning the Swiss government's decision to simultaneously stress on the importance of decarbonization and the phase-out of nuclear power in the framework of the "Energy Strategy 2050" that was passed published in 2011 and passed in 2017 (Borner et *al* 2015).

2.2.2. The socio-technical perspective

Socio-technical system transition theory is guided by the assumption that the use of a certain technology is influenced by and embedded into societal structures like rules and institutions (Elzen et *al* 2004; Nie et *al* 2017). Core areas of interest within the socio-technical framework are phenomena like inertia, change and diffusion as a result of the interplay of social processes and technologies (Cherp et *al* 2018). One of the main pillars behind this concept are evolutionary economics, which provide the basis for a major strand relevant to energy transitions, namely the "technological innovation system studies" after Markard et *al* (2016) which examine the emergence of novel technologies and respective organizational and institutional changes.

2.2.2.1. Evolutionary economics

In contrast to neoclassical economics, evolutionary economics contest the idea of rationality in decision-making and introduce several basic concepts like "path dependency", "lock-in", "co-evolution" or "bounded rationality" that are grounded on founding ideas by Thorstein Veblen and later Joseph Schumpeter. The main idea of the concept is that economic organization is a dynamic process, which is influenced by instinctive human behavior like predation, emulation and curiosity (Investopedia 2018). The different derived concepts relate to each other as they are based on the premise that time is scarce and agents have only access to a limited amount of information. Means to compensate for this restrictive condition are for example imitation or replication of already existing practices to reduce uncertainty and to use their economies of scale. Network advantages and skilled workforce play also a role in nurturing this dynamism, that, in turn, would explain an energy system's inertia and the related reliance on certain energy technologies for decades (Van den Bergh et *al* 2006).

The co-evolutionary nature of energy systems and their infrastructures further nurture lock-in which has been in the focus of research since the rise of renewables has shown how difficult it is for them to fit into this co-evolved system (Nie et *al* 2017). The possibility of economic dynamism is a key assumption of evolutionary economics, suggesting that institutional and technological inertia due to positive feedback-loops is possible, which, in turn, is neglected by neoclassical economic theory (Van den Bergh et *al* 2006). Then again, due to the fact that dynamism also means that structural change is possible, the strand of evolutionary economics is becoming more and more important to explain transitions by combining economic theory and sociological aspects (Van den Bergh et *al* 2006). Namely, the concept also emphasizes rather on the importance of innovation and diversity for the resilience of energy systems than on their economic efficiency (ibid.). All in all, these assumptions are crucial in explaining why there are technologies that were phased out later and some innovations were entering the market faster than estimated by economic models (Cherp et *al* 2018).

The concept of diversity originates in the biological theorem of Fisher on genetic variability, whereby in the energy domain, it can relate to a country's preparedness inter alia for energy crises or general energy security issues through a diversified energy plant and technology portfolio, which can be improved by the absorption of innovations. Furthermore, it is also considered a crucial factor to prevent lock-in (Van den Bergh et *al* 2006). The authors differentiate between radical and incremental innovations, whereby the latter is absorbed by the existing technological paradigm and serves to improve the existing system unlike the destructive-type which strives "outside of the box". Therefore, the more a system faces lock-in, the more it is likely that rather incremental than radical innovations would occur, if they happen at all (ibid.). These innovations can be differentiated by sectoral, technological or national boundaries (Cherp et al 2018).

2.2.2.2. Socio-technical transition analysis

According to Cherp (2018) and his colleagues, the other strand of research relevant to energy transitions is the "socio-technical transition analysis" proposed by Turnheim et *al* (2015) and Geels et *al* (2016), which examines the "multiple dimensions of change" that give credit to different levels and temporalities, multiple actors and institutions, but also consider the role of inertia (ibid.). They especially emphasize on the historical and therefore long-term evolution of energy systems which are embedded in socio-technical regimes that are usually stable and resilient (Cherp et *al* 2018). The focus of interest thereby lies in the above described radical and outside-of-the-box approach to innovations that can emerge in protected niches, due to the fact that these are considered crucial “seeds” for a low-carbon transition. However, Geels et *al* (2016) suggest to study these innovations embedded in a certain context to assess if they were future-proof in a special environment, whereby the multi-level perspective can serve as a framework for analysis.

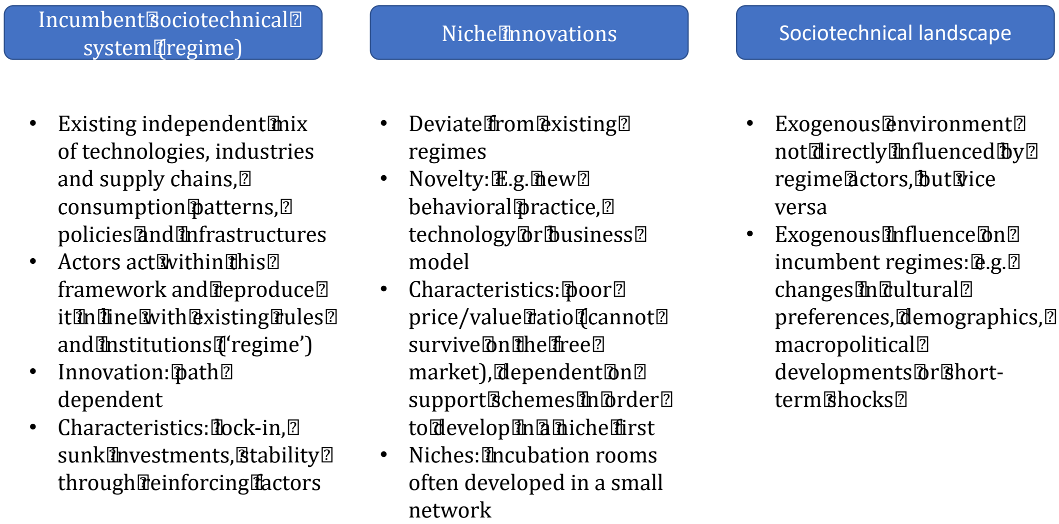


Fig. 2: Own presentation of the multi-level perspective analysis framework for socio-technical transitions summarized by Geels et *al* (2016)

Conclusion

While general neoclassical economic policy focuses on static equilibria, evolutionary policy is resolving the lack of explanation for innovation, but also inertia. According to Van den Bergh et *al* (2006), resilience of energy systems is a crucial asset for their long-term sustainability, which, on the one hand, can be strengthened through fostering diversity and enabling technologies with long learning curves to strive in niches apart from free market competition where short-term cost-effectiveness dominates. In this respect, the more a framework allows for different concepts and mergers, the higher the chance of serendipity becomes (ibid.). This is also described by the strategic niche management approach, which assumes that innovative technologies could be cultivated in niches where they could become fit for the market (Arentsen et *al* 2002). Therefore, the recommendation from evolutionary economics is – in order to win the “survival of the greenest” – to increase

R&D expenditure and therefore “the chance to find useful innovations for a certain energy system” (Van den Bergh et *al* 2006).

However, the authors state that in the long run, it will be crucial that prices account for external costs of economic activity to achieve a sustainable energy transition, which is in line with Hill’s (2001) claim of the need to acknowledge limits to growth. If including the cost of externalities became reality, like it is already attempted through the (European) emission trading system, it is likely that the market entrance threshold for sustainable energy innovations could be reduced and diffusion processes facilitated. However, in general, almost all innovations fail in the first stage of the development process, namely in the emergence phase, when trying to penetrate the stabilized system. Then again, this system is more or less influenced by the landscape or other destabilizing factors that can exert pressure on the regime to facilitate permeability and enable the diffusion of promising novelties, which, in turn, have the opportunity to create real impact (Geels et *al* 2016).
It will be crucial in the framework of the comparative analysis to examine these processes as it emerges from the literature that innovations can only survive the “Valley of Death” if there are selected ones among them that are encouraged to enter the diffusion phase and to become mature. However, it should be mentioned that in the diffusion phase, innovations compete against each other for financial resources and the regulatory framework on the level of technology or the service they aim to replace (ibid.). Therefore, their survival depends on the specific policy design, e.g. technology-neutral and technology-specific policies (Markard et *al* 2016; Azar and Sandén 2010).

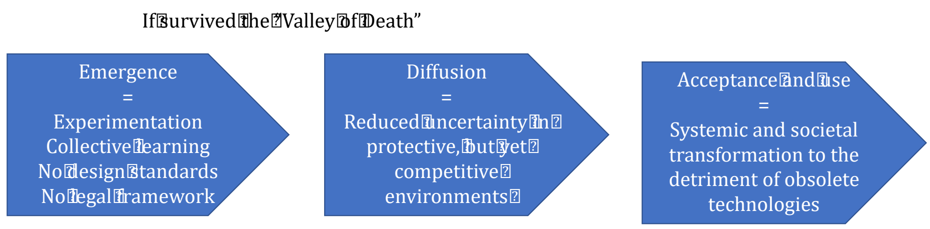


Fig. 3: Own presentation of possible evolution paths of innovations by Geels et *al* (2016)

For example, in several European countries, renewable electricity generating technologies might face technology-neutral, price-bound tendering procedures for subsidized tariffs, meaning that the cheapest technology would outcompete others. This is often the case with biogas and photovoltaics (PV) or wind, whereby the latter two always "win the battle"[1]. However, this often applied approach falls short to integrate additional advantages of certain innovations compared to others besides the original service it aims to replace (electricity generation). Within the mentioned example, a technology-neutral competitive system neglects the fact that electricity generation within biogas plants usually additionally fulfils an environmental function, namely agricultural waste processing while guaranteeing production stability. This example shows that the transition to sustainable energy technologies greatly depends on the regulatory environment and whether governments and regulators recognized their added value besides economic feasibility. This assumption is supported by Markard et *al* (2016), who state that "in a guided transition, political actors, as well as regulatory and institutional support, can be expected to play a major role".

2.2.3. The political perspective

Hence, the political perspective and the respective role of actors examined within could prove to be particularly important in assessing and predicting the nature and future of current low-carbon energy transitions, as policy changes can significantly impact the evolvement of energy systems. The political perspective puts decision-makers in the focus of analysis, which differs from the other perspectives where governments are certainly part of, but not the decisive entity influencing energy transitions (Cherp et *al* 2018). Their role is crucial in the current sustainable energy transition debate as they have the power to design policies that can be lifted out from the "economy first" into a more sustainable paradigm.

The state is the level chosen for analysis because it is still considered the main policy-making entity that has a direct influence on sovereign national energy systems. This is even the case for EU member states in the field of renewable energy policy, although the framework and individual national targets are set by the European Commission, at least since 2009 (Schaffer and Bernauer 2014). The comparative analysis will later focus on examining the framework that constrains and enables decision-making including institutions, structures and rules as well as their effects (Knill and Tosun 2009). Inter alia, the assessment of institutional capacity could potentially explain why a certain country performs better in implementing policies on sustainable technologies than the other.

[1] Due to lower generation costs due to the fact that no raw materials are needed unlike in the case of biomass plants

Therefore, identifying influential factors on policy-making in the subsequent sections is crucial for the objectives and aims of the comparative study.

2.2.3.1. The role of institutions for policy formulation

The role of institutions and the way how they are designed is emphasized in several studies and is used for explain policy development. The institutional argument is for example used in Ćetković and Buzogány (2016), who claim that political-economic settings matter to explain the nature of policies, stating that there is a correlation between varieties of capitalism and innovative regimes and renewable energy growth in particular. In this regard, they argue that the analysis of different forms of capitalism could also contribute to the assessment of future development of technology use, as the institutional framework they provide for offers different opportunities for innovations to strive due to differing structural constraints. The type of capitalism that fostered renewable energy use in a long-term and in a sustainable way was, according to Ćetković's and Buzogány's (2016) findings, the 'coordinated market economy' (CME) model. In CME-countries, innovation was rather incremental, whereas 'liberal market economies' (LME) were rather dominated by a 'cut-throat competition' (ibid; Hall and Soskice 2001).

The difference can be explained by the fact that in a CME the central government is considered to have a stronger role in promoting cooperation between the state, businesses and research institutes through public spending while fostering the broad participation of actors. This entails a certain path dependency for particular technologies, which, in turn, can provide a favorable environment for protected niches. In LMEs, the administrative capacity might be insufficient due to general "limited coordination mechanisms among the state, industry and the financial sector" (Ćetković and Buzogány 2016). However, both Austria and Switzerland are considered CMEs, wherefore this concept does not explain differences but rather adds to the list of similarities between the two subjects of analysis which benefits the "comparable case – most similar system" study design as even more influential factors on energy transitions can be ruled out. Then again, cooperative structures in the framework of CMEs are not immune to vested interests which can foster self-reproduction of incumbent regimes and impede the evolvement of innovations. Cherp et *al* (2017) differentiate between two types of state's strategies: Within the first, states rather work with incumbent regimes whereas within the second, they rather tend to support protected niches (ibid.).

The importance of the institutional setting for RES development is also recognized in Schaffer and Bernauer (2014) who look at institutionalism from a different angle. In this regard, they claim that a federalist structure is among the driving factors for national renewable energy policies and therefore low carbon energy transitions. They assume that a decentralized decision-making structure left more room for policy diffusion by enabling enhanced learning, competition and adaptation processes (ibid; Levy 2007). However, vertical division of authority structure is not unanimously seen as supportive by scholars, as it also might paralyze (environmental) policy-making or its implementation (ibid; e.g. Jahn and Wälti 2007).

Furthermore, Schaffer and Bernauer (2014) argue in line with Lizzeri and Persico (2001) that the design of the electoral system would also influence the government's devotion to environmental spending in general. In this regard, they hypothesize that in a proportional election system, political candidates had to seek support from a broader spectrum of voters than in a "winner-takes-it-all" system, which they would do by striving for a maximum of aggregate welfare. This is based on the presumption that environmental spending – and with regard to the study's topic – support for sustainable technologies is seen as beneficial and important by the general public (ibid; Fredriksson and Millimet 2004).

2.2.3.2. Policy spill-over

Concerning policy spill-over, countries' spatial connectivity (geographic and commercial relations) and especially the embeddedness in an overarching framework can play a role for adopting sustainable energy supporting policies. This is shown in the empirical analysis of Schaffer and Bernauer (2014), whereby they conclude that renewable energy policy diffusion is supported by and comes along with Europeanization. According to Busch and Jörgens (2012) or Holzinger et *al* (2008), in general, a significant convergence of environmental policies has been observed in the past 30 years among EU member states. This kind of international policy coordination can be defined as "the mutual adjustment of the interests, goals and actions of collective actors" and diffusion processes as cross-national imitation and learning (ibid.; Keohane et *al* 1997).

However, there might be gradations and nuances in diffusion processes, depending on the decision-making entity's positioning. Busch and Jörgens (2012) specify three broad classes of government policy coordination: (1) cooperation, (2) coercion and (3) diffusion. The first assumes the existence of a strong, consensus-based supranational top-down approach supported by institutionalized national compliance systems. In this regard, the EU serves as convenient example for a legally-binding international cooperation. The second form, coercion, results less from consensual decision-making, but more from unequal power relations among governments (Busch and Jörgens 2012). In this respect, an appropriate example is the asymmetric power and economic relationship between the EU and candidate countries that have to fulfil certain policy compliance requirements to become members. In general, this kind of policy imposition is often related to a conditionality with prospects for additional benefits in the receiving country, which is (highly) dependent thereof. The third approach is based on the assumption that, for example, innovative technologies can be disseminated and adopted on a voluntary basis through information flows rather than through hierarchical pressure and contractual obligations. According to the authors, this type of policy acceptance is determined more by political and economic competition or by the prospect of reducing uncertainty through the deployment of a proven technology developed in certain countries. These are considered the 'core' countries where technologies emerge and spill over to the rim and periphery, depending on the acceptance capacity of the recipient state (e.g. Cherp et *al* 2017). In this regard, policy adaptation is characterized by horizontal and decentralized processes, whereby the nation states act autonomously. This kind of policy spill-over was typical for the EU-countries in the 1990s, when there was no binding legal harmonization yet (ibid.).

2.2.3.3. The influenceability of governments

Technology diffusion also depends on the permeability and influenceability of governed entities. In this regard, Hall (1993) lists two different approaches to policy making processes: state-centric and state-structural. States classified according to the former category are less sensitive to societal and other external pressure, whereas those of the latter are rather open to input from the political system as a whole (i.e. political parties, international organizations or interest groups). However, actors characterized by both the state-centric and state-structural concept are able to learn within the constraints of "policy legacies" which might be more important to new policy-making than other factors (Hall 1993; Weir and Skocpol 1983). Basically, learning itself can be considered as the absorption and application of new information in the framework of the individual's past experience. In the policy context, this learning process may result in policy-change. However, this process is complex and is biased by the interplay of different factors which are according to Hall (1993) the (1) overarching goals, (2) policy instruments to attain the goal and the (3) precise settings of these instruments. The hierarchy and design of these means might be influenced by the prevailing *policy paradigm* and, if radical changes occur, overthrown by a *paradigm shift*.

2.3.3.4. Paradigm shifts

According to Fudge et *al* (2011), based on Helm's assumptions (2005), a paradigm shift can occur in the domain of energy policy-making which they demonstrate by the example of the United Kingdom, by having identified at least three policy paradigm shifts since the emergence of the concept of the "nation state". Respectively, the first paradigm emphasized the importance of (1) "bringing vital services under public ownership", whereas the second was dominated by the (2) premises of liberalization and privatization. In the wake of this paradigm shift, energy was more and more perceived an economic commodity rather than a public good (Cherp and Jewell 2011). The third, which is likely to be experienced by several decision-making entities today, is the current one on cutting carbon emissions while showing willingness to correct market failures and therefore to account for the externalities of the economy on the environment (e.g. Aguirre and Ibikunle 2014). In this regard, the authors conclude that policy-making might currently be stuck between the two paradigms as there are attempts to shape sustainable energy policies within an obsolete framework. At that point, it is demonstrated again that commodifying the environment while choosing the cheapest options for energy supplies, which matches with paradigm (2), could be unreconcilable if policy-makers truly strived for a low-carbon energy transition. Against this background, it will be of interest to analyze energy policies of the different paradigms and how these have evolved within time. In which of the paradigms did sustainability technologies start to play a role? Can a revision of these policies eventually be associated with a paradigm shift and is a drastic change possible at all?

2.2.3.4. The question of energy security

What has been neglected so far concerning the development of policies is the correlation of sustainable (renewable) energy policies or strategies and energy security concerns. Several studies have found that the strive for energy security can be a driver for the deployment or renewable energy technologies in order to strengthen the resiliency of a country's energy system (e.g. Aguirre and Ibikunle 2014; Lucas et *al* 2016).
First, it has to be clarified how the concept of energy security can be understood. According to Proskuryakova (2018), energy security theories are widely based on the availability of "fossil fuels at affordable prices in centralized systems". According to Chester (2010), in

general, energy security literature largely focuses on the availability and accessibility of oil and gas. However, for example Lucas et *al* (2016) criticize that energy research's emphasis has laid too often on the geopolitics of fossil fuels rather than on the relationship between renewable energy strategies and energy security, whereby the multidimensional nature of the concept is often ignored (ibid.). They claim that the use of renewables is not only driven by environmental and sustainability concerns or even the plain aim to reduce imports, but it is also a matter of how energy security is conceptualized by a certain entity. According to their findings, energy security is even the main driver of renewables deployment in the EU, whereby environmental concerns are secondary if the right proxies are used for analysis. However, results for individual member states vary as the relationship between energy security and renewable energy use depended on the importance of certain energy security targets (Lucas et *al* 2016).

A framework to analyze energy security in a more comprehensive and complex way has been proposed by Cherp and Jewell (2011), by listing three dimensions of energy security that have historically evolved, namely sovereignty, robustness and resilience. Inter alia, they describe how the paradigm shift that occurred in the 1980s and 1990s in the context of deregulation also changed the perspective on determinants for energy security. Namely, in parallel to the rise of privatization, affordability of energy became an important factor alongside the determinants of resource availability in the geopolitical context. The sovereignty aspect primarily focuses on the threats imposed by external actors whereby risk minimization is about the question of how to prevail over these determinants of uncertainty, for example through resource and technological diversification. A system's robustness is largely defined by quantifiable and objective variables like risks arising through a system's infrastructural and technical properties as well as its vulnerability to demand growth or vis major. The third aspect of energy security is the degree of a system's *resilience* which relates to the question of adaptability, flexibility and diversity while energy systems develop dynamically (ibid.). All in all, Cherp and Jewell (2014) define energy security as 'low vulnerability of vital energy systems' (Cherp et *al* 2017) Further aspects and ways of risk minimization are summarized in graph 3.

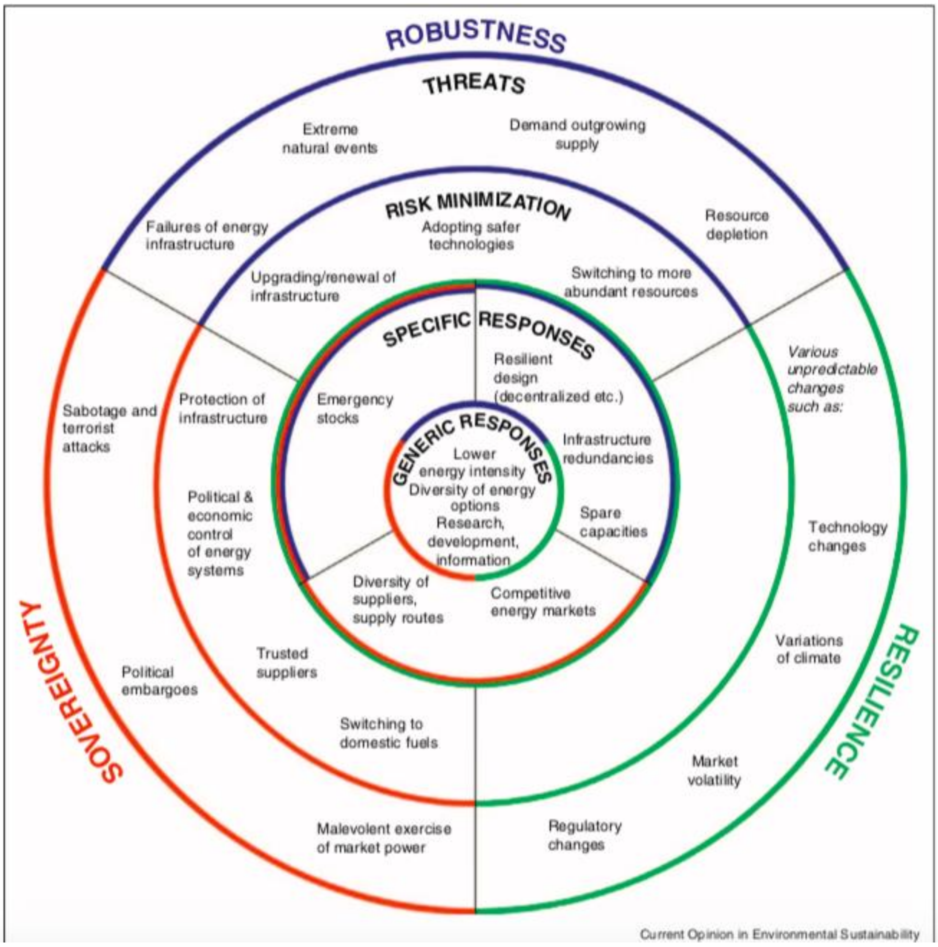
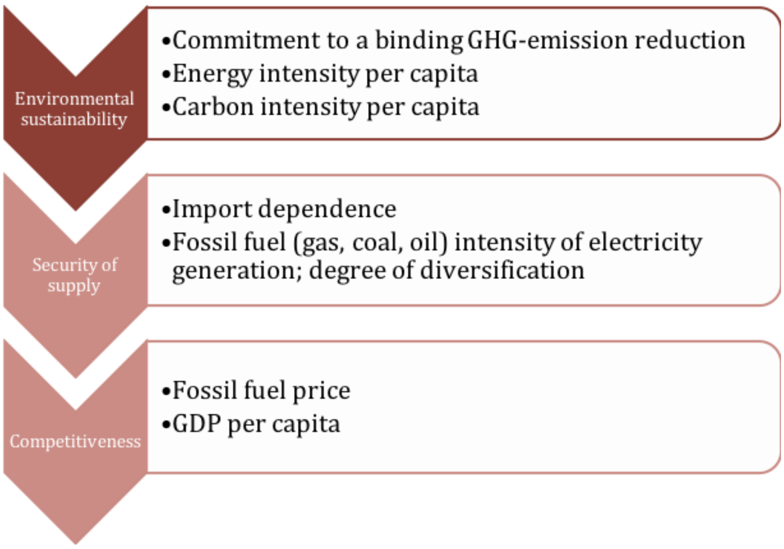


Fig. 4: Summary of the three perspectives on energy security including threats and risk minimization opportunities (Cherp and Jewell 2011).

According to Lucas and his colleagues' (2016) findings, renewable energy technologies (RET) could address the threats related to the above described dimensions (see *fig. 4*). For example, the risk of physical failure, accidents or sabotage could be reduced when turning away from a centralized to a rather decentralized energy system. Moreover, the rather atomistic organizational structure could prevent market abuse which was more likely in an oligopolistic system that is typical for conventional energy systems. Furthermore, fuel-independent RET did not depend on market price volatility making them inter alia less exposed to political power-plays (ibid.).

The role of energy security in the context of low-carbon energy transitions is also discussed in Jewell et *al* (2014). Their findings showed that deploying low-carbon energy strategies could imply a higher diversity of fuel sources used while the energy security concerns related to oil trade could disappear in the long-term. However, also certain arising vulnerabilities were detected which are related to the respective switch to new fuel sources (ibid.). In this regard, Lucas et *al* (2016) claim that the current scientific debate showed that the aim to reduce emissions by deploying RET was prone to a trade-off between different energy security goals, especially if the reduction of energy prices (affordability) constituted an important policy target. In this respect, it is more the re-modeling of the energy infrastructure for RES integration that posed cost-related challenges than investment-related costs of RET (ibid; Röpke 2013). For example, Röpke (2013) found that the costs of RES integration into the German electricity system outweighed the gains in terms of energy security (ibid.).

However, it is difficult to measure the economic value of energy security which makes these kind of findings contestable (Lucas et *al* 2016). Grid development issues come along with currently unresolved supply security problems due to the intermittency of renewable electricity generation (ibid; De Nooij et *al* 2007). All in all, Lucas et *al* (2016) conclude that the way energy security is perceived could play a crucial role for RET deployment and how these new challenges and vulnerabilities are weighted against the benefits of RET use. They assume that the scientific debate on whether energy security goals are a driver or a barrier to RET use remain unresolved as specific circumstances of a particular energy system mattered more than generic assumptions on the concept of energy security. Hence, the emphasis on a particular energy security dimension can differ (see *fig. 5*).



Fig, 5: Different dimensions of energy security based on the European Commission's findings used for analysis in Lucas et *al* (2016).

This insight is important for the comparative analysis as it helps to understand how energy security is conceptualized in the country studies at hand and if energy transition is seen as beneficial within the constraints of their understanding of energy security. In this regard, Jewell et *al* (2014) conclude that "understanding energy security implications of climate mitigation policies is critically important for anticipating the degree of political support they are likely to command." Against this background, the ambitions to significantly expand RES use in Austria and Switzerland – that has been mentioned in the introduction – is especially of interest as the carbon intensity of their electricity generation is considered to be among the lowest in international comparison (Ang and Su 2016).

2.2.3.5. Other possible determinants of adopting policies on sustainable energy technologies

Other and coinciding factors which were found being in positive correlation with the likelihood of adopting support schemes for sustainable (here: renewable) energy technologies are (Schaffer and Bernauer 2014):

- High income levels; GDP/capita
- Development of energy demand and population growth
- The use of fossil fuels and nuclear power
- High CO_2-emissions and energy intensity of the economy
- Embeddedness in an international legally-binding framework

Interestingly, the study[2] found that fossil fuel use and support for renewable energy do not contradict each other in the examined countries. Furthermore, countries using nuclear power were more likely to adopt support schemes for renewable electricity production, whereby the likelihood[3] even increased with the share of nuclear power within an energy system. However, the authors do not mention if the power plant parks' age played any role. It is not inconceivable that countries that are about to phase out a significant share of their nuclear power plant (NPP) capacity would rather rethink their production patterns than those where NPPs still have a long production lifetime.

Aguirre and Ibikunle's (2014) global study on the determinants of renewable energy use partially obtained similar results as mentioned by Schaffer and Bernauer (2014). For example, they also assume that welfare positively correlates with RES deployment or the implementation of support schemes, respectively. However, the findings are different when it comes to fossil fuel or nuclear power use as Aguirre and Ibikunle (2014) observed a negative correlation between the latter and RES deployment. The contradictory results might be explained by the fact that the studies used different dependent variables (RES support schemes versus actual RES deployment) or, which is more likely, by the different

[2] Data from 26 IEA-member countries between 1990 and 2010, including Austria and Switzerland
[3] Wide confidence interval

country samples. Schaffer and Bernauer (2014) analyzed 26 advanced industrialized countries while Aguirre and Ibikunle (2014) took 38 country samples with a broader economic and regional distribution. The latter highlight that especially European countries sought for complementarity of nuclear power and renewable energy use. However, their study also emphasizes on the fact that the levelized cost of electricity (LCOE) and therefore economic feasibility of RES deployment played a role, which depended on the geographic conditions and availability of resources (ibid.).

Conclusion

The extensive analysis of the political dimension reflects the complexity of the factors that can play a role for sustainable energy policy development. Furthermore, it showed again how important it gets for today's energy transitions to implement respective schemes that tend towards a paradigm shift rather than to follow the principle of short-term rentability without internalizing long-term costs of energy production with fossil fuels. In this regard, the analysis has shown that the strength and design of institutions played a crucial role for policy development. Among others, Europeanization and in certain cases federalism have been found beneficial for the adoption of renewable energy support schemes, as they tend to promote learning and acceptance processes. On the other hand, the influence of general contextual factors as well as the conceptualization of energy security should not be neglected in the upcoming country analysis either.

2.2.4. Summary: the comprehensive set of analysis

As indicated in the beginning of the chapter, the different theories and approaches listed to explain energy transitions are far from being exhaustive, which is partially owed to the limited scope of the study. However, this does not mean that a profound analysis is not possible, but merely that the author recognizes that alternative explanations existed. The following table shows a summary of the theories and approaches explained in the framework of the literature review, which is partially designed in line with Cherp et *al* (2017). The 'tool box' for analysis that has been developed will serve as a guide for analyzing and comparing historical electricity transitions in Austria and Switzerland.

Table 1: Analytical framework summarizing the comparative analysis' focus

Hypotheses derived from the literature	**Comparative focus of this study**	**Elements of analysis**
The geographic location plays a role for the deployment of weather-dependent renewable energy sources	Does the wind and solar energy deployment differ by region?	Regional distribution of generation capacity and potential
The way states conceptualize energy security influences their energy resource policy	How vulnerable are these systems? What are the main drivers to reduce their vulnerability? What is the role of renewables within the states' energy security concept? What is the trade-off between different energy security goals?	Domestic resource availability; Population and (sectoral) demand growth; Meaning of affordability and accessibility for energy security; diversification of the plant portfolio
New technologies strive in an environment where innovation is seen as beneficial for the system's resilience	What are the factors nurturing the electricity sector's dynamism or inertia? Are there protected niches for new technologies? How high are R&D expenses for different technologies?	Inertia (path dependency, positive feedback-loops), imitation and replication of existing practices, co-evolution of technology and infrastructure; incremental vs. radical innovation; vested interests (incumbency)
Supra-national and intergovernmental institutions have an impact on domestic policy development	What are the effects of Europeanization? Does it make a difference that CH is not in the EU in terms of technology diffusion? What is the relationship between governments and the influence of hierarchical pressure?	Countries' spatial and legal connectivity; legal harmonization; Adoption of technology through information flows; spill-over in core vs. rim and peripheral countries
Domestic institutional design and capacity matter for the absorption and cultivation of innovative energy technologies	Does a certain governance system enable a better diffusion of new (and sustainable) technologies?	Decentralized decision-making structure/vertical division of authority structure; learning, competition and adaptation processes; Design of the electoral system; Industry and state interaction
The governments' influenceability depends on their sensitivity for landscape factors	To which extent are states able to learn within the constraints of their policy legacies? Two different approaches: (1) state-centric and (2) state-structural	(1) less sensitive to external pressure (2) Open to input from the political system
Societal or economical paradigm shifts have an impact on the evolvement of energy systems	How did the paradigm shifts of the past influence transitions of energy systems? Is a drastic change possible at all with regards to the climate imperative?	The climate imperative OR 'external shocks' influencing energy systems, e.g.: (1) The 'oil crisis' 1974 (2) Nuclear accidents

3. Comparative analysis of electricity transitions in Austria and Switzerland

3.1.Outline of the study

This chapter represents the centerpiece of the thesis as the theories and approaches examined in the previous chapter are going to be applied to the comparative analysis of electricity transitions in Austria and Switzerland. Energy transitions – but not *electricity* transitions – in both countries have been examined separately by scholars before (e.g. Markard et *al* 2016; Kucharska 2017) or the electricity sector in particular, but for a short period of time (Sutter 2011; Verhoog and Finger 2016) or a particular perspective (Jegen 2003; Markard et *al* 2016). Comparisons that reflect short-term developments or focus on a particular problem within a certain perspective might ignore important multi-dimensional patterns that prevail over time. Therefore, the analysis comprises information on electricity use patterns that goes back to the time when electricity became a public good, which occurred in the beginning of the 20th century. All in all, this study can add to the existing research body as country comparisons similar to Cherp et *al* (2017), that analyze the historical development of electricity use, remain rare.

As a first step, the methodology of comparative analysis in the study at hand will be presented, together with its shortcomings. In general, the main point of criticism is that it is difficult to identify generalizable patterns of covariation as, in complex cases, it is barely possible to incorporate all the intervening variables (Levy 2008). Second, it should be explained why it is important to focus on electricity transitions in the light of sustainable development. The third step will be the comparison of electricity use between Austria and Switzerland by mainly focusing on socio-technical and political processes in the light of economic constraints that determined the different use paths. In this regard, it is assumed that a certain lock-in through deploying nuclear technology determined the progress in the area of renewable electricity use of the past two decades. Thereafter, particularities of the two electricity (and political) systems will be illustrated by the countries' wind energy deployment. It is important to mention that in order to accurately identify certain turning points process tracing is non-negligible (Levy 2008), which means that analysis will always be conducted in a time-dependent manner.

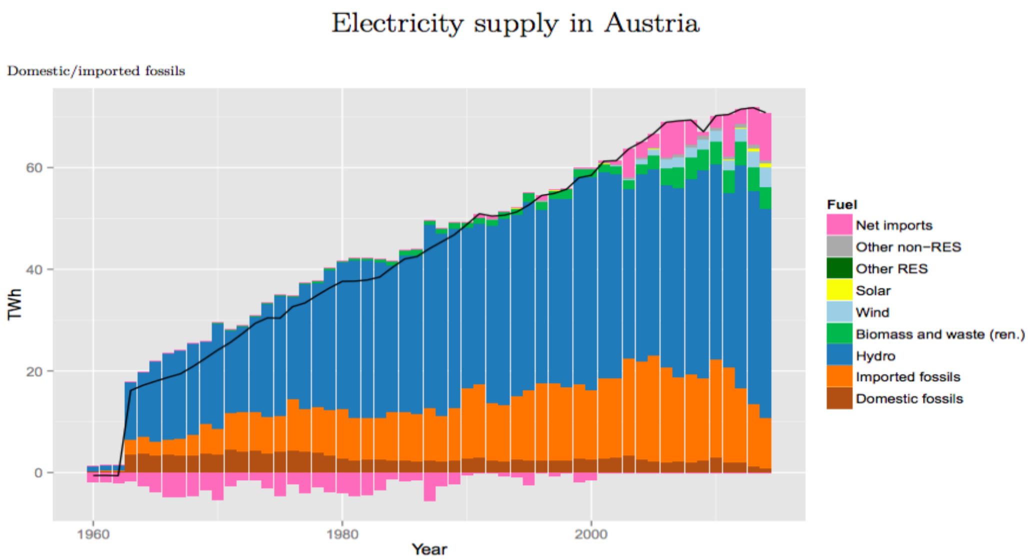
3.2.Methodology

As mentioned above, first, the methodology with its advantages and shortcomings should be described. As already indicated, the study at hand uses the "comparable case

– most similar system" approach (Cherp et *al* 2017) as the researcher assumes a case with similar values on most of the causal variables and different values on the dependent variable, following John Stuart Mill's method of difference (1970)[4] that is described in Levy (2008). The scope of the study is the historical evolvement of electricity use and therefore comprises the entire development of the two countries' electricity sectors since the beginning of the 20th century. In order to outline this development, mostly German-language documents are analyzed that reflect on transformant processes.

It will be shown in the upcoming chapters that similarities on the independent variable are given. First, this holds true when it comes to topographic conditions concerning hydro and wind energy utilization. Second, the countries' conditions on resource availability, energy dependence and future electrification plans are quite alike. Third, both countries developed a socio-technical framework for a nuclear program. Third, it will be demonstrated that both countries enabled a socio-technical framework for the utilization of renewable energy sources (here: wind power), among others through technology import, long-term research and development (R&D) spending and the creation of own industrial niches from early on.

Therefore, the dependent variable is considered what was the different outcome of these decision patterns, namely that Switzerland covered a large part of its electricity demand from nuclear power and Austria from a far more differentiated portfolio, inter alia with a larger focus on the deployment of wind power as of the late 2000s. The differences in the countries' electricity use paths can be seen from the following graphs depicting the development of resource use for electricity generation:



[4] A similar approach is followed by Przeworski and Teune (1970)

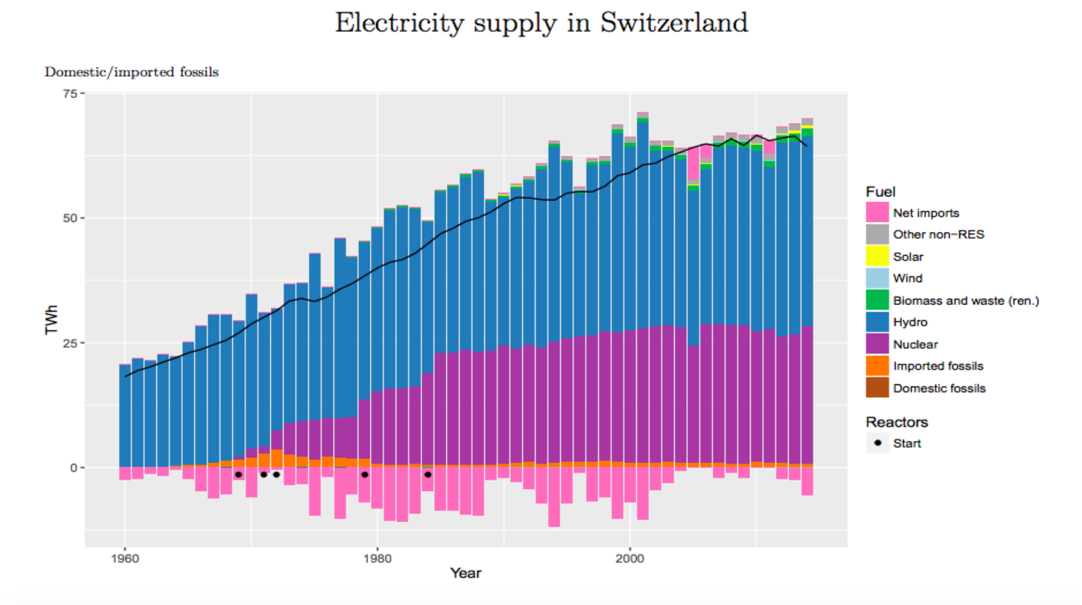


Fig. 6 and *7*: Electricity supply and development of demand in Austria and Switzerland based on the data obtained from the IEA. Graphs provided by A. Cherp (2018).

The main task thereby will be to identify the explanatory variable(s) that can be considered decisive for the different paths. However, as indicated above, due to the causal complexity, it is not possible to rule out intervening variables as different sets of conditions can lead to a similar outcome (Levy 2008). Then again, the disadvantage of these kinds of studies is what has been described by Lijphart (1971) as ‘many variables, small number of cases’ (ibid.).

The Most Similar Systems Design (MSSD) is mostly used in comparative political research whereby two modes of deployment are possible: A looser and a stricter application (Anckar 2008). The latter implies that the cases examined differ concerning one aspect only, whereby the former recognizes that cases can also be compared even if they are not matched on all the relevant control variables. In this comparative study, the looser type is used in order to explain the different outcome, whereby it can be explored by deductive or inductive reasoning (Anckar 2008). The former was performed in the framework of the literature review, but the researcher reserves the right to integrate inductive aspects as “we can never pay regard to all possible explanations of a phenomenon” (ibid.).

3.3.Why analyze electricity transitions?

Before starting the analysis, the researcher aims to explain why it is important to research electricity transitions, which is not obvious at first glance due to the fact that the electricity use currently plays a rather minor role concerning the total final energy consumption both in Austria and Switzerland. As it is, the electricity use with regard to the total final energy supply in both countries is around 25% in Switzerland and 20% in Austria, respectively, whereby *fig. 7* rather shows a rising tendency in the case of the former. This is widely consistent with global trends whereby as of 2015, electricity made up 18.5% of the share in total fuel consumption, which only increased by 9 percentage points since 1973. Then again, total fuel consumption has more than doubled since (IEA 2017b). All in all, these figures show that electricity has played a minor role in global energy consumption in the past decades. However, in the light of sustainability transitions, electrification is becoming increasingly important. For example, when comparing the mentioned figures with trends in OECD countries, one can clearly see that in the latter, energy consumption is growing significantly slower and that electricity is slowly but steadily replacing fuels like coal and oil (ibid).

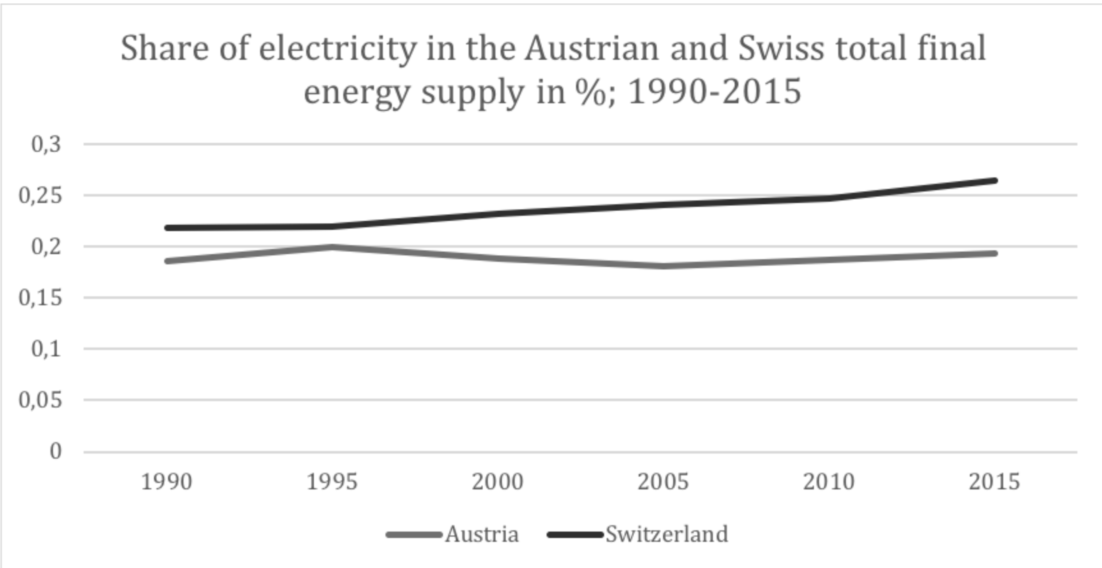


Fig. 8: Development of the share of electricity in the Austrian and Swiss total final energy supply in % in line with the available data from the International Energy Agency Statistics (in ktoe)

Furthermore, several countries are incorporating measures on electrification into their national strategies as research has shown that 'extended electrification of transport, buildings and industry can play an important role in displacing fossil fuel consumption' and therefore provide not only for a significant GHG-emission reduction potential in both short- and long-term scenarios, but also for a prospect to become less dependent on imports. In the short-term, the highest potential is seen for the transport sector becoming electrified (ETC 2017). This trend of substitution is likely to be followed in the studied countries: In the framework of the newly released Austrian climate and energy strategy, it is stated that electrification was necessary to decarbonize the transport sector until 2050, as with a share of 35%, it is the sector with the largest energy demand (BMNT 2018). Therefore, compared to 2014, Austria expects an increase by 14 TWh to 88 TWh in 2030 with an overall need for approx. 20 TWh of production capacity, which is also supposed to compensate for current electricity imports (Schitter 2017). Regardless of different indicators used for scenarios, calculations in different studies expect a certain increase of electricity demand in CH as well, namely by 26 TWh[5] to 82 TWh until 2050, stating that electricity should become the backbone of the energy system (VSE 2018a).

On the other hand, the desired shift in fuel use is related to the fact that the political and economic costs of imported energy are considered outstandingly high: In this regard, both Austria and Switzerland are traditionally highly energy dependent countries as show in *fig. 9*.

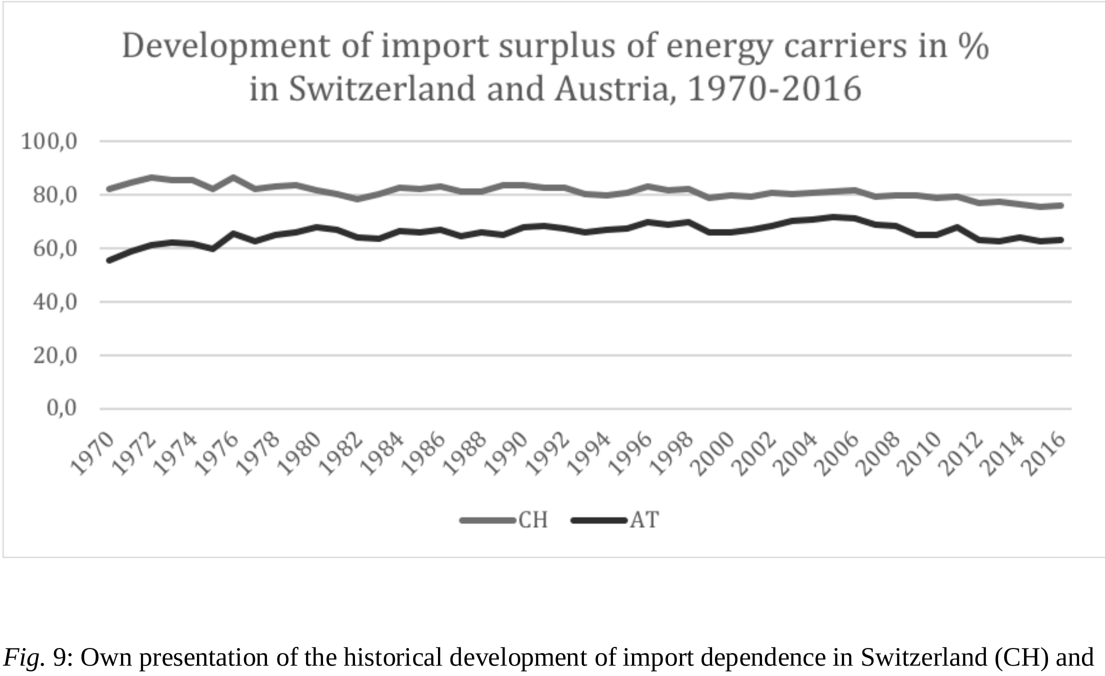


Fig. 9: Own presentation of the historical development of import dependence in Switzerland (CH) and Austria (AT). Data obtained from the Swiss Energy Office (2018) and Austrian Statistical Office (2018).

[5] This is the business as usual scenario.

Interestingly, the import surplus in Switzerland is higher, although the domestic share of electricity is higher than in Austria while at the same time, Switzerland is considered a traditional electricity export country (see upcoming chapter). The reason for this is the dependence on nuclear fuels that have to be imported to CH, which is absent in AT.
Thereby, the economic leverage imposed by the costs of energy imports is high in both countries. In Austria, costs of fossil fuels imports account for approximately 12 billion Euro per annum, which is equal to 40% of the gross domestic product (Kucherska 2017). In Switzerland, the costs of imported energy amount up to approx. 11 billion Euro per annum which accounts for one fifth of the federal budget (Häne 2014). According to a study of the Swiss Energy Foundation, a domestic energy transition would entail a massive reduction of fossil fuel imports leading to a redirection of cash outflows of annually five billion CHF when assuming a moderate price development of fossil fuels (SES 2014).
All in all, the comparison shows that energy dependence in both countries is historically high, whereby studies and energy strategies suggest a significant reduction of imports, inter alia by shifting to electricity that is produced by domestic renewable energy sources[6]. This reflects the assumption that the deployment of renewable energy are viewed as beneficial for strengthening domestic energy systems. Due to that, a significant rise in electricity use is expected in the upcoming decades, both for Austria and Switzerland (e.g. Schitter 2017; VSE 2015), which reflects the importance of this field of analysis in the light of sustainable energy transitions.

3.4.Comparison of historical electricity use in Austria and Switzerland

The previous chapter already identified important aspects of similarity concerning energy dependence and future plans of electrification. In this section, the aim is to determine selected indicators of resemblance in order to adhere to the criteria of the 'most similar systems' study design. On the other hand, the differences on the dependent variable(s) will be explained as well. Due to the focus on the electricity sector, indicators that influence its development in terms of supply and demand will be presented.

3.4.1. Early development of electricity demand, resource availability and supply

On the basis of relevant figures, a significant correlation between population growth, economic growth and electricity demand can be demonstrated. The key indicator for

[6] And implementation of energy efficiency measures, which is not in the focus of the study.

this is the gross domestic product (GDP), which is directly and indirectly responsible for higher electricity use (VSE 2018). In relative terms, the GDP growth and electricity use per capita both in Austria and Switzerland have almost developed in parallel, whereby the latter has almost increased threefold in CH and fourfold in AT since the 1960s (Worldbank 2018a). The stagnation or even decline (in CH) which can be observed since around 2005 is mostly owed to energy efficiency measures that contributed to the decoupling of electricity consumption and economic growth in both countries, but presumably was more successful in CH (OE 2015; VSE 2015).

In order to detect possible path dependencies that might prevail until today, it is important to examine the past development of the countries' electricity sectors. With regard to demand in the 1960s, the power use per capita was one third lower for AT compared to CH, but in the beginning of the 2000s, the former has overtaken the latter (see *fig.10*).

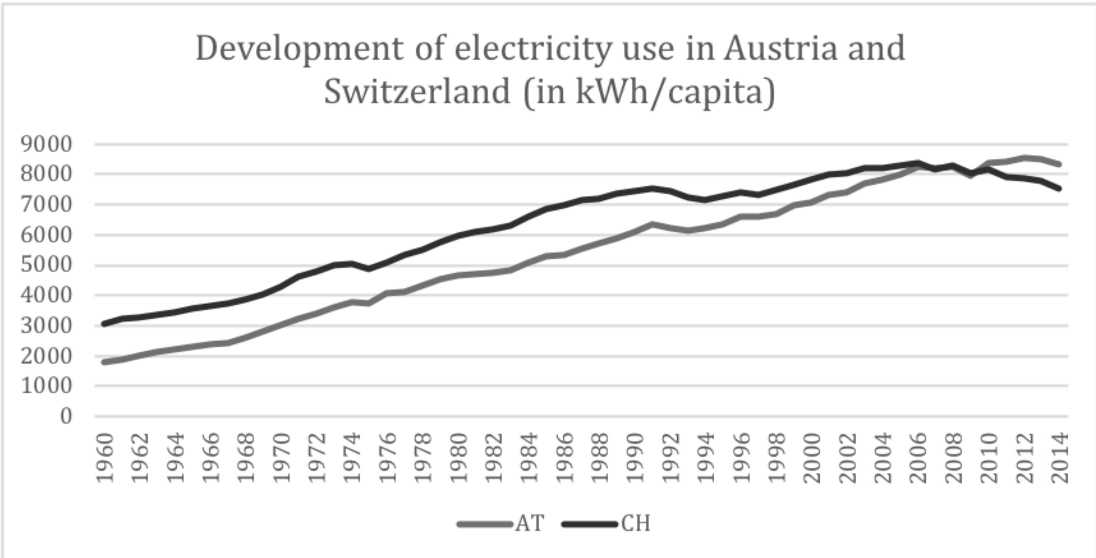


Fig. 10: Development of electricity demand per capita in Austria and Switzerland 1960-2014. Data obtained from the World Bank (2018a)

In this regard, experts referred to a 'catch-up effect' after the Second World War (WW II), as Austria was considered the Western European country with the lowest demand beforehand (Wifo 1960).

3.4.1.1. Early patterns of electricity demand and supply in Austria

In Austria, the electricity demand started to grow remarkably in the beginning of the 20th century which was endorsed by the introduction of the concept of public power supply. At this stage, the most important resource was coal to power steam engines. In the 1920s, there were efforts to replace them by hydro power plants; their installed capacity rose by 203% between 1918 and 1930 and was further pushed forward in the course of the WW II, as demand grew immensely. In the beginning, the electricity sector was financed by private investments which changed in the course of Austria's annexation by Germany in 1938, leading to the nationalization of the sector. With the Second Nationalization Act (1947), most of the electricity companies became the property of the Austrian federal states. The large power plants were transferred to Special-Purpose-Associations and the majority were subordinated to the federal government. The fiduciary administration was taken over by the Austrian Electricity Industry Corporation (Verbundgesellschaft). This structure has mainly remained until today (Huber 2010).

In general, when it came to the development of new capacity in the first decades of the 20th century, the question was to find a balance between steam and hydro power plants, which was influenced by the volatile utilization capacity of the latter during winter times, which is mostly the reason why not the full potential of hydro power was exploited back then (Wirtschaftsforschungsinstitut 1952). However, coal demand sunk gradually in parallel to the increasing electrification of the industry which was triggered by the lack of coal resources after WW II. The increased demand was mostly owed to the production allocation to particularly electricity-intensive industries like aluminum production, which grew immensely. Electricity demand also grew fast in the household and railway sectors which magnified the substitution pressure on coal, as electricity was considered a significantly cheaper resource. Economists refer here to a feedback effect as the expansion of the heavy industry was attracted by low electricity prices due to domestic hydro power production opportunities other Western European countries did not possess. This also applied for oil resources as Austria became one of the largest producers in Europe after WW II (Wirtschaftsforschungsinstitut 1960).

All in all, the self-sufficiency could be maintained in Austria's electricity sector, but issues with security of supply arose in the framework of long-term prognoses due to rapidly shrinking domestic resources as well as problems with hydro power utilization in the framework of the available technology at that time, whereby nuclear power was considered as a complementary solution to balance its volatility in the winter (Wirtschaftsforschungsinstitut 1974). At that point, it was assumed that the first nuclear power plant (NPP) would go online 1974, the second in 1980 and the third in 1984 (Wirtschaftsforschungsinstitut 1974); while expecting that "nuclear energy will already account for a considerable share of consumption over the next ten years (1980: 7%, 1985: 11%)", delivering 17 TWh of electricity p.a. until 1985. Simultaneously, it was assumed that solar and wind energy would make only marginal contributions to domestic energy supply in the future (Wirtschaftsforschungsinstitut 1974).

3.4.1.2.Early patterns of electricity supply and demand in Switzerland

The history of Swiss electricity utilization is marked by several turning points, which begun with the increasing electrification in the late 19th century, mainly fostered by the hotel industry. In the beginning of the 20th century, the demand increased remarkably as view on electricity changed when it was no longer perceived as a luxury, but a public good. However, energy transitions always had a "political component" (BFE 2013): In the course of electrification, the question of sponsorship stood in the focus which finally brought the nationalization of electricity supply early. In general, the structure of the national electricity industry reflected the federalist political landscape of Switzerland, which was characterized by heterogeneity and decentralization. More than 1,000 electricity companies ensured the production and distribution of electricity, from local cooperatives to regional companies to major national and international companies (Kupper 2003). The historical development of the Swiss electricity industry is still reflected in its structure today – the current situation is largely due to decisions made between 1880 and 1916. Inter alia, in 2013, approx. 90% of the largest electricity companies were publicly-owned (BET Suisse 2015).

The paradigm shift to the "right to electricity" endorsed the fast expansion of hydropower capacities, which was seen as a cheap domestic alternative to coal that was largely imported from neighboring countries (Kupper 2003). Between 1945 and 1960, electricity use increased by 5% on average p.a., which was typical for Western European countries. Historians called this period 'the 1950s-syndrome', an era that was characterized by economic and energy use growth that came along with recklessness towards the environment. However, the Swiss electricity sector had little greenhouse gas emissions, similarly to the Austrian one as many hydropower projects that were put on hold during WW II have been realized in the 1950s. In this regard, hydropower was called 'the white coal', which reflects that it was seen as a lucrative substitute. From 1945 to 1970, the installed capacity of hydropower plants rose from approx. 3,000 MW to more than 12,000 MW. Almost all hydropower plants with a capacity of over 100 MW operating today date from this period (Kupper 2003).

3.4.1.3.First concerns of security of supply

The focus on domestic production for decades left electricity companies in Switzerland anxious about the future of supply in the early 1960s as demand grew and hydropower expansion slowed down due to economic reasons. The lack of economic viability to build new hydropower plants was mostly influenced by the growing investment uncertainty as a consequence of exhaustion of economically viable utilization potential in geological terms within the framework of the available technology at that time. Furthermore, first issues with conflict of use arose in terms of nature conservation. Simultaneously, key actors of the Swiss government predicted an 'energy dilemma' that could force the government to 'install hydraulic and thermal power plants against the will of the general public' (Kupper 2003). Therefore, a complementary solution had to be found (ibid.). *Fig. 11* below demonstrates that forecasts of demand outgrowing supply with hydropower were accurate: The figures show that this became reality in the end of the 1960s at the latest. The fluctuations, as illustrated in *fig. 11*, are explicable by a certain volatility as production with hydropower can be impaired in winter times, which often came along with the interruption of supply in the 1950s and 1960s, making the question of additional capacities even more urgent (World Energy Council n.d.).

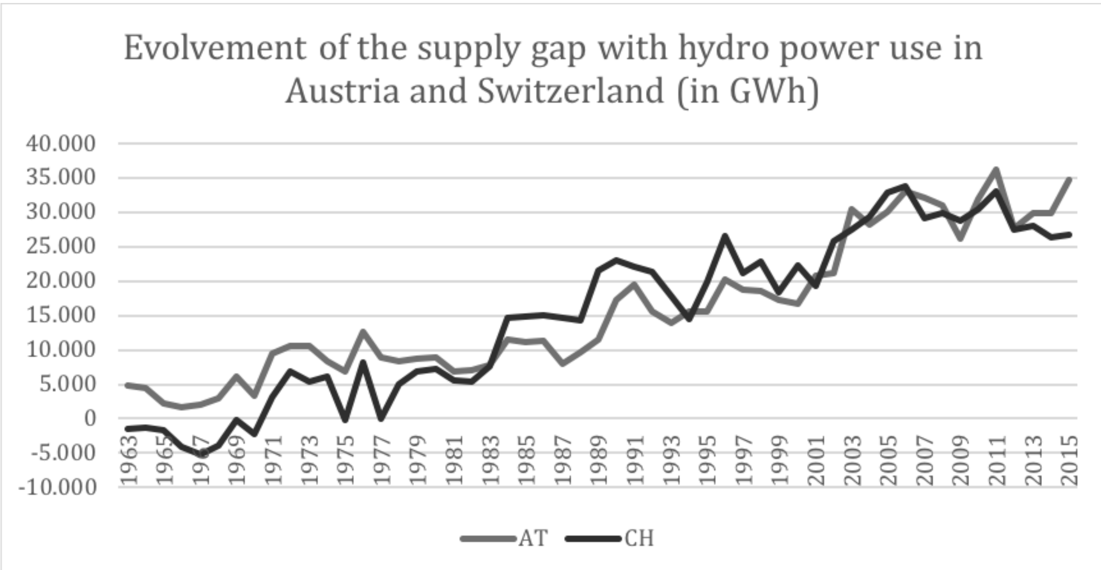


Fig. 11: Evolvement of the supply gap in Austria (AT) and Switzerland (CH) 1960-2014. Data obtained from the IEA data base.

In Austria, the question of electricity supply security arose later only due to the fact that steam power plants that run first on domestic and later mostly on imported coal (due to rentability) were kept in operation to compensate for the fluctuations of hydropower production (Lackner 1980; Weiß 1988). Furthermore, in the 1960s alone, four new thermal power plants were put into operation. Therefore, the country already had a complementary technology to hydropower in use. Moreover, as demand grew, Austria additionally exploited the unused potential of hydropower: Between 1970 and 1980 alone, the capacities grew by approx. 50%[7]. Although in Switzerland, the main energy carrier was coal in the beginning of the 20th century as well, it has not been further utilized for electricity production. While in 1885, about 20% of the electricity was generated by fossil-thermal plants in CH, this share sank below 5% by 1910 and became negligible until the First World War. In this regard, the Federal Act of 1918 on the utilization of hydroelectric power gave further impulses to the expansion of hydropower (World Energy Council n.d.).

3.4.2. The question of nuclear power in Switzerland

All in all, the description of the evolvement of electricity demand and respective supply options revealed that the security of supply question had to be resolved more urgently in Switzerland than in Austria. Concerning the former, neither thermal power plants nor imports were considered a solution. On the one hand, concerns were raised in the Swiss population against the construction of thermal power plants. The fears were fueled by the rumors around the detrimental environmental effects of fluorochemical emissions, which caused a crisis of the Swiss aluminum industry in the mid-1950s. Inter alia, the experiences of this "Fluor War" mobilized the general public against conventional-thermal power plants. In consequence, numerous projects launched for thermal power plants and refineries met with massive resistance, which was supported by local governments (Kupper 2003). Concerning imports, the argument was that the economic and political costs of imported electricity would be higher in the long term than those of domestic production (ibid.).

First, Swiss utility companies planned to rely on oil power plants, but this idea was rejected after the Federal Council announced in its report of 1963 that the peaceful use of nuclear energy is being considered out of "environmental protection and dependence risks" (Kupper 2003). This took the electricity companies by surprise, as the public consensus was that the nuclear technology was not ready for deployment yet (ibid.). Then again, the governmental decision did not appear by chance: In the 1940s, nuclear

[7] From approx. 20,000 GWh to 30,000 GWh

power already was a widely researched field in Switzerland with the involvement of both the government and the scientific community (Aegerter 2016). This cooperation was institutionalized in the framework of the "Academic Commission for Nuclear Energy" in 1945 to explore the new technology's potential. Although publicly denied, the Swiss government primarily had military interests in this research as the construction of an atomic bomb was considered (Berg 2017).

In cooperation with the private sector, the Academic Commission carried out intensive research that was supported and financed by the federal government (Aegerter 2016; Berg 2017). The gradual formation of a strong nuclear lobby and the developing socio-technical system was significantly influenced by the scientific cooperation with the U.S. In this respect, in 1957, the country signed a working agreement on the cooperation regarding the peaceful use of nuclear power with the U.S.-American government (Aegerter 2016). Thereupon, a research reactor of 10 MW, which was an American import, was put into operation (WNA 2017). In general, after WW II, bringing the nuclear technology from the U.S. to Europe was part of the politics of Western integration (Bayer 2014). On the other hand, most domestic electricity companies rejected e.g. the deployment of research reactors[8], which might explain their ignorance concerning the available state of the art at that time.

Nevertheless, a regulatory framework was created in 1959 by implementing the Law on Nuclear Power, which paved the way for the establishment of a nuclear science council. According to Kriesi (2017), the policy-making process was strongly influenced by the nuclear lobby. In 1961, the National Committee for the Promotion of Nuclear Power[9] was established and institutionalized close cooperation structures between politics and the industry (WNA 2017). The fact that U.S.-based Westinghouse and General Electric offered economically attractive turnkey nuclear power plants in 1964 including trainings for employees opened the possibility of a technology spillover from the USA to Switzerland (Aegerter 2016). This offer was crucial for the success of nuclear power in CH, since the core industry remained skeptical towards the introduction of a widely unexplored technology (Kupper 2003). In 1969 and 1972, two reactors in Beznau (both 380 MW, Westinghouse) and one in Mühlenberg (1972) were brought on line right before importing a significant amount of electricity would have become necessary

[8] "Until now, it has never been considered necessary by the power companies to build a plant solely for the purpose of gaining experience. It is not clear why it should be different for nuclear power plants" – CEO of a large electricity company (Kupper 2003)

[9] Gesellschaft zur Förderung der Atomkraft

(Kernenergie CH 2018). Their construction and commissioning went without any resistance (Kriesi 2017).

According to Kriesi (2017) who argues in line with Midttun and Rucht (1994), it was the ownership structure of the electricity companies that facilitated the technology spill-over. As indicated above, cantons were usually shareholders in electricity companies. Furthermore, the cantons and large cities were not only electricity producers, but also considered the main decision-makers in the energy domain – theoretically except for questions on nuclear power use – until the 1990s. The strong participation of the cantons in the federal decision-making process is an important feature of Swiss federalism. The binding co-decision takes place via the second parliamentary chamber (Council of States), the cantonal majority in popular referendums and the possibility of the cantons to use the instruments of popular initiative and the referendum. In addition, the cantons take political influence in the pre-parliamentary procedure of legislation. All this gives the cantons a strong influence on the decision-making process at the federal level (Linder 2010).

In the 1960s and 1970s, most of the cantons belonged to the 'pro-growth' coalition together with the industry and the central government. This 'pro-growth' coalition was well organized and institutionalized in the framework of the so-called 'energy forum'. All in all, it is assumed that these local governments, which were embedded in economic interest structures, aimed at securing their popularity among voters after having experienced resistance against thermal power plants. In this regard, nuclear power was considered an environmentally friendly alternative to fossil-fueled plants (Kriesi 2017). Public opinion surveys have shown that until the mid-1970, only one fifth of the Swiss population was standing opposed to a nuclear power program. Furthermore, it was supported by the central-right government which was present on all levels of Swiss policy-making (ibid.).

However, a change in attitude among some parts of the Swiss population has emerged in the 1970s and culminated in an anti-nuclear movement in 1975 – which, at first glance, seems to have led to the halt of several NPP projects in Switzerland. In sum, eight projects were thwarted until today[10]. Interestingly, this movement or the often-cited 'change in values' did not impede the commissioning of another two large NPPs, namely in Gösgen (1979, 1,060 MW) and Leibstadt (1984, 1,275 MW). Furthermore,

[10] Graben, Inwil, Kaiseraugst, Rüthi, Verbois, Niederamt, Beznau 3, Mühleberg 2

the first protests in 1969 were not even targeted at the commissioning of the first NPP in Beznau, but the planned plant in Kaiseraugst.

Certainly, this issue is more complex than that, which should be demonstrated on the NPP project in Kaiseraugst, a plant whose construction begun in 1973 and was almost completed in 1977. However, the plant was never commissioned and was abandoned finally in 1988. Interestingly, the planning of the later realized NPP in Gösgen (1979) was taking place almost at the same time (Kupper 2003). This requires further analysis especially with regard to the fact that the Swiss case is different from the Austrian concerning the direct-democratic instruments that the electorate has at its disposal. In this respect, it has been demonstrated that energy projects could be impeded by local protests, like in the case of fossil-thermal power plants. Kupper (2003) lists following reasons why the NPP-project in Kaiseraugst failed:

(1) Exclusion from profits for the region: The company in charge for the NPP, 'Motor-Columbus', did not involve the municipalities in the vicinity of the envisaged plant with regard to tax payments. Therefore, the local politicians had no interest in supporting the project.

(2) Lack of compliance with the federalist culture: The geographic location played an important role with regard to the plant's governance. Although situated in the Canton of Aargau, it would have bordered with the Cantons Basel-Landschaft and Basel-Stadt which were (financially) not involved. Thereby, the centralized regulation of nuclear energy seemed to collide with the historically anchored federalist principles. The displeasure concerning missing competences (and financial participation) discharged in protests which were supported by the local governments and the labor union in the Basel region. As indicated above, the power of local pressure due to the direct-democratic levers in Switzerland should not be underestimated.

(3) Forecasts on the development of electricity consumption have not materialized and were questioned in the light of the economic crisis in 1974 (Schilling 2008).

(4) Highly competitive nuclear industry: The Swiss electricity sector was considered highly competitive as far as the nuclear projects were concerned. Among others, the time factor played an important role. Mutual learning processes were not possible due to the isolation of these companies. The missed opportunities for early coordination have had an impact on the licensing procedures for the nuclear power plants in the 1970s, which were partly due to the different technical interpretations of the installations. This further impeded the early commissioning of NPP Kaiseraugst. Due to external and internal

pressure, the different companies finally started to show willingness to cooperate in the late 1970s. However, a domestic nuclear power industry could not be developed.

(5) Timing: According to Kupper (2003), it could be shown that at the time of construction, topics concerning the corrupt 'nuclear elite' as well as issues on environmental protection were dominating the public discourse, partially due to the publishing of the 'Club of Rome' report on 'Limits to Growth' in 1972 (Schilling 2008). The lack of acceptance (see (2)) fueled the projection of the these issues on this particular project.

The analysis reflects that certain contextual factors played a decisive role, from which project planners in Gösgen and Leibstadt could learn (Kupper 2003). The realization of NPP Gösgen, which was almost built simultaneously to NPP Kaiseraugst, was also threatened by protests. However, with the Socialist cantonal financial director[11], Willi Ritschard, being simultaneously the Vice-President of Atel, the electricity company in charge for the plant in Gösgen, the local government clearly had an interest in the construction of the nuclear power plant (von Arx 1970). The wide political support was considered the reason why inter-cantonal police forces could be mobilized to impede the occupation of construction sites very efficiently (Kupper 2003). Furthermore, the planning of NPP Kaiseraugst was not abandoned yet[12], which therefore symbolized that the electricity industry has not given up on nuclear power. Then again, the planning and approval procedures became more and more tedious and complex, which was foremost reflected in the price. While the nuclear power plant in Gösgen (1979) costed approx. 2 billion francs, the costs for planning and construction of NPP Leibstadt already amounted up to 4.8 billion (Baur 2011).

The short reflection of the early Swiss nuclear power sector shows that indeed, protests were also present and powerful in Switzerland in the 1970s, simultaneously to the situation in other Western European countries like in Germany or Austria. However, reasons underlying for the failure of certain NPPs are related to several contextual factors as demonstrated on the project of Kaiseraugst. The latter has been chosen as interestingly, Austria started its first nuclear a nuclear plant project at the same time, which makes these two projects comparable in a temporal context.

[11] NPP Gösgen is located in the Canton of Solothurn.
[12] The project "Kaiseraugst" was officially abandoned only in 1988 with a compensation payment of 350 million francs to the developer

3.4.3. The history of nuclear power in Austria

As indicated above, in Austria, economists have counted firmly on the development of nuclear capacity in order to cover for the increasing electricity demand. According to initial plans, three reactors should have been put into operation between 1974 and 1984 that should have contributed 33% to AT's electricity production by 1985 (Wirtschaftsforschungsinstitut 1974; Müller 2017). In the end, the completed plant in Zwentendorf was never put into operation after its rejection in a popular vote in 1978. Today, in the framework of the public discourse, Austria's refusal of nuclear power is often portrayed as 'deeply anchored within the population' while referring to the strong voice of the anti-nuclear movement in the 1970s (Bayer 2014). However, the rejection of putting an already constructed plant into operation cannot be explained by a haphazard formation of a social movement only (ibid.). In sum, according to Bayer's findings (2014), "the anti-nuclear-consensus is mostly the result of top-down processes and not the achievement of the anti-nuclear movement or 'the Austrian population'."

In Austria, like in other Western, prospering countries, the discussion on nuclear power started between the 1940s and 1950s (Müller 2017). At that time, like CH, AT also had a research platform (1956) and several research reactors (as of 1960) established. Moreover, the launch of the nuclear program (1968) and construction of the first NPP in Zwentendorf in 1972 were unanimously supported by politics and also welcomed by the industry, as additional production capacity was deemed economically necessary (Bayer 2014). The political decision was reached based on the consensus of the grand coalition between the conservative ÖVP (People's Party of Austria) and SPÖ (Socialist Party of Austria) in cooperation with important pressure groups like the labor party (ibid.). Furthermore, according to Bayer (2014), the content analysis of several documents has shown that nuclear power was considered a promising and modern technology also by the Austrian population, whereby ecologic concerns did not play a role. However, similar to the situation in Switzerland, certain electricity companies were considered skeptical towards the new technology due to the unresolved question of uranium imports (ibid.).

Certainly, some anti-nuclear resistance was formed on local level, which played a minor role in 1967, when the final decision on the construction of the first nuclear power plant was made (Bayer 2014). Interestingly, a real protest of more than 20,000 participants was only raised in the framework of the Swiss NPP-project in Rüthi in 1973, which is situated close to the Austrian border. In parallel, demonstrations against the second Austrian NPP-project were organized. Due to the fact that NPP Zwentendorf has not been put into operation yet, the Austrian government saw the need for an information campaign on the advantages of the technology in 1976 which failed and triggered further protests. This downwards spiral of rejection was also supported by the organizational skills of the anti-nuclear movement, extending the local protest to a national level in 1977. Finally, in 1978, the national parliament, that was led by SPÖ initiated a referendum to decide on the fate of the NPP Zwentendorf (e.g. Bayer 2014).

Apparently, the explanation that nuclear power plants were deployed in Switzerland but not in Austria due to better organizational skills of the opposition, seems to be too obvious to be true. In this regard, Bayer (2014) suggests a more profound analysis by deploying the political opportunity structure approach as well as the political process theory (Della Porta and Diani 2010). According to these, opportunity for policy formulation is given depending on the (1) closeness/openness of a system, (2) the (in)stability of the electoral behavior and (3) conflicts within the political elite (Bayer 2014). This approach resembles those discussed in the chapter on the influenceability of governments and reflects that an energy transition – or decisions that influence an energy system's long-term path – can be an outcome or a symptom of a political transformation too:

Bayer (2014) assumes that between the 1960s and 1970s, Austria's political system experienced a shift from a consensual to a competitive democracy, whereby the inner party disputes within the grand coalition between ÖVP and SPÖ, who have governed conjointly since WW II, led to first one-party governments in 1966. The increasing conflict within the Austrian political elite was mirrored in the NPP-project as well: As the parties drifted apart, the need to position themselves for or against the commissioning of the already built plant in Zwentendorf in line with their electorates' attitude emerged (Müller 2017). In this regard, the conservative ÖVP held majorities in federal states with dominating electricity companies who had economic interests in pursuing the NPP-project and put pressure on the party to further support it. Thus, the governing SPÖ, which originally supported the project, had to unite its electorate behind the abandonment of the project, which was considered very risky, as for example the labor union was in favor of the nuclear program (Bayer 2014). Due to the conflicting interests of different voter groups within one party, in order to surrender responsibility, the SPÖ-government decided on a referendum, which was held in November 1978 (ibid.).

All in all, the electorate decided on the abandonment of the project by a very small margin, whereby 49.5% voted in favor of and 50.5% against the commissioning with a voter turnout of 64.1%. With regard to the result, an East-West-divide could be identified, whereby the Western regions like Vorarlberg, Tirol and Salzburg voted against. On the one hand, the result reflects that anti-nuclear protests were more intense and therefore better organized in those regions due to the closeness to the Swiss NPP-project in Rüthi or the Geman NPP in Wyhl. It was shown that the greater the physical distance of the electoral districts to a nuclear power plant was, the more voters were in favor of the project. This could be also observed in Switzerland, where protests rather formed in the vicinity of NPP projects to be built or under construction in neighboring countries (Kriesi 2017). However, on the other hand, Bayer (2014) emphasized the lack of economic interest in Western Austria, as it was rather the Eastern part, which, as an industrialized area, expected prosperity through the additional electricity generating capacity. Apparently, in this respect, the physical proximity of the NPP was considered beneficial, particularly in the light of its job creation potential. This was the reason why the use of nuclear power was supported by the labor union – that traditionally belonged to the voter's camp of the socialist party SPÖ – thereby imposing even more pressure on the governing party to initiate the referendum (ibid.).

Bayer (2014) concludes that it was the fragility and induced change of the political system that made it permeable to the idea to reject the commissioning NPP Zwentendorf. Due to the fact that the governing parties' strategies had changed as a consequence of the conflict within the political elites, the NPP-project was deemed as convenient – as a project of national interest – to let different interests play off against each other. Furthermore, it reflected the emergence of social movements in general that had to find an outlet (Gottweis 1997). Gottweis (1997) called the NPP Zwentendorf a 'field of experimentation of grass-roots democracy'. These assumptions are crucial in understanding the reasons why a government would allow an economically detrimental decision of that kind – in the end, the costs of the constructing and decommissioning of the completed NPP Zwentendorf, that was never put into operation, amounted up to 1 billion Euro[13] (Müller 2017). However, it also shows that analyzing energy transitions in the framework of the economic perspective would be insufficient to explain this development. And so would the approaches discussed in the framework of the socio-technical perspective. As described above, a socio-technical framework was provided

[13] https://www.nuclear-power-plant.net/index.php?lang=de&item=history

to let nuclear technology strive in Austria: First, a scientific-governmental cooperation was created. Second, the technology could develop in a protected niche, fostered by R&D expenditure. Third, the plant was constructed which was welcomed in the region to secure jobs, also with regard to the forecasts on the supply-demand gap.

Campbell (1991) concludes that the described developments can be called nothing else than a paradigm shift in Austria's political system that has been translated into the energy sector. Furthermore, a shift in values took place at that time with the younger generation having developed a post-materialist attitude and a consciousness toward the environment as well as the tendency of issue-voting rather than party-voting (ibid.) Albeit the general framing of the anti-nuclear movement in Austria claims that after the decision, Austria became the beacon for anti-nuclear policy, the commissioning of NPP Zwentendorf was debated on the highest political levels at least until the nuclear accident in Chernobyl 1986 (Campbell 1991).

3.4.4. Interim conclusion I – The role of the nuclear program for future electricity transitions

Establishing a nuclear program became a crucial topic for energy governance after WW II in many Western European countries. Thereby, the technological spillover from the U.S. was fostered in the light of the general Western integration. Both Austria and Switzerland made provisions to establish a receptive environment for the new technology by providing for its socio-technical embeddedness, having recognized the urgency for new electricity generation capacity as it became evident that the demand could not be covered for by hydropower only.

However, the time factor played a greater role in Switzerland due to the vehement refusal of thermal power plants on local level. This reflected the power of political lever of the traditional direct-democratic decision-making structure in the country, which made the question of alternative generation opportunities more urgent. On the other hand, in Austria, further hydropower potential could be exploited in the 1970s. Furthermore, commissioning fossil power plants did not evoke any protests, not even in the light of 'the change in values' away from growth-promoting to an environmentally conscious society, that is often associated with the anti-nuclear protests that arose at that time. Between 1970 and 1986 alone, a fossil-thermal electricity generation capacity of more than 2 GW has been installed[14].

[14] E.g. Linz-Mitte (1970, 217 MWel, gas and oil); Theiß (1974; 775 MWel, gas and oil); Voitsberg (1983; 330 MWel, coal); Dürnrohr (1986; 405 MWel, coal)

Furthermore, the analysis has shown that the construction of the plant in Zwentendorf (AT) and the first three plants in CH between 1969 and 1972 was realized without notable protests. Concerning the former, the use of nuclear power was seen as a necessity: “The construction of nuclear power plants will become necessary in the light of supply security: The uranium deposits are scattered regionally, the storage of nuclear fuel requires only a small storage space and is relatively cheap” (Wirtschaftsforschungsinstitut 1975). However, the weakening of the political elite that has governed for more than two decades made the system more permeable to let vested interests play off against each other, whereby the political transition lead to a shift in power relationships.

In Switzerland, the early protests were clearly not against the technology itself, which was reflected in the fact that until 1986, only one project – Kaiseraugst – was brought to a halt. Thus, the societal processes around this project violated core values of Swiss societal structures which motivated the local governments and advocacy groups to provide a platform for political discourse around the hazards of nuclear energy that was instrumentalized as lever after having been ignored by project planners. The problem of contradictory scientific debate on nuclear power added up to the uncertainty in siting regions, which can be explained with the simple fact that constructing a nuclear power plant comes with high information asymmetries, alone due to its complex nature.

Nuclear power was and has remained a highly contested and politicized topic for decades, both in Austria and Switzerland. The outcome of the referendum in Austria not to commission NPP Zwentendorf was decided by a margin of 30,000 votes only; discussions on the possibility of a nuclear program went on at least until the accident in Chernobyl in 1986. In Switzerland, although a nuclear program was pursued, eight referenda were held on the question of nuclear energy until 2015 (Kriesi 2017). The historical comparison of the societal processes in the examined countries shows that the decision for or against a nuclear power program depended on the complex interplay of political constellations and advocacy coalitions, respective vested interests and the permeability of this system at a given time. On the one hand, this insight serves as an approach to resolve the contradictions around the early Swiss nuclear power history. On the other hand, it makes the cases of Kaiseraugst and Zwentendorf comparable; two projects of high technological complexity and national interest that failed due to conflicting powers that enabled the permeability of the system and thereby a platform for protests. With regard to the analysis, certain questions remain: Would it have made a difference, if the first Swiss NPP had been the project in Kaiseraugst in the early

1970s? Did the smooth construction of the first plant in Beznau initiate a path dependency that enabled the construction of additional four reactors? Would the situation be different in Austria today if Zwentendorf had been built similarly to Beznau, in the late 1960s?

3.4.5. Austria – quo vadis?

Although as a consequence of the referendum, a Law on Banning the Use of Nuclear Power ('Atomsperrgesetz') in 1978 was adopted, the Austrian history of nuclear power was not over yet (Bayer 2014). In the autumn of 1980, a comparatively successful pro-nuclear referendum was launched under the leadership of the unions, which, however, failed. The last efforts to enforce commissioning of the Zwentendorf nuclear power plant marked the failed attempt by the SPÖ under Chancellor Fred Sinowatz in March 1985 to initiate a renewed referendum (ibid; Pelinka 1993). In this regard, the parties strived for consensus, as most of the representatives could not think of alternatives to satisfy the increasing electricity demand.

3.4.5.1. Searching for alternatives

Interestingly, the public opinion in the period of 1978-1986 developed significantly in favor of commissioning of NPP Zwentendorf, as it has been proven that countries deploying nuclear power were economically more competitive and had no issues with regards to safety. Furthermore, the anti-nuclear protests faded (Bayer 2014). However, the attempt to initiate a referendum fell victim to inter-party quarrels, mostly in order to please certain electorate groups (Schefbeck 2006; Bayer 2014). Therefore, the consequences of the political shift were still perceptible. The fact that all the parties represented in the National Council unanimously took a conflict issue off the agenda a few months before a National Council election definitely suggests that none of the political groups involved expected to benefit from the possibly negative outcome of the referendum (ibid.). In the light of the nuclear catastrophe in Chernobyl (1986), non-commissioning of NPP Zwentendorf could be booked as great 'Austrian political success', whereby the future of the project was finally sealed (Bayer 2014).

Initially, waiving of the nuclear power plant project did not constitute a problem with regard to the security of supply due to sufficient generation with hydropower and thermal power plants. However, due to the new situation, the dependence on oil imports could not be reduced as initially planned by the Federal government. In this regard, the initial longer-term electricity production forecast indicated that 4,200 GWh/p.a. of electric power would be generated from nuclear power plants between 1985 and 1990. If it were to be necessary to reduce the dependency on oil, it would have required the commissioning of a second nuclear power plant to generate a total of 12,000 GWh/p.a. of nuclear power until 1990. In this regard, the prevailing opinion was that oil extraction would reach its maximum between 1985 and 1995 which would make the switch to alternative resources indispensable (Wirtschaftsforschungsinstitut 1978). However, in order to secure electricity supply only, demand could be met by building several thermal power plants and increasing hydropower capacity during the above discussed period. Concerning the former, a shift from oil and coal as fuel source should be complemented and gradually replaced by gas due to its comparably small environmental impact. *Fig. 12* below shows the installed and planned capacities that would compensate for the missing NPP (Wirtschaftsforschungsinstitut 1978).

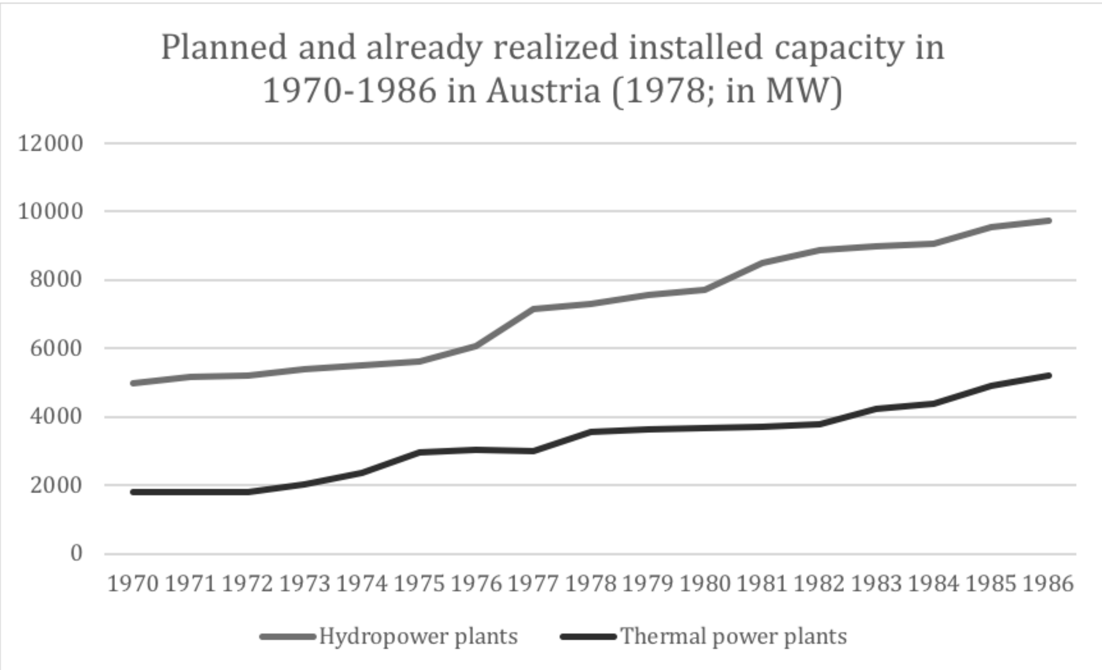


Fig. 12: Planned and already realized installed capacity within Austria’s power plant portfolio. The figures up to year 1978 indicate the capacity already installed. Figures between 1979-1986 reflect the planned capacity. Own representation of the figures in Wirtschaftsinstitut (1978).

However, the development of demand was difficult to estimate (ibid.). Interestingly, it was the first time – namely after the referendum – that economists suggested the exploration of the potential of alternatives like geothermal, wind or solar energy, whereby “certain minimum requirements of economic viability accepted by the general public” were considered crucial (Wirtschaftsinstitut1978). In general, one of the most important tasks of a longer-term energy policy without nuclear energy was to minimize the feared burden of higher electricity generation costs, increasing energy imports and energy dependence (ibid.).

3.4.5.2. Energy research and international cooperation in Austria

In the light of these projections and suggestions, the government started to increase spending in energy research to explore the country's opportunities not only for alternative resources, but also energy saving potentials. The founding stone for energy research in Austria was laid in 1974, when the country became a founding member of the International Energy Agency (IEA), which was established in order to secure the OECD-countries' energy security after having experienced the vulnerability of their energy systems in the course of the 'oil crisis'. Having been institutionalized in the beginning of the 1980s, research was carried out in the framework of the 'Austrian Energy Research Concept 80'. Thereby, the government obliged electricity companies to establish a research pool with the focus on energy savings and alternative energy systems (Österreichische Bundesregierung 1990).

The National Energy Report 1990 points to a possible substitution of fossil energy carriers through renewable energy sources to a certain extent which was even quantified – something that would not been thought possible in the early 1970s. In this context, external costs of fossil energy carriers were recognized for the first time (ibid.). The report named a potential for biomass and solar energy only and projected a possible production capacity of 60 PJ[15] until 2000. However, wind power was not mentioned yet, since at that time it was believed that Austria's geographical conditions would not be suitable for its deployment.

In order to reach the set target, the government aimed at strengthening the R&D-sector as well as implementing educational programs to promote alternative technologies. As shown in *fig. 13* the domestic energy research program started in 1977, whereby the focus already lied on exploring the potential of domestic renewable energy sources rather than fossil fuels (BMVIT 2015)[16]. Furthermore, nuclear power was the most intensely researched field, whose importance faded after the nuclear accident in Chernobyl as the government declared that Austria is not going to deploy the technology.

[15] As a reference value, the electricity consumption in 1990 was approx. 176 PJ, in 2000 already 210 PJ.
[16] The R&D spending will be analyzed later in more detail in the chapters on wind and solar power.

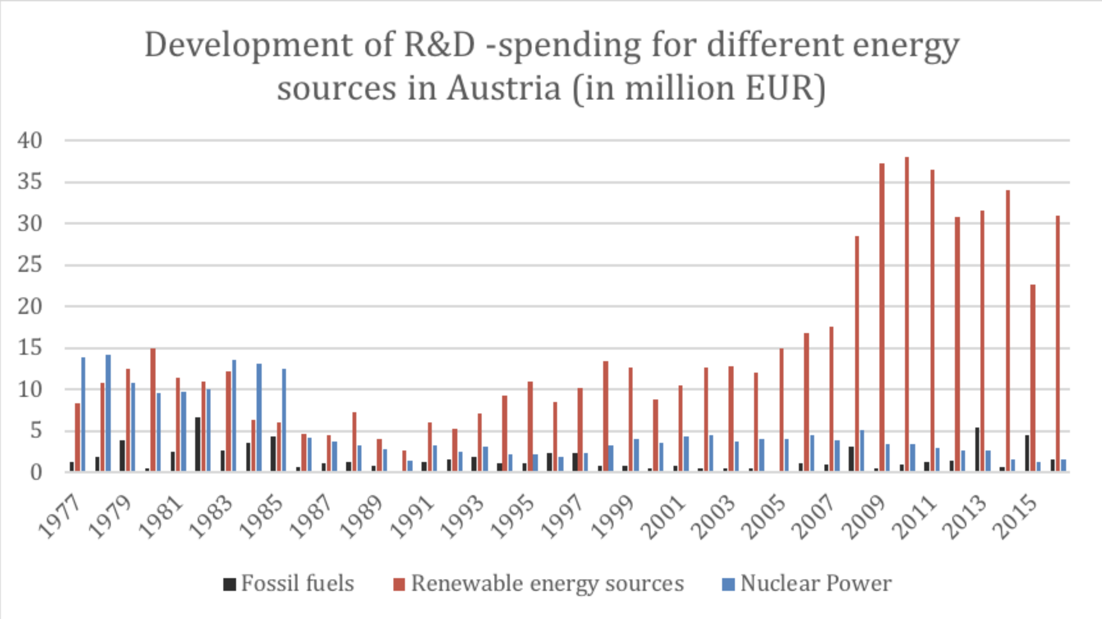


Fig. 13: Development of R&D spending for different energy sources in Austria (in million EUR). Data derived from the IEA's R&D-spending database (IEA Data Services 2018)

Interestingly, the budget for R&D in the energy sector followed the same patterns as the price trends for oil (see *fig. 14*). In this regard, the funds made available were significantly cut in the mid-1980s as the oil price shrunk:

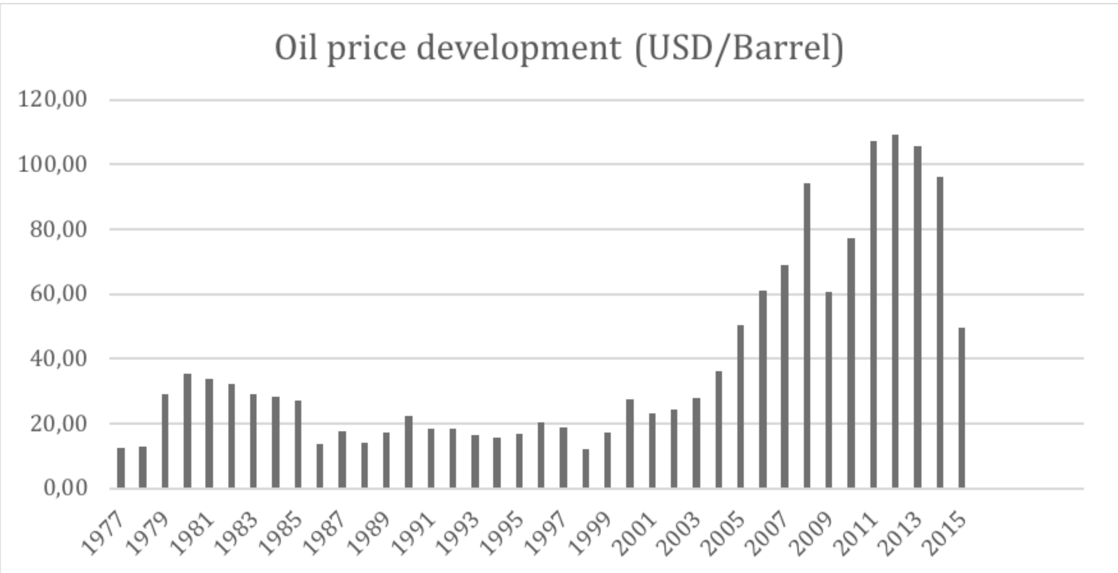


Fig. 14: Average annual OPEC crude oil price from 1977 to 2018 (in U.S. dollars per barrel). Own representation based on data obtained from Statista (2018)

According to Paula et *al* (2009) only with the continuous increase in energy prices and the increasing intensity of the climate change debate has there been a gradual increase in budget funds for energy research in Austria. However, when comparing *fig. 13 and*

14, clear patterns can be detected between the development of the oil price and R&D-spending for renewable energy sources in the long run which reflects the importance of the economic aspect for energy transitions, even if the public discourse is dominated by the climate imperative. Moreover, R&D-spending for energy research is clearly motivated by the strive for energy independence and security of supply which seems to come to the fore when the oil price rises, showing that oil is still considered the 'lead currency' in the energy sector.

3.4.5.3. Austria's embeddedness in the framework of the European Union

A further aspect which might have had an impact on an electricity transition in Austria is the embeddedness in the research and policy structures by the European Union (EU) and the targets set in the area of energy and climate policy. Besides joining the first international research cooperation in the framework of the IEA in 1974, Austria became a member of the EU in 1995, allowing Austrian companies and researchers to fully participate in the EU's Research and Technological Development Framework Programs, which both provided for financial support as well as knowledge transfer among Member States (Paula et *al* 2009). On the other hand, the membership entailed several obligations concerning emission reduction and renewable energy sources.

According to Paula et *al* (2009), Austria's companies and researchers have been able to benefit from the opportunity of being part of the EU's research network, especially in the energy sector[17]. In this regard, however, they mention the importance of abandoning the nuclear program which served as an important stimulus for researching alternatives. Another early driving factor was the obligation to comply with the first target set by the EU with regard to climate goals, namely to stabilize common GHG-emissions by 2000 at the levels of 1990 (Hackl 2001). These developments went hand in hand with the increasing importance of the 'polluter pays' -principle. The new provisions of the European Community Regulation, as amended by the Treaty of Amsterdam, expressly established the Community's competence for environmental protection, confirmed the 'polluter-pays' principle and called for the integration of respective measures in several domains, which should also apply for the electricity sector. Concerning the latter, regulatory intervention was considered justifiable due to the fact that price was guiding

[17] Austria is considered a pioneer in the area of solar heating systems (Paula et *al* 2009), which, however, is not in the focus of this study.

consumers' and producers' decisions in a liberalized market without the internalization of external effects on the environment (Holzinger 2001).

A tightening of the emission reduction targets was reached after the ratification of the Kyoto-Protocol which came into effect in 2002. While the EU adopted a reduction target of 8% for the Community as a whole until 2012, individual country targets were set. For Austria, this meant an obligatory emission reduction of 13% compared to 1990-levels (ibid.)[18]. Within the framework of the EU's Climate and Energy Package, Austria has to reach a GHG-reduction target of 16% until 2020 compared to 2005-levels (BMWFI 2009). Interestingly, the Kyoto Protocol even had an influence on drafting climate strategies on the level of federal states[19] (Junker et *al* 2013). Although Austria is currently not on track when it comes to emission reduction goals (Chiari 2017), the situation is different as far as the utilization of renewables is concerned:

Concerning renewable electricity, the principles of EU energy policy were incorporated into the Electricity Management and Organizational Act (ElWOG[20]) in 2000. The ElWOG emphasized the Austrian legislation's compliance with the European Commission's White Paper on Renewable Energy of 1997. In paragraph 32, the increase in electricity production from renewable energy is prescribed to at least 4%[21] by 1 October 2007 (Hackl 2001).

In 2008, the EU-wide obligatory target for a 20%[22] share of renewables – to be reached by 2020 – was set including the electricity, heating & cooling and mobility sectors. Thereby, Austria's individual target was set at 34% (BMWFI 2009). The relatively high share assigned can be explained by the fact that initial values were taken into consideration when calculating the individual targets. In 2005, Austria already showed a share of 23% of renewables in gross final energy use, coming forth after Sweden, Finland and Latvia in European comparison (ibid.). However, the related European Commission's Directive on Renewable Energy (2009/28/EC)[23] does not prescribe obligatory, but rather indicative sectoral targets, which means that member states can introduce targets, inter alia for the electricity sector, but are not obliged to do so. Therefore, when analyzing the development of wind and solar power deployment, it

[18] While the industrialized countries as a whole and the EU have fulfilled their goals, in some cases even exceeded them, Austria has missed its target by far. At the end of the Kyoto period, Austrian emissions even exceeded the level of 1990. The "missing" emission reductions had to be compensated for by the purchase of emission rights amounting to more than 400 million Euros (Chiari 2017).
[19] E.g. the Lower Austrian Climate Program 2004-2008
[20] Elektrizitätswirtschafts- und Organisationsgesetz
[21] Excl. hydropower
[22] In gross final energy consumption
[23] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028

should be shown whether there are special targets formulated within the legislation for the electricity sector, as it would highlight a certain commitment of the national government, not only for the development of renewable capacities in the energy sector as a whole, but in the electricity sector in particular. In this regard, it should be analyzed to which extent the embeddedness into the framework of the EU contributed to the development of the electricity transition in Austria.

3.4.6. Electricity use in Switzerland – a history of lock-in?

As it was mentioned earlier, the last NPP built in Switzerland was the one in Leibstadt in 1984, whereby several planned projects were cancelled. In this chapter, answers should be found for the reason why the history of the Swiss nuclear program ends at this point. As shown in *fig. 15* below, the five operational reactors with a total capacity of approx. 3.2 GWel could theoretically compensate for the supply gap – namely the demand that could not be satisfied by hydropower use – until 2003.

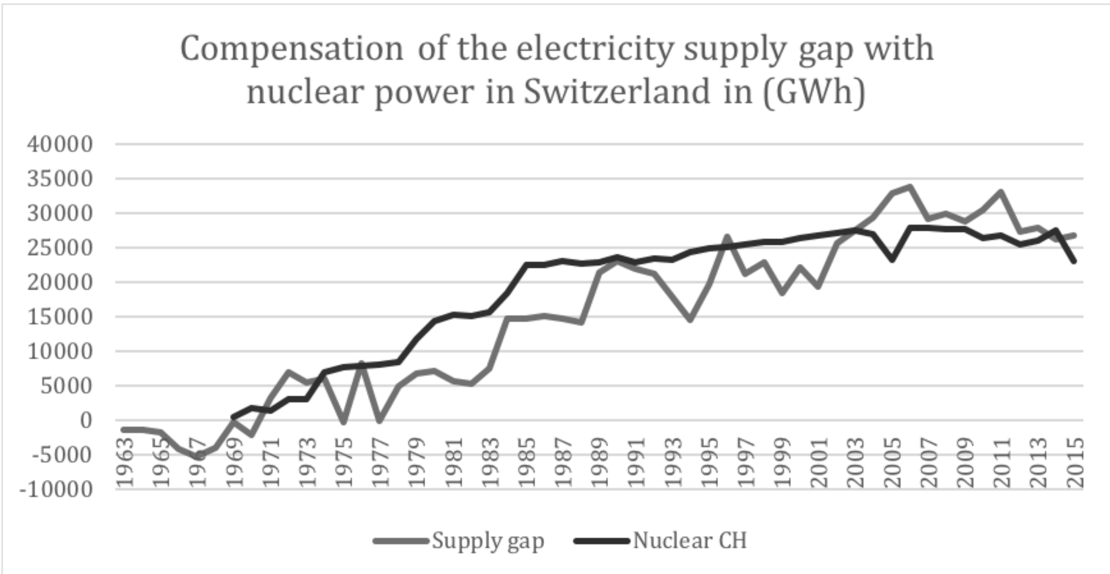


Fig. 15: Compensation of electricity supply gap with nuclear power. Supply gap thereby relates to the difference between electricity demand and its compensation with hydropower. Own representation of data obtained from the IEA Data Services (2018).

First, the early developments in the 1980s should be analyzed. Second, it will be reflected on whether the use of nuclear power evoked a certain lock-in effect, thereby allegedly negatively influencing the country's aspirations to invest into research for alternative energy sources or the expansion of its research network. In this regard, it should be analyzed whether the missing EU-membership for developing renewable electricity capacities constituted a decisive factor.

3.4.6.1. The use of nuclear power

As indicated in the literature review section, a technological lock-in can be fostered by different factors, inter alia by vested interests of incumbents – particular interest groups and policy-makers –, but also by established professional networks and institutional frameworks which, due to their nature, are prone to support a certain status quo. In the case of Switzerland, it was shown that the development of nuclear power greatly depended on the cantonal power constellations and their ties to electricity companies and the electorate. The political leverage that can be imposed by the latter through exceptional direct democratic instruments is a great influential factor, that would explain a greater success of anti-nuclear movements than in representative democracies. These contradictory forces are reflected in the history of nuclear power use in Switzerland, which has proven to follow a certain pattern since the mid-1970s. Although the federal government was theoretically in charge for the country's policy on nuclear energy, decision-making procedures often ended in a trial of strength between the cantonal and the federal governments, whereby many decisions were put on hold, bringing energy policy to an impasse (Kriesi 2017). Striving for a consensus led to the delay of authorization and construction procedures, like in the case of the NPP-projects in Graben or Verbois and finally Kaiseraugst in 1989[24], which entailed considerable economic losses for project planners and a lack of clear signals for future development (Kriesi 2017). However, the difference in the 1980s – compared to the situation in the late 1960s – was that the five reactors in operation compensated the supply gap by far, which allegedly left some leeway for the extension of debates on the future of the electricity sector. *Fig. 16* below shows the constellation of actors in the Swiss energy policy-making, reflecting the reasons why a clear line on nuclear energy or energy policy in form of a strategy could not be formulated for decades:

[24] Although – as already described – the project was brought to a halt in 1975 but not completely discarded

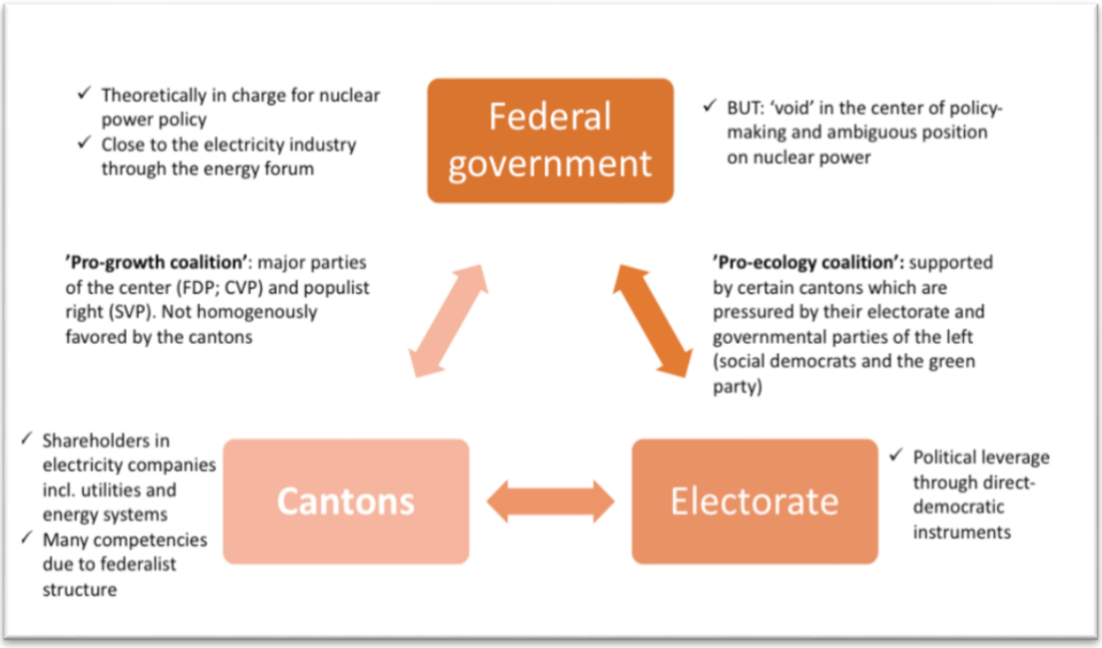


Fig.16: Complex constellation of interests influencing the nuclear debate in Switzerland. Own representation based on Kriesi (2017).

Kriesi (2017) uses the expression 'void in the center of policy-making' which mirrors the reasons for that in the most convenient way. As discussed in the literature review, according to Hall (1993), states' approach to policy-making can be categorized by different concepts, namely the state-centric and state structural. Clearly, Switzerland belongs to the second category, which, however, did rather contribute to the paralysis of the system than to its dynamism. Particularly, in the Swiss case, this was enhanced by the lack of urgency to find a solution to satisfy future electricity demand paired with the increasing pressure by the electorate as well as a missing comprehensive energy strategy on the national level.

This state of inertia was slowly loosening only after the constitutional amendment in 1990 that clarified the role of the government in crucial energy issues. The federal government has realized that the question of governance is a significant one if security of supply should be ensured in the upcoming decades. This was finally recognized after a ten-year-moratorium on the construction of new nuclear power plants was passed in 1990 due to a referendum showing that opportunities to extend the nuclear power plant park were diminishing (Kriesi 2017).

However, a federal energy strategy has not existed until 1990 to elaborate binding and quantified measures to reach the goal of long-term security of supply, a target that has been formulated within the 'integrated energy concept' published in 1978 by the

Commission for a Holistic Energy Concept (GEK)[25]. The first binding strategy 'Energie 2000' was passed along with the mentioned moratorium and should compensate for the lack of agreement on the priorities of federal energy policy. Furthermore, it provided for tangible instruments to establish a multi-level-governance system (Bundesrat 2000).

The historical analysis has shown that the collision of different political powers impeded efficient political decision-making on the federal level. In sum, reasons why a final clarification of the nuclear question failed to materialize until 2011 can be suggested as follows (Kupper 2003; Kriesi 2017 and own assumptions):

(1) Void' in the center of policy making that could not manage conflicting interests of three key players (federal government, cantons and electorate) enabling a certain influence of landscape factors on decision-making (accidents in Chernobyl 1986 and Fukushima in 2011).

(2) Deteriorating investment climate and increasing investment costs. For example deposition of nuclear waste could not be solved, whereas electricity imports from France suddenly appeared to be more attractive (Kriesi 2017).

(3) Lack of urgency to deal with the projected increase of electricity demand (security of supply did not play a crucial role).

(4) Underdeveloped domestic nuclear energy industry due to high competition and a failed attempt to develop an own reactor 'Made in Switzerland' (Kupper 2003).

Therefore, the case of Switzerland is rather one of a 'political lock-in' than a technological lock-in. Due to the fact that the public and political debate was dominated by the question on the future of nuclear power, the actual use of alternatives was widely ignored (Bundesrat 2000). Thereby, the question arises whether the dominance of the nuclear debate and the lack of hierarchy in the political structure as well as the absence of clear policy goals had an influence on energy research and therefore the development of a socio-technical framework for innovations in the field of alternatives. In order to enable comparison with the Austrian case, the evolvement of energy research will be outlined and the potential of technological and policy spill-over will be analyzed.

[25] Eidgenössische Kommission für die Gesamtenergiekonzeption

3.4.6.2. Energy research and international cooperation in Switzerland

Although public opinion on nuclear power improved somewhat from the year 2000 onwards, which was after the termination of the moratorium, the political constellations remained, leaving little room for the further expansion of nuclear power. According to Mayencourt (2003) for the first time ever, renewable energy has really been seriously researched and considered as a potential replacement. However, *fig. 15* shows a somewhat different picture when it comes to the question of research in the field of renewable energy sources, which dates back to the mid-1970s, similar to Austria.

Albeit similar patterns between the oil price development and the spending for R&D in the renewable energy sector are recognizable, it is also noteworthy that the overall amount between 1977 and 2015 was more than twice as high on average than in Austria[26]. In the case of nuclear power, the figures reflect the high hopes of the government and the industry until the 1990s concerning the technology's future, which slowly, but gradually faded during the 10-year-moratorium phase. Interestingly, the graph also shows the shift towards intensified research on renewable energy sources, which grew significantly in the 1990s and consequently surpassed the amount for nuclear power after 2011. This year simultaneously constitutes a landmark in Swiss energy policy: After years of the above described 'trial of strength', the Federal Council and the Parliament finally decided on the phasing out of nuclear energy in Switzerland.

[26] The average value for R&D-spending in the RES-sector between 1977 and 2015 was 15 million EUR/p.a. in Austria and 36 million EUR/p.a. in Switzerland (IEA Data Services 2018)

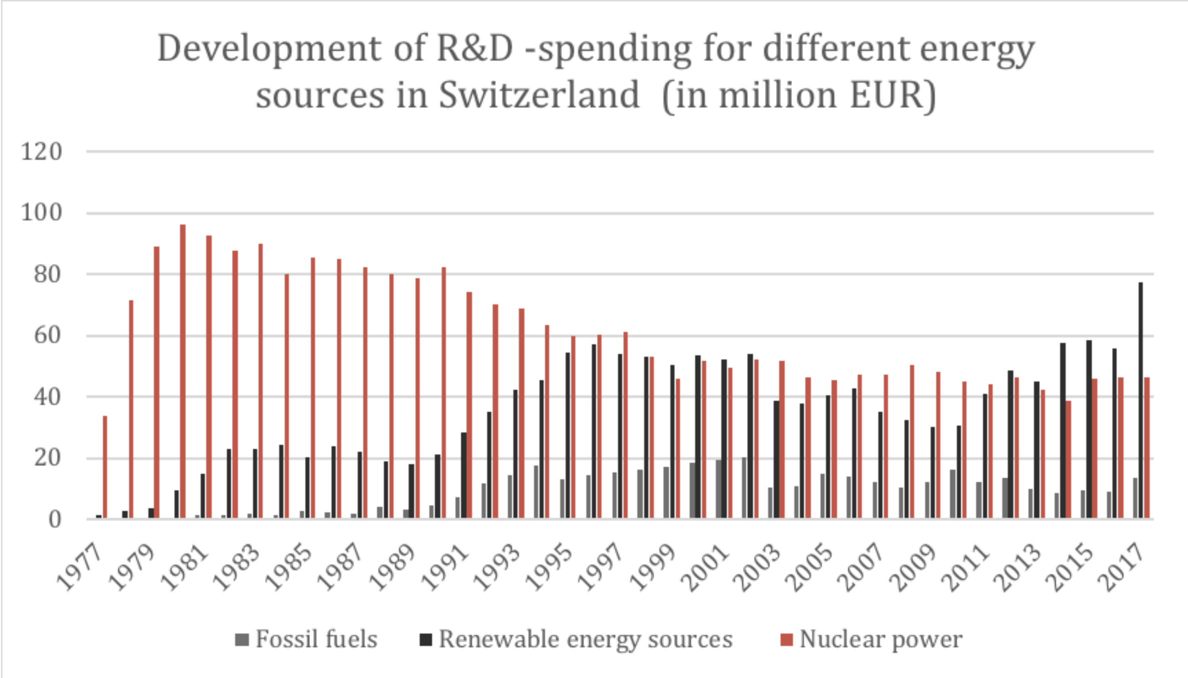


Fig. 16: Development of R&D spending for fossil fuels and renewable energy sources in Switzerland (in million EUR). Data derived from the IEA's R&D-spending database (IEA Data Services 2018)

The high spending in the R&D sector shows in general that research in the field of energy was considered important in different areas, not only the nuclear energy sector, which was also reflected in the institutionalization of research in the mid-1970s. First, Switzerland was a founding member of the IEA like Austria inspired by the oil crisis in 1974. Thereby the shortage of oil supply by the OPEC created an incentive for highly import dependent to rethink their energy resource management (Hug 2001). Thus, the conclusion that resources were finite also brought a paradigm shift in Switzerland concerning the way energy was viewed. In the framework of the IEA, Switzerland participates in several research projects, inter alia on wind and solar energy systems[27]. Domestic research was institutionalized in the early 1980s, whereby first multi-year plans for energy research were issued by the Foundation of the Federal Commission for Energy Research (CORE), among others in order to "research sophisticated energy technologies that are still subject to a high risk of success and that can only reach market maturity in the medium and long term" (BFE 1984).

[27] IEA Technology Cooperation Programs

3.4.6.3. Regional cooperation and embeddedness into the structures of the EU

Concerning regional cooperation, namely between Switzerland and the EU[28], the field of activity was dominated by the cooperation in the framework of the EURATOM-treaty until the late 1990s (Schiber 1999). However, cooperation in other areas of the energy domain became increasingly important for Switzerland due to its geographical proximity to the EU. In 1999, the first bilateral research cooperation treaty, including the energy sector, was signed, whereby the cooperation was significantly intensified. Since 2017, Switzerland is a fully associated member of 'Horizon 2020', the research framework program of the EU (EDA 2017).

In general, the country's embeddedness into the EU's infrastructural system is especially striking when it comes to the electricity sector. Switzerland has been connected to the French and German networks since 1958, whereby it has played an important role as a power hub for international trade (UVEK 2017). This interconnectedness was considered beneficial for Switzerland due to the fact that it could export its electricity to neighboring (EU) countries. However, since 2004, the country is increasingly dependent on imports whereby the functioning of the EU's electricity network became increasingly important. Being exposed to the EU's electricity markets leaves Switzerland with new problems with regards to energy security (Kiener 2018).

The short reflection on the energy research domain shows that the initial focus on nuclear power did not impede the research in other sectors, which contributes to the hypothesis that it was not the technological lock-in that has restricted the use of renewables like wind or PV in the past decades, but rather due to the general underlying problem of inefficiency of enforcement like in the case of nuclear power. In this regard, the IEA's country report on Switzerland (2012) concludes that "barriers to the use of renewable energy sources are often non-technical".

[28] On 6 December 1992, the Swiss voters rejected accession to the European Economic Area (EEA), which would have brought economic integration into the European market even without membership of the EU political system. While the other members of the European Free Trade Association (EFTA) - Austria, Finland, Iceland, Norway, Sweden and Liechtenstein - decided to join, Switzerland wanted to stay outside. (Geschichte Luzern n.d.)

3.4.7. Interim conclusion II: Preparing for the integration of renewable energy

Although unlike in Austria, no shift in the political system of Switzerland took place that would have had an influence on the nuclear policy, there are still similarities that led to the halt of capacity expansion. Both governments' energy policy is significantly influenceable through the social system, which, in Austria's nuclear policy case, was rather a momentum, whereas in Switzerland, the high permeability constitutes a permanent state. In both cases, it was shown that permeability and a decentralized decision-making structure might not only lead to the long-term integration of new technologies, but also to their rejection. Thereby they fail to succeed among others due to a deteriorating investment environment, but also the lack of a developed industry due to the missing stability.

Concerning R&D-spending, the focus on different technologies was given since the start of the energy research programs in the 1970s, whereby landscape factors certainly played a role, but it also shows the countries' general openness to the integration of innovative technologies. Surprisingly, it was found that Switzerland spent an amount twice as high on renewable energy research as Austria in the past decades although having less concerns about resource availability. Moreover, Switzerland participates in international research networks and is a close research partner of the EU. Furthermore, the importance of portfolio diversification was emphasized in strategic documents since the 1980s, even though CH was an electricity exporting country until 2004.

In the upcoming chapters, the development of renewable energy sources, using the example of the wind energy sector, will be reflected against the background of the previous findings of the study with the support of the 'tool-box' for analysis developed in the literature review section.

3.4.8. Comparison of wind power deployment

As *fig. 17* shows, the evolution of wind power deployment could hardly differ more between Austria and Switzerland. After the first plant was built in 1994, Austria today counts 1,277 wind turbines with a capacity of 2,899 MW (IG Windkraft 2018)[29]. The development was mainly facilitated by the provision of adequate legal stipulations

[29] Figures based on the 'windmill-counter' provided by the Austrian wind power interest group IG Windkraft. https://www.igwindkraft.at/

since 2002. However, as the *fig. 16* shows, this development cannot be considered linear, mostly owed to the altering conditions within the support scheme (Schreuer 2012), which will be illustrated in the upcoming chapter.

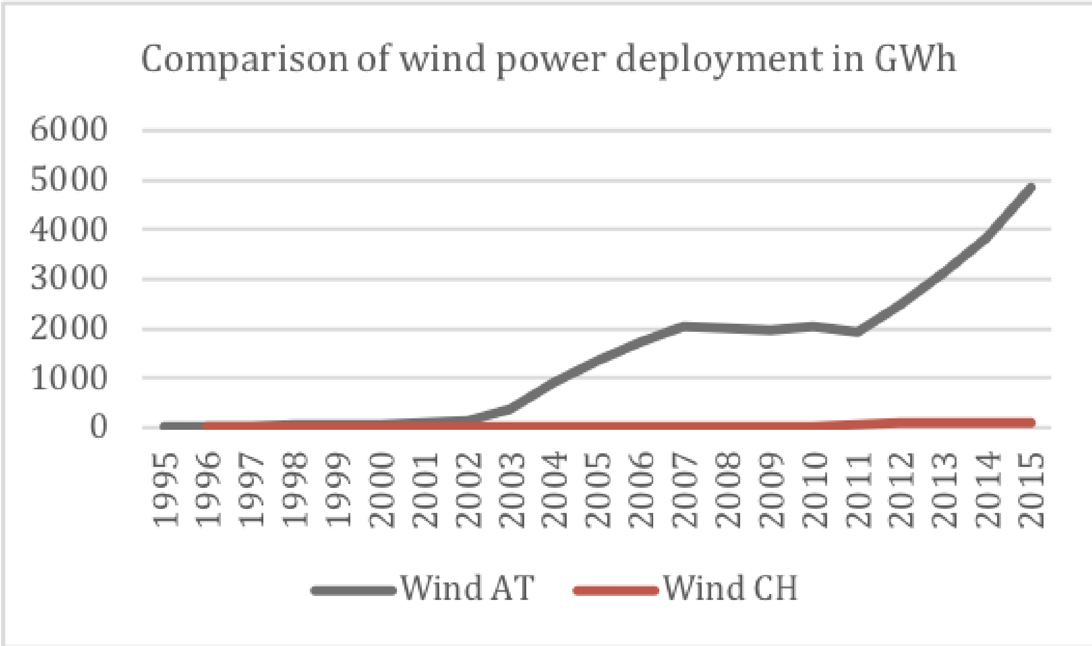


Fig. 17: Development of electricity generation with wind power in GWh in Austria (AT) and Switzerland (CH). Data obtained from the IEA Data Services 2018.

In general, renewable energy sources[30] play an increasing role in Austria and now account for approx. 15% of the total electricity supply. The graph below demonstrates that the recent growth is mainly due to the deployment of wind power. Then again, the role of biomass and PV should not be neglected either, especially with regard to the fact that the installed capacity of the latter grew from 3 MW in 2,000 to 1,077 MW in 2016 (Biermayr et *al* 2017).

[30] Besides hydropower

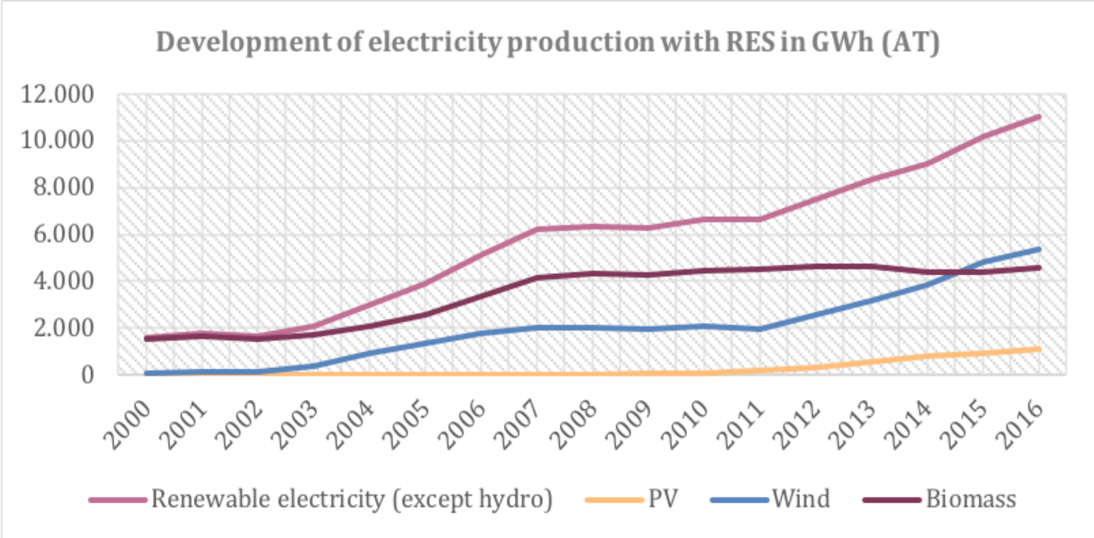


Fig. 18: Development of renewable electricity generation in GWh in Austria (AT). Data obtained from the IEA Data Services 2018

In Switzerland, the share of wind power in the total electricity supply was less than 0.2% (VSE 2018b). As demonstrated in the precedent chapters, the supply gap between hydropower production and demand could be mostly compensated by Switzerland's five nuclear reactors for over three decades[31], indicating that the need of resource diversification in the electricity sector was relatively low. However, since Switzerland announced its withdrawal from nuclear power in 2011, 40% of its electricity production will have to be replaced as a consequence of the decommissioning of the NPPs until 2034 (Jegen 2015).

Simultaneously, the tendency is towards turning from a net-exporting to a net-importing country in the medium run due to the expected increase in electricity use and if the expansion of wind and photovoltaic generating capacities is not pushed forward (Morf 2017). In this regard, as it is, security of supply is only guaranteed if Switzerland's integration into the European electricity market succeeds. However, the electricity agreement with the EU, which could regulate market access and integration, has been blocked since 2007 due to the fact that Switzerland would have to fulfil the framework agreement of the EU, which contains two key demands: a complete market opening for small customers and the unbundling of electricity trading and network operation (Stalder 2017a; Heim 2018).

[31] And marginal use of gas and oil, whereby this type of electricity is produced by Switzerland's single thermal power plant.

Concerning both renewable capacity expansion and market opening towards the EU, Switzerland has remained in a state of inertia due to conflicting interests. Especially electricity suppliers (which are partially owned by the cantons) are against the market opening whereby they would have to lower their prices if competition prevailed (Heim 2018). Simultaneously, the integration of the European market is progressing rapidly, whereby Switzerland is excluded from planning procedures but still influenced due to the interconnectedness of infrastructures. Since 2015, unplanned load flows from neighboring countries have reached levels that, according to Swissgrid[32], endanger national security of supply (Der Standard 2018).

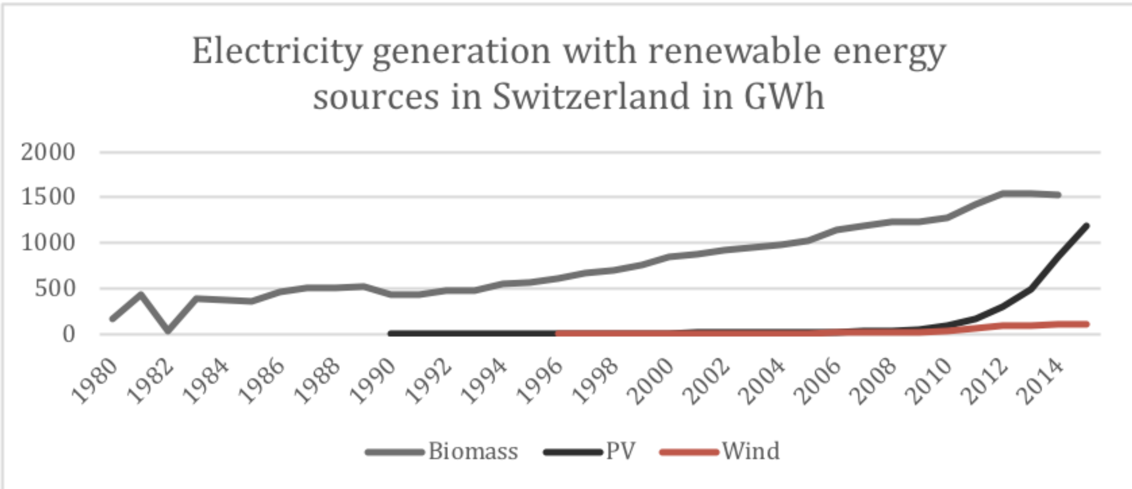


Fig.19: Evolvement of electricity generation with renewable sources in Switzerland. Own representation based on figures obtained from the IEA Data Services (2018).

The short review of the current situation has shown that urgent action was needed in order to secure electricity supplies. In this regard, the question is why the expansion of renewables is not progressing accordingly, which will be illustrated on the development of the wind energy sector. First, the evolvement of the wind energy sector in Austria will be analyzed. Second, the same will be done for Switzerland in order to be able to draw conclusions on the different results in the past decades.

[32] Swiss transmission system operator

3.4.8.1. Early use of wind power in Austria

In Austria, research on deployment opportunities for wind energy started in the 1980s, but rapid success was missing and the stabilization of the energy market and insufficient demand made research efforts less attractive (IG Windkraft 2015). Furthermore, the prevailing view in the country was that wind use was uneconomical due to unfavorable wind conditions. Nevertheless, after visiting Denmark and learning about wind power deployment there, a group of pioneers proved that certain regions are excellently suited for the use of wind energy (ibid.). Especially the (North-) Eastern part of the country proved to bear a specific location potential (Hantsch et *al* 2003).

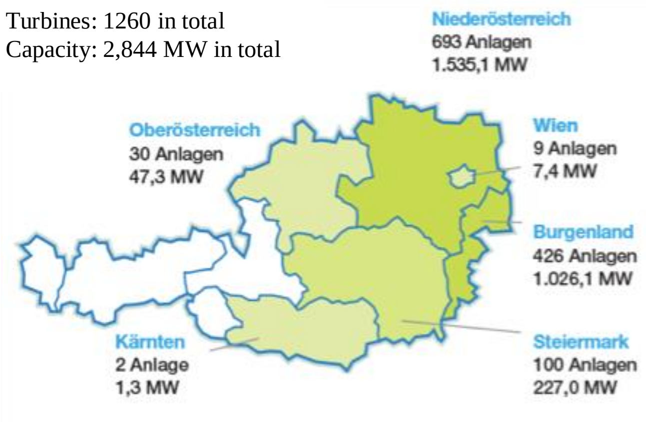


Fig.20: Regional distribution of wind power plants in Austria (IG Windkraft 2018).

Due to the technological spill-over and the fundraising activities of the research group, the first wind turbines could be built in 1994 (IG Windrkaft 2015). Furthermore, attempts were made to involve residents and the regional population financially in projects, which has significantly contributed to the acceptance of wind power projects and overcome the ‘not in my backyard’-problem (ibid.). Involving of the local population added to the political leverage effect on energy issues later on, especially on the state-level (Schreuer 2012). In order to support their dissemination, feed-in tariffs on a regional level were introduced between 1999 and 2001 based on the stipulations of the Electricity Economy and Organizational Act (ElWOG) in 1998 which obliged the federal states to enact individual regulations on support schemes. Thereby, in certain states, the tariffs were so low that no projects could be realized at all (Holzinger 2001). Still, the states had to provide for equalization payments if a given target was not reached (ibid.) However, wind power deployment remained a regional phenomenon until today and the respective industry mainly strived in the regions where the first turbines were built (see *fig. 20*).

Then again, the wind utilization potential had to be constantly reassessed due to the gradual sophistication of the technology (Haas et *al* 2001). Whereas in the beginning of the 1980s, researchers calculated with a turbine capacity of 50 kW at a height of 20m, a capacity of 3-5 MW per plant at a height of 100-150m on average is now considered, which overthrows initial calculations completely and also explains the expansion to central Austria. Furthermore, additional generation potential can be tapped through the repowering of existing plants (Hantsch and Moidl 2007). However, investors generally strived for constructing plants in areas with outstanding wind conditions due to increasing yields especially after the introduction of a nation-wide feed-in tariff (ibid; see below).

Another explanatory factor for regional differences is the fact that the approval process of plants is not standardized on a federal level and therefore depends on the regulation of municipalities or pure judgement of the local authorities in case of loopholes, which can lead to different project costs and delays eventually, especially when it comes to spatial planning (Schreuer 2012). The legal loopholes leave room for polarized discussions on a local level, whereby the prevailing political interests can influence the realization of projects (ibid.). The distribution of regulatory competences between the federal government and the states has remained in this area since the beginning of the expansion of renewable energy sources in Austria. For example, Lower Austria (Niederösterreich) and Burgenland have determined so called eligibility spaces for wind energy plants in 2017 to avoid a conflict of land use in the future[33]. Another regulation in Lower Austria obliged plant manufacturers – as a result of a legal dispute – to develop unique fire protection techniques for their plants, which is not required in other states.[34]

3.4.8.2. Policies supporting and constraining wind power development

As *fig. 17* shows, wind power use started to grow rapidly in 2002 but stagnated until 2011 and finally took off after this period. The reason for the slow development in the first years was the lack of a stable incentive system and regulatory measures to create investment certainty and therefore a protected niche where new technologies could

[33] This might be explained by the fact that the density of wind power plants is already high in these regions, creating potential for land-use conflicts.

[34] Results of the barrier analysis for wind energy expansion in Austria in the framework of the Renewables Networking Platform program carried out by the author of this study on behalf of the European Commission. The results are based on interviews with project developers and analysis of national statutory provisions. Further information can be found under: http://renewables-networking.eu/reporting and http://www.res-legal.eu/search-by-country/austria/

reach market maturity (Holzinger 2001; Haas et *al* 2001). The European Commission also recognized the need for a secure legal environment for the development of renewables and took appropriate action through issuing the already mentioned White Book on renewable energy deployment in 1997.

At this time, the Federal government enacted the environmental subsidy guidelines in order to enable investment subsidies for renewable energy plants[35], both in order to meet the 'Toronto-goals' as well as the future obligations that were planned on an EU-level (Holzinger 2001). The amount of the investment grant depended on the technology used. In the case of wind energy projects, they were awarded in the form of a "Call for Projects", in other words to the best bidders in a competition[36]. Furthermore, as indicated above, feed-in tariffs were introduced by the federal states in the framework of the legislative reform of the ElWOG in 1998. In addition, it required grid operators to draw 3% of the electricity sold from renewable energy sources[37] until 2005 and stipulated that electricity generation from renewable energy sources should be increased to 4% of electricity supplied to end consumers by 2007 (Hantsch et *al* 2001). The amendments were justified both by the fact that the deployment of renewable energy carriers served both the substitution of fossil energy sources in the light of increasing lack of resources as well as for the reduction of the CO2-emissions and the development of new employment possibilities for the peasant population in the rural areas (Holzinger 2001). However, due to the lack of standardized tariffs on a national level, the policies did not bring the investment certainty needed to attract a large amount of investors.

In 2002, the National Council passed the Green Electricity Act (ÖSG[38]) in 2002 that introduced feed-in tariffs that were standardized on a national level based on the German and Danish models (Hantsch et *al* 2003). In general, Schreuer (2012) found that the German law on renewable energy is often cited as a good practice example by representatives of the Austrian renewables industry, as it provides for long-term investment security due to its stability and reliability.

Concerning the ÖSG 2002, it is noteworthy that there was no legal restriction on the available funding. In other words, operators of plants approved as green power plants

[35] For up to 35% of the investment costs
[36] The average subsidy rate was 11.42% of the investment costs.
[37] Excluding hydropower
[38] Ökostromgesetz

had an unrestricted, legal guarantee to purchase all electricity generated at the feed-in tariffs regulated in the act paired with an unrestricted acceptance obligation by electricity suppliers (Riehs 2012). It initiated the first major expansion phase of wind power in Austria. At the end of 2002, a capacity of 140 MW was connected to the grid. From 2003 to 2006, an average of 200 MW were built annually (IG Windkraft 2015). On the one hand, the implementation of a national support scheme was fostered by the EU's Renewable Energy Directive which envisaged a target for increasing the share of renewables in Austria's electricity use from 70% in 1997 to 78.1% in 2010 (Hantsch et *al* 2003, Rihs 2012). On the other hand, although Austria does not have an own wind turbine industry, a myriad of domestic companies became suppliers for the growing European wind energy business. The latter has become a significant economic factor between 1995-2000, whereby wind power capacity has grown by an average of 40% p.a. in Europe, especially through the emerging markets in Denmark, Germany and Spain (ibid.; Haas et *al* 2001). The comparison of the volume of exports of plant components against the imports of complete plants shows that four times as much was exported between 1999 and 2001 as it was imported, which attests that the early introduction of regional support schemes could initiate a successful development of an economic niche, leading to mass production and fast price reductions of 50% due to economies of scale (Hantsch et *al* 2003). Therefore, the increasing employment effects on the domestic market led to the emergence of a niche market within a couple of years and the respective formation of lobbies especially on the states' level.

Another factor that might have contributed to the implementation of a comprehensive support scheme was the fact that Austria became an net-electricity importer in 2001 (see *fig. 21*). According to Waltner (2007) the increase of electricity demand was significantly underestimated for years. In general, electricity imports are not considered popular in Austria due to the fact that it might come from nuclear sources (e.g. SPÖ 2004). As shown in the chapter on nuclear power deployment, after the commissioning of NPP Zwentendorf was finally rejected, politicians strived to establish a myth around this topic by depicting Austria's progressive nature having declined the use of this technology (Bayer 2014).

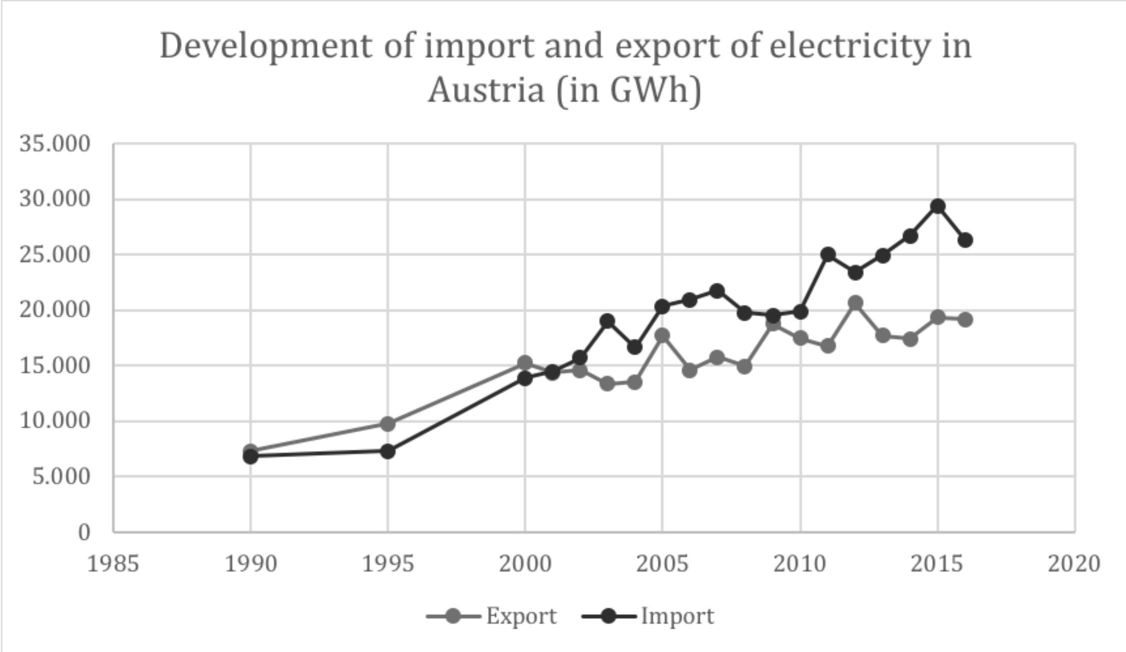


Fig. 21: Development of electricity imports and exports in Austria. Own presentation based on data obtained from E-Control (2017)

The amendment to the Green Electricity Act of 2006 nearly halted the expansion of wind power for four years (IG Windkraft 2015). Thereby, the amount available for new installations was significantly reduced and the obligation for electricity providers to take off renewable electricity ceased[39] (Wallnöfer and Holzer 2007). This radical cut was preceded by a controversy on the financing of renewables between the largest electricity supplier, Verbund AG and several states, whereby the latter vetoed to put additional financial burden on households, in the light of potential resistance by their electorate. As a result, Verbund AG stopped payments to projects that had already been connected to the grid. (Waltner 2007). Furthermore, the company initiated a review of the Green Electricity Act concerning constitutional conformity. This foray was welcomed by the industrial association and the chamber of commerce as well as the governing ÖVP who strived to please these pressure groups. Finally, the unresolved question of financing paired with the pressure imposed by incumbents led to a legislative amendment to the detriment of renewables in general (Moidl 2016). It is noteworthy that large incumbent utilities like Verbund, EVN and BEW AG stood opposed to the development of wind power in Austria in the early years as these projects were based on citizen participation models which – due to their nature – contested the market dominance of large companies. In some cases it went so far that

[39] Except for small hydropower plants.

utilities offered to buy out citizen-owned wind farm initiatives (Schreuer 2012). The initial skepticism only changed in the light of the increasingly efficient technology, when utilities began to see a real business case behind wind energy projects (ibid.).

However, this standstill after 2006 could not be sustained in the light of the introduction of the Renewable Energy Directive in 2009 in the framework of the EU's Climate and Energy Package (Junker et *al* 2013). Furthermore, the change of government supported a new course concerning the support of renewables (Moidl 2016). Certainly, the obligation to draft a National Action Plan on how to reach this goal served as catalyst to rethink the regulatory framework for renewables (Junker et *al* 2013). Another impulse was given due to the infringement procedure initiated by the European Commission against Austria due to the exclusion of energy-intensive industries from contributing to the financing of the feed-in tariff system. The benefit granted to energy-intensive companies (and consequently what had to be borne by the rest of the end-users) was estimated at around 44 million euros p.a. (Rihs 2012).

In mid-2011, a landmark Green Electricity Act was passed which contained measures to manage the long queues of waitlisted projects. In July 2012, this law came into force, setting a target for additional wind power expansion of 2,000 MW between 2010 and 2020[40]. According to Moidl (2016), the debate on electricity supply was reignited in the light of the nuclear catastrophe in Fukushima due to the increasing imports from countries producing electricity from nuclear power and thus, to the renewed awareness for energy topics among the electorate. In this regard, propagating Austria as a nuclear-free country proved to be a popular topic that pleased large parts of the electorate (Rihs 2012). Furthermore, large utilities were more and more involved in wind energy projects as well, thereby constituting an additional pressure group with high influence on the government's policy. This is especially emphasized by the fact that certain states are major shareholders of large electricity companies (Schreuer 2012). This resulted in a wide consensus in the society for supporting renewables and wind power in particular (Rihs 2012). However, the again increasing costs for fossil fuels also played a role for re-opening the debate on the support for renewables (OÖ Nachrichten 2011).

[40] In total: 3,100 MW (Kommunalkredit 2017)

As a result, the support volume for renewables was raised from 21 to 50 million Euro p.a. Due to the fact that the ÖSG 2012 was approved until 2022 by the European Commission, an appropriate stable legal environment was now provided to attract investments.

However, in order to increase the acceptance on an economic level, the legislator has introduced efficiency criteria like tariff digression and annual reassessment of the tariff height in order to promote the marketability of the technology (Rihs 2012). On the basis of the new Green Electricity Act (ÖSG[41] 2012), a second intensive expansion phase of wind power was triggered with considerable success. Between 2012 and 2016, an average of around 310 MW of new capacity was installed each year, attracting investments of 550 million Euros p.a. Besides the chemical industry, the wind power sector thereby became the most prospering branch in Austria (Moidl 2016).

The legislative framework was considered so reliable that the number of new projects surpassed the amount that was annually available for wind power. Another reason for the accumulation of projects was the decreasing price for electricity on the energy exchange market. Due to the fact that the amount of the remuneration was calculated as a difference between the market price and the actual feed-in tariff, which then was deducted from the overall capped budget, a decreasing amount of projects could be supported only (Res Legal 2017). Until the end of 2016, 230 projects could not be realized (Moidl 2016). Although an exceptional financial package was enabled to successively construct the queuing projects with a capacity of 1,060 MW in total, the current framework does not offer a perspective for new ones (IG Windkraft 2017).

3.4.8.3. Use and potential of wind power in Switzerland

In Switzerland, the first wind power plant with a capacity of 28 kW was built in 1986, almost a decade earlier than in Austria (UVEK 2018). This foray – like in other countries – was inspired by the technological breakthrough in Denmark in the beginning of the 1980s. However, thereinafter, the further developments in Europe did not have a spillover effect on Switzerland (BFE 2004). As of today, the overall installed capacity amounts to 75 MW and a production of 123 GWh p.a. only which makes up 0.2% of total electricity supply (VSE 2018b). On the other hand, a myriad of Swiss companies are also participating in the worldwide ‘wind boom’ – primarily

[41] Ökostromgesetz

as a supplier and service provider who are barely active on a domestic level (Brand 2008).

According to the Federal Energy Office, the reasons for the inertia after the attempt to introduce this technological innovation in the 1980s were the lack of incentive schemes and unfavorable topographic conditions, as most of the suitable areas with favorable wind conditions are located in protected landscape areas or in areas with high population density. (Diezi 2016). However, especially listing the first as an argument for the missing development appears to be a fallacy – there must be reasons why no incentive scheme was adopted until 2009. Concerning the second argument, it has been shown that wind conditions in Switzerland have been underestimated at least until the mid-2000s due to ignoring the technology's sophistication potential (Brand 2008). Furthermore, the topographic conditions are similar to those in Austria[42], where already in 2006, wind power plants produced an amount of electricity that was 127-times higher than in Switzerland (SES 2007).

In general, wind power has a considerable theoretical potential in Switzerland, which is reduced by a number of restricting criteria that have remained unresolved until today. (VSE 2018b). If all the wind projects listed in the 'Windenergy for Switzerland' concept of 2004 were to be realized, the generation potential would be as high as 4,000 GWh per year (ARE 2004)[43]. This could cover around 7 percent of today's domestic electricity consumption or that of over one million Swiss households (Brand 2008). However, if the strict landscape protection regulations stay in place and the critical areas will remain excluded, then the economic potential of electricity production potential with wind power would be cut by half, namely from 12,000 GWh to 5,300 GWh. If woodland is excluded as well, production will be maximally 3,400 GWh, which contradicts the target of 4,300 GWh set in the Energy strategy 2050 (Diezi 2016).

However, the developments in the last three decades indicate that the country is far from reaching even the target of producing 600 GWh until 2020[44]. Opposing parties have usually been profiting from the lack of binding regulations on a cantonal level, legal loopholes and broad definitions that left room for interpretation. 69 planned projects with 390 turbines and a capacity of 1,099 MW, which pend only due to the missing construction authorization, could not be realized yet: Inter alia, they become

[42] However, the national territory of AT is twice as large
[43] 100 locations with a total of 730 wind parks plus 1,900 individual wind turbines
[44] The target has been set in the framework of the Energy Strategy 2050

economically less viable due to long revision processes mainly due to referenda, which can be conducted for every project (Stalder 2017b). Even if the electorate approves a particular project, powerful environmental non-governmental organizations might impede realization – currently, this is the case for 11 plant (park) projects (Diezi 2016). In some cases, approval processes can take 10 to 15 years, whereas in Germany or Austria, this is not more than 1-3 years. According to the well-organized nature and landscape protection lobby, in general, "the impact on the landscape is very high compared to the low energy yield" (ibid.).

3.4.8.4. Policies supporting wind power deployment

The expansion of wind power has always been a delicate issue in Switzerland, whereby concerns of landscape protection play a dominant role (NZZ 2007; VSE 2018b). The first attempt to coordinate wind power use on a federal level was the wind energy concept of 2004, which aimed to define suitable construction areas together with the cantons and landscape protection organizations. However, the concept contained recommendations only and can therefore be perceived as guidelines, but not as a serious regulation (NZZ 2007).

Certainly, the climate debate has catalyzed discussions around the deployment of renewable energy in Switzerland as well. Then again, the at least equally important question was the feasibility of alternatives, like large plant projects on Swiss territory in general, for several reasons. On the one hand, the economic viability became increasingly uncertain in the light of shrinking electricity prices on European markets (AZ 2016). On the other hand, the Swiss history has shown that the conflict potential of these kind of plants is high, potentially leading to considerable delays and additional costs and therefore less attractive investment conditions compared to the investment situation in other countries.

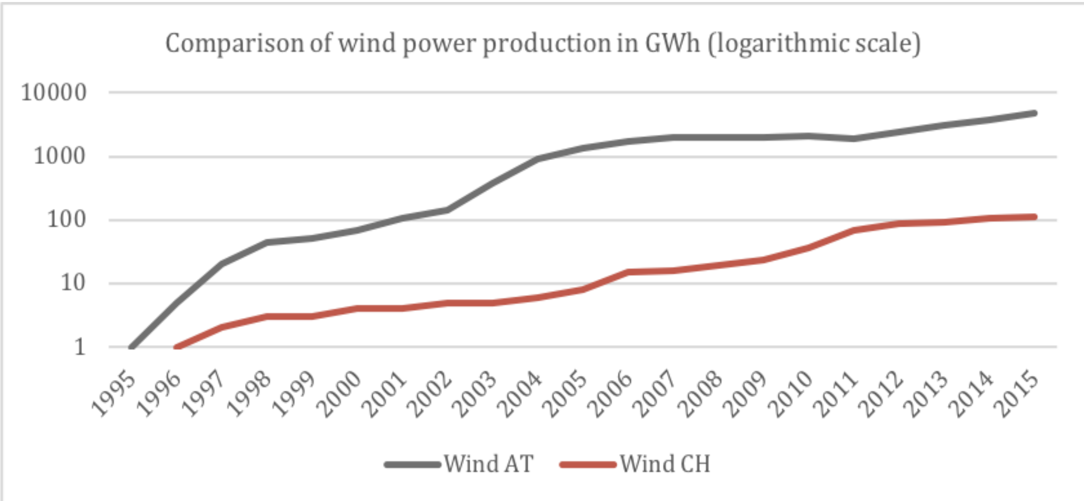


Fig. 22: Comparison of wind power production in GWh between Austria (AT) and Switzerland (CH).Logarithmic scale. Own representation based on figures obtained from the IEA Data Services (2018)

The federal feed-in tariff scheme that was introduced in 2009 brought a considerable development to wind power deployment in relative terms which, however, was followed by a period of stagnation (see *fig.22)*. Thus, how can the comparatively late introduction[45] of a federal support scheme for renewable electricity be explained? On the one hand, the proxy to enact federal energy policy in general was granted by the electorate in 1990 only, whereby the federal government gained greater decision-making authority through a constitutional amendment. In 1999, the first Energy Act came into force, based on a comprehensive energy concept. This was preceded by a century characterized by an increasingly intense public debate about energy, which challenged the previously cautious federal regulator. Therefore, it is assumed that there was a lack of institutional capacity to introduce a far-reaching support scheme earlier. Second, the authorization of three nuclear plant projects was still pending, whose realization would have made the support of alternatives less attractive (SES 2017).

Still, this does not explain the stagnation of wind power development after the introduction of the support scheme, which could only be extended through the realization of a few projects. As mentioned in the previous chapter, projects of a capacity with more than 1 GW are currently pending, which reflects that the scheme is considered reliable and economically attractive. However, due to the lack of

[45] In Germany, the feed-in tariff scheme (Erneuerbare Energien-Gesetz) was introduced in 1991. In Austria, the nation-wide support scheme was introduced in 2002.

enforcement and standardization of procedures on local level, the contestability of wind power plant projects has remained high.

In general, the relationship between nuclear power deployment and renewable energy support policy in Switzerland is evident. In 2011, the federal government finally decided on the gradual phase-out of nuclear energy, whereby the first plant could cease operation in 2019 and the last in 2034, however, without a fixed date. The new corresponding energy law and the pursuit of the Energy Strategy 2050 was decided on in the framework of a referendum in May 2017 with a 58 percentage of votes. According to a representative poll, the nuclear disaster in Fukushima was considered as an influential factor in Switzerland on the public debate due to the fact that the ageing reactor in Mühleberg (construction year: 1971) is of the same type (Tresch et *al* 2017). However, a fast phase-out was rejected a year before mostly due to concerns of the unresolved question for substitutes (FAZ 2016).

In order to achieve the goals of the Energy Strategy 2050, namely to substitute nuclear power with renewable energy, Switzerland would have to massively expand its wind production capacity. In this regard, easing of the strict protection regulations has commenced due to the increasing pressure to reach the set targets (Diezi 2016). It is expected that several projects can be implemented in the course of the new energy law which is in place since January 2018: The law stipulates that if authorities or courts had to decide between the interests of nature and landscape protection and the interest of electricity production from renewable energies, both concerns will enjoy the status of "national interest" and will be equally weighed against each other. Specifically, new and existing wind turbines with a production volume of 20 GWh or more receive the status of "national interest" (Suisse Éole 2018). Furthermore, the feed-in tariff system has been revised.

All in all, is assumed that the core problem for the stagnation of wind energy use was the lack of institutional capacity on the federal level to establish simplified planning procedures and appropriate funding conditions, as well as to strive for acceptance of the affected population, due to the strong bargaining position of cantonal governments, the electorate and interest groups like incumbents (VSE 2018b). As it could be shown in the previous chapters, this problem is applicable for any plant project, as it meets with complex and non-hierarchical decentralized structures. At the same time, there were enough electricity production capacities to satisfy demand for decades paired with the prospect of adding new nuclear capacity that hampered the political will to support wind power deployment by more than loose regulations. Moreover, in the light of the climate debate, incumbents strived to frame the use of nuclear power as a climate friendly technology, which was successful to a certain extent. Furthermore, with Switzerland not being a member of the EU, there was no external pressure to adhere to regulations that were aimed at the enhanced use of renewable electricity.

Indeed, political advocacy coalitions have remained quite stable after the ‘Fukushima shock’, which basically means that incumbents kept standing opposed to major policy changes. Then again, arguments that come along with the maturity of certain renewable technologies like job creation and regional prosperity address the core values of the rather conservationist pro-economy coalition, increasing the likelihood of fragmentation of this advocacy group (Markard et *al* 2016).

4. Conclusion and outlook

In the framework of this study, the complex relationships of historical electricity usage in Austria and Switzerland were compared and analyzed. The motivation was to find reasons why two countries that share several commonalities would decide for a different electricity generation path, with a special focus on the nuclear and wind power sectors. As of 2017, wind power generation accounted for 0.2% of the total Swiss electricity supply, whereas in Austria, it was already 7%. Therefore, a certain lock-in through the significant deployment of nuclear power in Switzerland was assumed.

First, a definition on energy transitions was given, acknowledging that it is a complex process taking place on different levels involving economic, socio-technical and political factors. In this regard, it was aimed to show that it is useful to combine different perspectives in order to gain a profound insight into national energy or electricity transitions. Therefore, a comprehensive set of analysis was developed which served as a backbone of the subsequent comparative study. Conducting a historical analysis has inter alia revealed a certain role of path dependency, energy security, the significance of actor constellations and the decision-making structures as well as the meaning of regional policy integration for the development of different electricity use paths.

Main results show that analyzing the political perspective in case of the nuclear program was particularly conclusive to find answers for its rejection or approval, which slightly contradicts the claim that this perspective is more important in the light of sustainable energy transitions. Simultaneously, the comparison has displayed the importance of the time factor. Especially in the case of Austria, it was unlikely that the rejection of putting an already constructed plant into operation can be explained by a haphazard formation of a social movement only. In the beginning of the 1970s, both countries' population viewed nuclear power as a progressive technology. However, the Austrian political system experienced a transition at that time which was translated into the electricity sector, making it permeable to conflicting powers. Although unlike in Austria, no significant shift in the political system of Switzerland took place that would have had an influence on the nuclear policy, there are still similarities that led to the halt of capacity expansion. Both governments' energy policy is significantly influenceable through the social system, which, in Austria's nuclear policy case, was rather a momentum, whereas in Switzerland, the high permeability constitutes a permanent state. In the case of the latter, the 'void in the center of policy making' was crucial for the implementation or rejection of certain power plant projects.

In this regard, the analysis has shown that the impact of the decentralized decision-making structure can paralyze transformative processes, which is especially the case in Switzerland. Although being a federalist country as well, Austria has developed a strong national energy policy from early on, which was crucial when imposing a ban on nuclear power and later in the light of European integration. In the case of the latter, the role of environmental policy-making on the EU-level can be considered an important stimulus for designing national renewable energy support schemes that finally created a stable investment environment.

In the case of Switzerland, the early spill-over of wind power technology, the emergence of a respective domestic industry, significant R&D-expenses in the area of renewable energy and the embeddedness into international research structures – which showed the general openness to alternative electricity generation technologies – could not compensate for the missing enforcement of promoting policies on a national level. In this regard, a certain lock-in effect through the long-term deployment of nuclear power could be identified. This is mostly assumed due to the fact that – through the analysis of historical development – it could be seen that the federal government's decision-making power only increased with the diminishing likelihood of constructing new nuclear power plants. On the one hand, this was the case when the first federal energy strategy was implemented as the electorate decided on the 10-year moratorium. On the other hand, lately when it resolved the nuclear phase-out in 2017 by simultaneously adopting a new energy strategy and corresponding laws that reform existing support schemes and declare certain renewable energy projects as ‘projects of national interest’.

These sudden policy changes were inspired by external shocks, whereby in the first case, the alternatives to nuclear power, did not seem convincing enough to decide on a complete phase-out. In the latter case, a respective study has shown that the ‘pro-growth’ coalition is changing its attitude on renewable energies due to their economic potential that came along with the maturation of the respective technologies. However, this reflects that currently, in Switzerland, only an incremental change is possible that is absorbable by the existing paradigm.

What does the future hold for the two countries in terms of energy transition then? In 2018, both countries have adopted important policies that can bring significant change to their energy systems. In the case of Austria, this is the integrated Climate and Energy Strategy, which “induces a paradigm shift”, stating that renewable energy and energy efficiency will play the dominant role when it comes to investments. In this respect, the target is to achieve a target of 100% renewable electricity in total net supply by 2030[46] (BMNT 2018). Simultaneously, according to the strategy, Austria has a very high level of security of supply due to the existing network infrastructure, power plant capacities and domestic energy resources. In transforming the energy system, the top priority will be to maintain this high level of energy security. In the context of the latter, renewable energy is considered beneficial to become more independent and resilient, especially with regard to the high fossil-fuel dependence in other than the electricity sector (ibid.). In general, concerning overarching goals, Austria has to align its climate- and energy policy with the commitments made in the framework of the European Union, which has proven to be an effective means of enforcement with regard to the promotion of renewable energy sources.

In Switzerland, as already mentioned earlier, the issue of energy security is one that rather led to skepticism among the electorate in the light of the new energy strategy,

[46] Currently, renewables account for 72% of the Austrian electricity supply

which has several reasons. First, it is feared that capacities cannot be substituted with renewables while phasing out nuclear power, which has been demonstrated by the lack of feasibility of wind power projects. In this regard, it is expected that constructing gas power plants could become necessary which would impair the climate footprint of the Swiss electricity supply (SATW 2014). Then again, it is likely that large (thermal) plant projects would meet with resistance similar to what has been experienced before. Thereby, the question arises whether investors would be found under uncertain investment conditions that simultaneously could lead to higher project costs – an argument that led to the abandonment of planned nuclear projects as well. Second, importing even more electricity from other European countries might become necessary which is partially seen as problematic too in light of the absence of market integration.

All in all, it is evident that Switzerland will have to overcome systemic issues that are strongly connected to its decision-making system, if it aims at performing a real energy transition. With adopting the 'Energy Strategy 2050' the step into the right direction was made. However, its true implications, inter alia for the development of the wind energy sector remains to be seen, as fundamental issues with acceptance have to be overcome. In Austria, the recent progress towards energy transition was a mosaic of a long-term process that started more than two decades ago, made available through a - more or less – consistent national policy.

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