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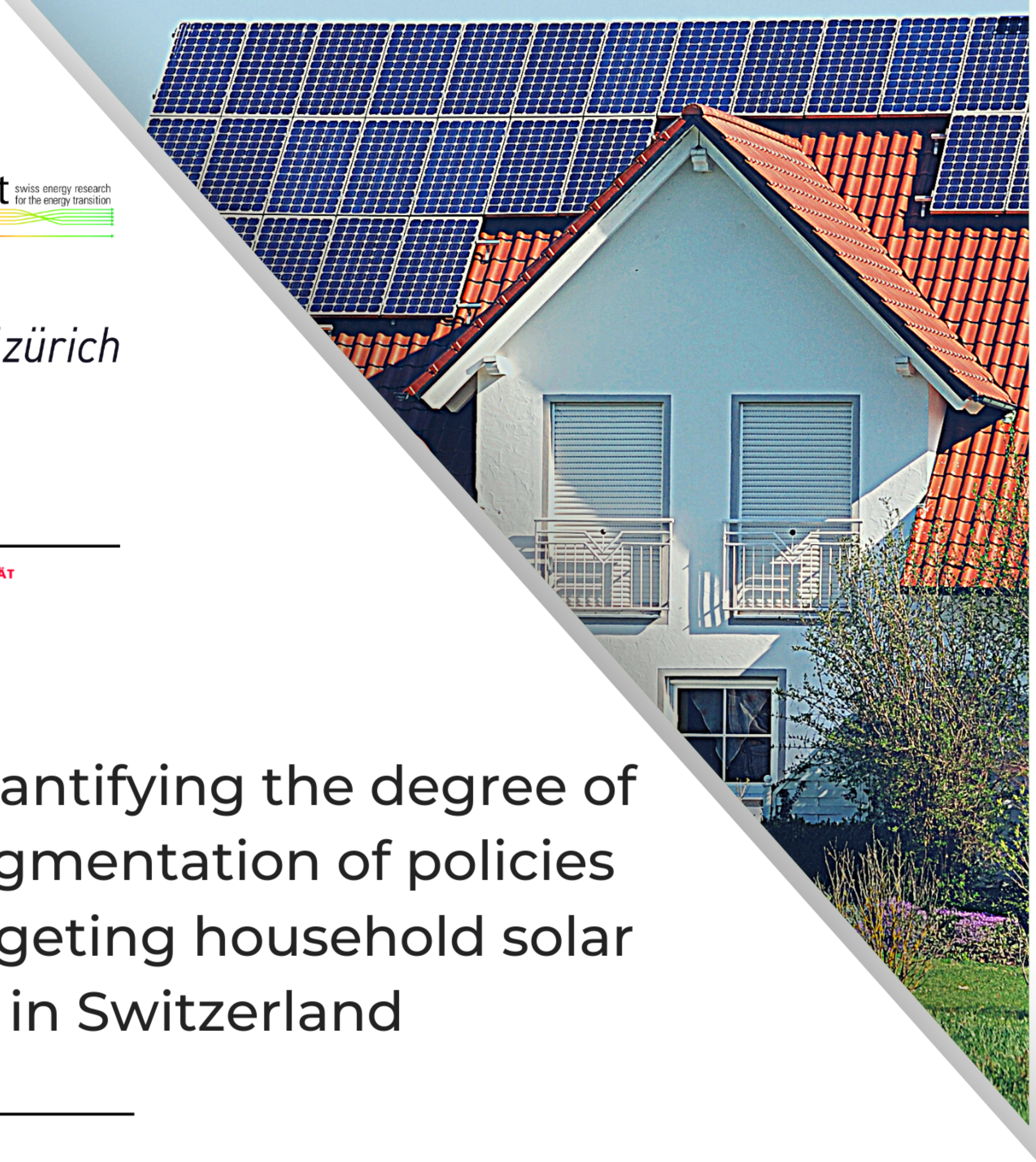

Quantifying the degree of fragmentation of policies targeting household solar PV in Switzerland

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Summary

To reach its climate targets and secure its energy supply, Switzerland needs to multiply the annual deployment of renewable energy technologies, especially solar PV (as also shown in the SWEET EDGE inter-model comparison). However, household solar PV deployment is lagging and needs to be accelerated significantly through a supportive policy environment. Yet, the fragmentation of Switzerland's energy policy landscape is large, resulting in higher search/transaction costs, risks and inefficient allocation of capital, which may represent a significant barrier to accelerated solar PV deployment. In this Policy White paper, we analyze the extent to which policy in Switzerland relevant for household PV is fragmented geographically along cantons and municipalities, and functionally along a set of policy instruments.

Our results show that cantons and municipalities have vastly different policies, including taxation rules, building codes, subsidies and many more. At the same time, more than 500 (largely) state-owned electricity utilities have implemented widely diverging solar feed-in-tariffs (5 to 22 Rp/kWh) and charge very different electricity prices (10 to 32 Rp/kWh). Overall, there is little evidence that cantons and municipalities push for highly ambitious policies, with only a few cantons using their leeway to provide stronger financial incentives to households/investors. Instead, the institutional structure seems to generate a tendency towards low-ambition compromise in the policy environment. Using a techno-economic model, we show that this policy fragmentation indeed creates a massive variance in the profitability – one of the key determinants of technology deployment – of rooftop solar PV installations. While rooftop household solar PV is highly profitable in some municipalities due to local subsidies, a favorable tax environment, or high tariffs, other municipalities have relatively unfavorable policy environments.

Based on our analyses, we propose a strategy to reduce this policy fragmentation while increasing ambition. We argue in favor of a targeted harmonization of selected policy instruments to create stronger incentives for accelerated solar PV deployment and to reduce unnecessary barriers, such as harmonizing the taxation of profits from solar PV installations on the cantonal level. Through their ownership of electricity utilities, municipalities and cantons should also work toward reducing the stark geographical differences in feed-in tariffs and electricity prices, while allowing for local differences where appropriate.

In sum, the White Paper argues that a targeted harmonization of the highly fragmented energy policy landscape, aiming at more ambitious minimal standards, is key for an accelerated deployment of solar PV, and thus for reaching the targets of Switzerland's Energy Strategy 2050.

Zusammenfassung

Um ihre Klimaziele zu erreichen und die Energieversorgung zu sichern, muss die Schweiz den Einsatz erneuerbarer Energien, insbesondere der Photovoltaik, vervielfachen (wie auch der SWEET EDGE-Modellvergleich zeigt). Der Zubau der Photovoltaik auf Hausdächern verläuft jedoch nicht schnell genug und muss durch ein unterstützendes politisches Umfeld deutlich beschleunigt werden. Allerdings ist die Fragmentierung der schweizerischen Energielandschaft gross, was höhere Transaktionskosten sowie das Risiko einer ineffizienten Kapitalallokation mit sich bringt und schlussendlich ein erhebliches Hindernis für eine raschen Photovoltaik-Zubau sein kann. In diesem White Paper analysieren wir deshalb das Ausmass dieser Fragmentierung in der Schweiz im Bereich der Haushalts-Photovoltaik, wobei das Augenmerk auf die Kantons- und Gemeindeebene gelegt wird.

Unsere Ergebnisse zeigen, dass die Kantone und Gemeinden sehr unterschiedliche Politiken verfolgen, etwa wenn es um Bauvorschriften, Subventionen oder die steuerliche Behandlung von PV-Anlagen geht. Zudem bieten die mehr als 500 (grösstenteils) staatlichen Stromversorgungsunternehmen sehr unterschiedliche Einspeisetarife für Solarenergie (5 bis 22 Rp/kWh) sowie Strompreise (10 bis 32 Rp/kWh) an. Insgesamt finden sich in den Kantonen und Gemeinden nur wenige Beispiele von wirklich ehrgeizigen Massnahmen zur Förderung des Photovoltaik-Zubaus, und nur wenige Kantone nutzen ihren politischen Spielraum, um Haushalten und Investoren stärkere finanzielle Anreize für die Installation von PV-Anlagen zu bieten. Vielmehr deuten die Analysen darauf hin, dass die föderalistische Struktur, mit ihrem starken Fokus auf informelle Koordination und kantonale Autonomie, eher mit wenig ehrgeizigen Minimalstandards und Kompromissen einhergeht. Anhand eines techno-ökonomischen Modells zeigen wir, dass diese politische Fragmentierung tatsächlich zu einer massiven Variation der Rentabilität - einer der wichtigsten Determinanten für den Einsatz der Technologie - von PV-Dachanlagen führt. Während PV-Dachanlagen für Haushalte in einigen Gemeinden aufgrund lokaler Subventionen, eines günstigen steuerlichen Umfelds oder hoher Tarife sehr profitabel sind, weisen andere Gemeinden weit ungünstigere Kontextbedingungen auf.

Auf Basis unserer Analyse schliessen wir, dass für einen beschleunigten Zubau von PV-Anlagen auf Hausdächern eine gewisse Reduktion der aktuellen Fragmentierung bei gleichzeitig ambitionierteren Minimalstandards sinnvoll ist. Im Zentrum steht dabei eine gezielte Harmonisierung ausgewählter politischer Instrumente, um insbesondere stärkere Anreize für einen beschleunigten Zubau der Photovoltaik zu schaffen und unnötige Hürden abzuschaffen, wie etwa die Harmonisierung der Besteuerung von Gewinnen aus Photovoltaikanlagen auf kantonaler Ebene. Gemeinden und Kantone sollten über ihre Beteiligung an den Elektrizitätsversorgungsunternehmen zudem darauf hinarbeiten, die grossen geografischen Unterschiede bei den Einspeisetarifen und Strompreisen zu verringern, wobei lokale Unterschiede berücksichtigt werden sollten, wo dies sinnvoll ist.

Zusammenfassend argumentiert das White Paper, dass eine gezielte Harmonisierung der stark fragmentierten energiepolitischen Landschaft mit dem Ziel ehrgeizigerer Mindeststandards der Schlüssel für eine beschleunigte Verbreitung der Photovoltaik und damit für die Erreichung der Ziele der Schweizer Energiestrategie 2050 ist.

Résumé

Pour atteindre ses objectifs climatiques et garantir son approvisionnement énergétique, la Suisse doit multiplier le recours aux énergies renouvelables, en particulier provenant du photovoltaïque (comme le montre également l'analyse comparative des modèles de SWEET EDGE). Cependant, le développement du photovoltaïque sur les toits des maisons n'est pas assez rapide et doit être nettement accéléré par un environnement politique favorable. Or, le paysage énergétique suisse est très fragmenté, ce qui entraîne des coûts de transaction plus élevés ainsi que le risque d'allouer inefficacement le capital. Cette situation constituerait un obstacle important à une expansion rapide du photovoltaïque. Dans ce White Paper, nous analysons l'ampleur de cette fragmentation politique en Suisse dans le domaine du photovoltaïque des ménages, au niveau géographique sur les cantons et communes, et au niveau fonctionnel à travers différents instruments politiques.

Nos résultats montrent que les cantons et les communes appliquent des politiques très différentes, par exemple en ce qui concerne les règles de construction, les subventions ou le traitement fiscal des installations photovoltaïques. De plus, les plus de 500 entreprises d'électricité (pour la plupart publiques) proposent des tarifs de rachat de l'énergie solaire (de 5 à 22 cts/kWh) ainsi que des prix de l'électricité (de 10 à 32 cts/kWh) très différents. Dans l'ensemble, on trouve peu d'exemples de mesures vraiment ambitieuses dans les cantons et les communes pour encourager la construction de nouvelles installations photovoltaïques, et seuls quelques cantons utilisent leur marge de manœuvre politique pour offrir aux ménages et aux investisseurs des incitations financières plus fortes pour l'installation de systèmes photovoltaïques. Les analyses indiquent que la structure fédéraliste, qui met fortement l'accent sur la coordination informelle et l'autonomie cantonale, va plutôt de pair avec des standards minimaux peu ambitieux et des compromis. A l'aide d'un modèle technico-économique, nous montrons que cette fragmentation politique entraîne effectivement une variation massive de la rentabilité - l'un des principaux déterminants de l'utilisation de la technologie - des installations PV en toiture. Alors que les installations PV en toiture pour les ménages sont très rentables dans certaines communes en raison de subventions locales, d'un environnement fiscal favorable ou de tarifs élevés, d'autres communes présentent des conditions contextuelles beaucoup moins favorables.

Sur la base de notre analyse, nous concluons que pour accélérer le développement des installations PV sur les toits des maisons, il serait judicieux de réduire quelque peu la fragmentation actuelle tout en fixant des standards minimaux plus ambitieux. L'harmonisation ciblée d'une sélection d'instruments politiques est essentielle, notamment pour créer des incitations plus fortes en faveur d'un développement accéléré du photovoltaïque et pour supprimer des obstacles inutiles, comme l'harmonisation de l'imposition des bénéfices des installations photovoltaïques au niveau cantonal. Les communes et les cantons, par le biais de leur participation aux entreprises d'approvisionnement en électricité, devraient en outre s'efforcer de réduire les grandes différences géographiques en matière de tarifs de rachat et de prix de l'électricité, tout en tenant compte des différences locales lorsque cela est pertinent.

En résumé, le White Paper affirme qu'une harmonisation ciblée de l'environnement politique énergétique très fragmenté, visant à établir des normes minimales plus ambitieuses, est la clé d'une accélération du déploiement du photovoltaïque et donc de la réalisation des objectifs de la Stratégie énergétique 2050 de la Suisse.

1 Introduction

By 2050, Switzerland needs to multiply its renewable electricity generation, especially solar PV. The Energieperspektiven2050+[1] plans for a tenfold increase of PV capacity within the next 30 years. So far, ground-mounted PV systems are not yet relevant in Switzerland (due to regulatory barriers) and alpine-PV is still a niche technology. Rooftop-mounted solar PV is an established technology with a nationwide production capacity of over 3 TWh p.a. However, rooftop household solar PV deployment is lagging and needs to be accelerated significantly through a supportive policy environment. This is also a robust finding of the SWEET EDGE inter-model comparison exercise. As Switzerland is one of the most federally organized countries in the world, energy policy fragments across cantons and municipalities. Cantons and municipalities have a high degree of autonomy and are strongly involved in the design and implementation of national (energy) policy (Stadelmann-Steffen, et al., 2018; Sager, Ingold, & Balthasar, 2017).

In the area of solar PV policy, in particular, the competences between the federal government and the cantons are strongly intertwined. The federal government generally defines the framework conditions, such as spatial planning and environmental protection, within which the cantons shape their more specific policies. Moreover, the federal government has set up a subsidy scheme for the promotion of solar PV. The cantons and municipalities, for their part, have the possibility to control the deployment of solar PV through their own spatial planning, policy competencies in the building sector, or local subsidies. The interconnectedness in planning and the specific local policy environments lead to the fact that in Switzerland all 26 cantons and even the municipalities regulate and promote the expansion of solar PV differently (Kammermann, 2017; Sager, 2014), i.e., use their leeway to shape energy policies differently depending on local priorities and preferences. This policy fragmentation leads directly to the question of which local policy environments are advantageous or disadvantageous with regard to the diffusion of rooftop household solar PV.

If Switzerland wishes to evenly distribute the diffusion of PV and take advantage of all available rooftops to achieve its energy targets, there is a need for a more harmonized policy landscape that at the same time caters to the needs of local specificities. For instance, Switzerland's energy market is not fully liberalized, and households and small consumers are bound to obtain electricity from their assigned energy provider. There are over 600 energy providers, of which the 20 most prominent fully or partially cover around 1500 of the 2148 municipalities (ElCom, 2022). Accordingly, the rooftop solar PV investment landscape is also fragmented in Switzerland, which to some extent requires a spatially differentiated policy landscape. The fragmentation of policy and consequently of markets has potential upsides (e.g., the opportunity to innovate and experiment with policy, technology and business models) but also downsides (such as higher search and transaction costs, entry barriers for new businesses, and reduced competition and inefficient allocation of capital).

In light of the highly complex policy and market landscape for solar PV in Switzerland, this White Paper aims at analyzing the extent to which Swiss solar PV policy is fragmented geographically along cantons and municipalities, and functionally along a set of policy instruments. We first provide an overview of the existing policy instruments targeting rooftop solar PV on the national, cantonal, and municipal levels. In a second step, we analyze how this (fragmented) policy landscape influences the profitability – a key driver of rational investment decisions – of rooftop solar PV projects for Swiss households. We conclude with recommendations on how to reduce policy fragmentation while increasing policy ambition in order to achieve the solar PV deployment aspired by the Energy Strategy. The generated insights shall inform policy makers on all governance levels about existing barriers to the rapid deployment of rooftop solar PV at the building level but also about best practices and innovation potentials. It shall also inform about where policy harmonization is warranted and in which areas local diversity is appropriate.

2 Policy instruments targeting rooftop solar PV in Switzerland

This section gives an overview on the policy instruments on the federal, cantonal, and municipal level for rooftop solar PV on buildings (see Figure 1). The section does not claim to comprehensively describe the regulations and framework conditions for PV, but concentrates on instruments that are most directly relevant from a policy perspective. It needs to be mentioned that, in the wake of the energy crisis, this policy field changes quickly so that some recent changes might not have been considered. The main aim is to show the vertical fragmentation of the policy landscape between the different levels – defined by the federalist structure of legislation and implementation competencies in Swiss energy policy – but also the horizontal fragmentation between the different cantons and municipalities, and to assess the consequences of this policy fragmentation. Our results show that horizontal fragmentation is asymmetrical, i.e., the large majority of subnational units in Switzerland uses their leeway in the federal system to implement low ambition rather than high ambition policies.

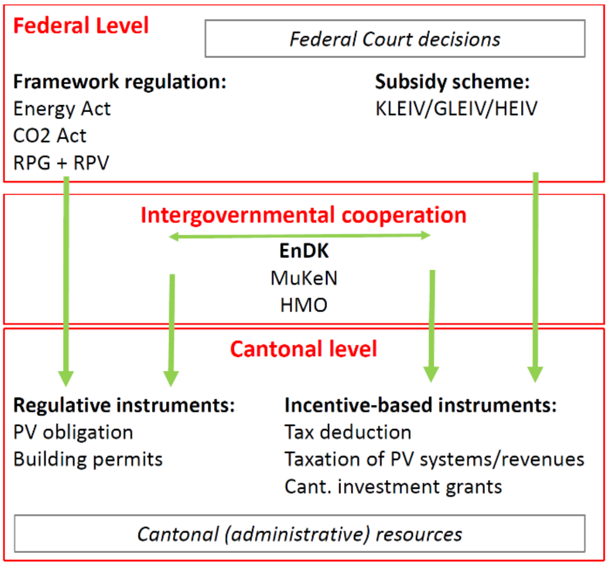

Figure 1: PV regulation and policies in the Swiss federal system (on the two upper levels). This is not an encompassing model of Swiss energy (or PV) policy and governance but illustrates the elements and interactions discussed in the White paper.

2.1 Policy instruments on the federal level

In the area of solar PV policy, the competencies between the federation and the cantons are strongly intertwined. The federal level sets the framework, namely through the Energy Act, the Spatial Planning Act, and the CO2 Act[2], whereas the cantons are responsible for the implementation of these acts, in general, and for the building sector in particular. This subsection therefore describes the instruments of the federation but also of the intergovernmental level used to coordinate cantonal activities.

2.1.1 Instruments of the federal government

At the federal level, two main instruments exist to steer the deployment of solar PV on buildings. First, in terms of ***regulation***, the Spatial Planning Act (RPG, Raumplanungsgesetz, Art. 18a) states that the installation of solar PV on "sufficiently adapted roofs" (as defined in the Spatial Planning Ordinance, RPV) in building and agricultural zones do not require a construction permit. Hence, the federal level sets the default regarding the approval process. In recent years, through the revision of the RPV, the definition of what "sufficiently adapted" means has thereby been broadened. At the same time, the article leaves cantonal room for maneuver to nevertheless require a building permit in clearly defined areas but also to expand the default to other types of PV plants (see subsection 2.2).[3]

Second, the federal government also promotes solar PV through a ***subsidy scheme***. With the Energy Act of 2009, the cost-covering feed-in tariff (KEV) was introduced to protect and promote renewable energy production in a newly liberalized energy market (Rieder & Strotz 2018: 26). At that time, the introduction of the KEV corresponded to a multiplication of subsidies for renewable energies (ibid.). As of 2014, the KEV was first complemented and then replaced by the investment grant scheme for small (KLEIV, Einmalvergütung für kleine PV-Anlagen) and larger (GREIV, Einmalvergütung für grosse PV-Anlagen) PV systems (Vettori, et al., 2020). Public investments in this subsidy have strongly increased since, from 200 million CHF in 2018 (Vettori et al. 2020: 35) to 470 million CHF in 2021[4]. At the same time, from the perspective of house owners, however, the investment grant is financially less attractive than the previous KEV, which basically aimed at a full cost funding (Vettori et al. 2020: 33). The amount of the investment grant varies depending on the capacity and type of system (EnFV). Operators of systems with an output of over 100 kW and a maximum of 50 MW still have the choice of applying for either a one-time payment or a feed-in tariff (EnFV Art. 7 and 8). Moreover, as of 2023, a higher investment grant (HEIV, hohe Einmalvergütung) is introduced for PV systems without self-consumption. Instead of the usual maximum of 30%, the grant for these PV systems will amount to up to 60% of the investment costs. In addition, for systems with an output of 150 kW or more, the HEIV will be awarded by auction. Overall, federal subsidies for photovoltaics further increases to 600 million CHF.[5]

In the context of the 2022 global energy crisis, triggered by the Russian war against Ukraine, further federal measures to promote renewable energy in general and (building level) PV have been introduced or are being discussed. Most important, in September 2022, the national parliament has accepted a new act about urgent measures for the short-term creation of a secure power supply in winter ("solar offensive")[6]. Whereas these measures are targeted at easing the regulations for building

[2] We focus on those laws and policies at the federal level that directly affect energy policy in general and PV deployment in particular, while we do not further discuss in this section other regulations that more indirectly or as side effect influence solar PV, e.g., national tax acts that imply that solar installations are considered assets (see section 2.2. for more details).

[3] The cantons are also allowed to define building zones in which other types of PV systems are permit-free as well.

[4] https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-81111.html

[5] https://www.bfe.admin.ch/bfe/de/home/news-und-medien/medienmitteilungen/mm-test.msg-id-91897.html

[6] AS 2022 543

high-altitude solar parks in the first place, the solar offensive also includes a PV obligation for new (large) buildings. However, cantons whose regulations already at least comply with the MuKEn 2014 (see Section 2.1.2) with regards to the generation of own electricity in newly built houses ("Eigenstromerzeugung") are exempt from this requirement.

2.1.2 Intergovernmental level

In the Swiss political system, in-between the federal and the cantonal levels, another intergovernmental level plays an important role in policy making (e.g., Strebel, 2013). Such formal or informal cooperation among the cantons is also relevant for energy policy generally, and solar PV policy in particular. The formal intergovernmental body (or: council) that enables policy-specific horizontal cooperation is the Energy Directors Conference (EnDK, Energiedirektoren Konferenz). In 2015, the EnDK adopted the so called "Mustervorschriften der Kantone im Energiebereich" (MuKEn 2014). While the MuKEn summarize the model regulations in the building sector (of which only a rather small part directly concerns PV) that the EnDK proposes to be applied and implemented by the cantons in the sake of cantonal harmonization, it is important to note that the MuKEn are not legally binding (in contrast to an intergovernmental agreement [or: "concordat"]). At the same time, as they were commonly agreed on in the Plenary Assembly of the EnDK, the MuKEn reflect the "common denominator"[7] of the cantons rather than an ideal or best-practice approach.

A similar instrument is the harmonized funding model of the cantons (HFM[8]), which aims at harmonizing cantonal subsidies for the economical and rational use of energy and for the use of renewable energies and waste heat (EnG Art. 15). In the revised HFM as of 2015, it is explicitly stated that the focus is on the promotion of building renovations, while – with a reference to the national investment grant scheme – the HFM does no longer include photovoltaics (HFM, page: 10).

2.2 Policy instruments on the cantonal level

This section gives an overview about the cantonal policy landscape, i.e., how cantons use their leeway in implementing national law or intergovernmental standards. To do so, we distinguish between regulative and market-based ***policy instruments*** (e.g., Capano & Howlett, 2020), on the one hand, but on the other hand also consider cantonal ***governance structures***, mainly organizational and financial resources that cantons assign to the field of energy policy. Where not otherwise stated, the cantonal data refers to the situation in March 2022.[9]

2.2.1 Policy Instruments

Regulative Policies

At the level of regulative policies (Figure 2), we focus on two aspects. A first aspect concerns explicit ***regulation to promote the deployment of solar PV*** on rooftops, i.e., through the obligation to install solar PV on newly constructed (or even existing) buildings. The current situation shows that cantons are not very prescriptive in that regard, despite the fact that the generation of own electricity in newly built houses has been part of the MuKEn 2014. In March 2022, only 16 cantons[10] had implemented a requirement regarding the generation of own electricity in new houses[11], while this was not the case in 10 cantons. Moreover, even in the cantons where such an obligation existed, the exact conditions and exemptions considerably varied. No canton required own power generation on existing buildings, i.e. during renovations, which is considered an effective policy to increase the deployment of PV.[12]

One could argue that the recent decisions by the national parliament (namely the PV obligation for large newly constructed buildings, see section 0) will lead to harmonization and make the current variation irrelevant. However, there are several reasons why it is still important to look at the current cantonal policy landscape.

[7] https://www.endk.ch/de/energiepolitik-der-kantone/muken

[8] https://www.endk.ch/de/dokumentation/harmonisiertes-foerdermodell-der-kantone-hfm

[9] Own data based on public available documents, mainly regarding the investment grants the cantonal participation in energy companies, was collected in February and March 2022. An important data source is BFE (2022), which largely builds on a survey conducted with the cantonal administrations in March 2022. Concerning building permits, we however deviate from the data presented in BFE (2022) for the cantons SZ, SO and FR, as we could not identify a deviation from the RPG in the cantonal spatial planning acts. This decision was confirmed by information provided by the energy office of the canton of Fribourg.

[10] The data comes from the SFOE publication «Stand der Energie- und Klimapolitik in den Kantonen 2022» and is based on a survey conducted among the cantons in March 2022. Since then several cantons have been working on the introduction of a similar regulation (see e.g., https://www.tagesanzeiger.ch/auf-jedes-dach-eine-solaranlage-858009240317).

[11] The MuKEn do not specify the source of generated electricity but state that photovoltaics will be typically used to meet the generation requirement.

[12] https://www.tagesanzeiger.ch/auf-jedes-dach-eine-solaranlage-858009240317

First, current variation in cantonal policies could inform about best practices or innovative regulations that could be used to define the direction of future federal- and/or cantonal-level policymaking. The current data implies, however, that the cantons have not yet used their leeway to move beyond common practices. Second, current regulation patterns demonstrate the relevance of the new national law, i.e., how many cantons need to change their PV regulation. In this regard, the data demonstrates that the new national regulation will require many cantons to act and therefore will lead to policy change eventually. Thirdly, back in 2015, the EnDK anchored self-generated electricity in the MuKEn 2014, but obviously, a considerable group of cantons so far refrained from integrating a related regulation into their cantonal rules. This variation can be seen as an indicator for the potential for successful implementation: It can be expected that cantons that “lag behind” in their current policy making, will also be more reluctant to implement new national requirements quickly and use their legislative autonomy to not fully comply (e.g., Bondarouk & Mastenbroek, 2018).

A second regulative aspect concerns the degree to which the cantons use their leeway to go beyond the national spatial planning law (RPG, Raumplanungsgesetz) ***to facilitate or complicate the approval process*** *(see Section 0).* Article 18a of the RPG states that rooftop PV in building or agricultural zones typically do not require a building permit. However, the second paragraph of the article specifies cantonal discretion to expand the scope of permit free constructions in building zones or to define further protection zones where a construction permit is still required. The right panel in Figure 2 illustrates that the majority of the cantons rather opt for more restrictive regulation. Only eight cantons expand building permit-free installations beyond the RPG, while 23 define further protection zones where a construction permit is required. Table A.1., in the Appendix, documents cantonal examples of more restrictive and more open regulations.

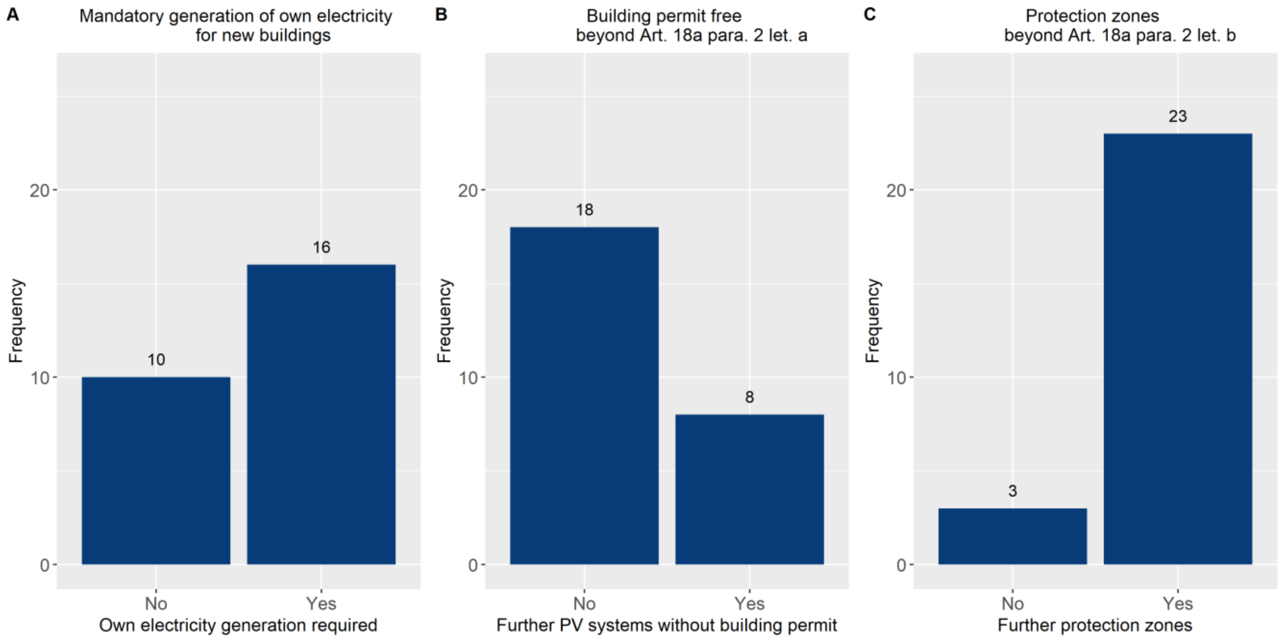

Figure 2: Regulative policies in the Swiss cantons. Source: Own calculations based on (BFE, 2022).

Incentive-based policies

Cantons can use different instruments to incentivize the installation of solar PV financially. We distinguish two groups of instruments: benefits that reduce the investment costs and the treatment of PV plants for the calculation of property and real estate taxes.

Besides the national KLEIV and GREIV, two instruments are used in the cantons to subsidy solar PV on buildings, namely an additional cantonal ***investment grant*** that covers a further part of the investment costs and the possibility to ***deduct investments in rooftop PV from the income tax***.

Nine out of 26 cantons incentivize the installation of solar PV through investment grants (Figure 3). In all of these cantons but AR not all types of PV plants are however eligible for investment grants but only if they meet varying conditions (See Table A.1 in the Appendix). Nevertheless, this finding is noteworthy given that the HFM 2015 does not include solar PV, meaning that these cantons go beyond horizontally agreed standards. The right panel of Figure 3 also reveals that the amount cantons spend per capita (including the federal financial contribution) to provide subsidies for the building sector varies considerably and correlates with cantons providing additional investment grants (t-value mean test = 3.89, $p<0.001$).

Further, all cantons with the exception of LU allow for a tax deduction for PV investments as property maintenance (Lüthi & Russi 2021: 6), which is another way to support investments in solar PV. In most cantons, the tax deduction can only be applied if the building is older than 5-years. This five-year rule is likely not least the result of a Federal Court decision in 2012[13] confirming that the Canton of TG did not need to allow for a tax deduction in the case of a newer building. While the original purpose of this condition probably was to incentivize (in the absence of an obligation) the installation of rooftop PV on new buildings, i.e., during construction, it can be considered an unnecessary regulation from the perspective of solar PV expansion in Switzerland.

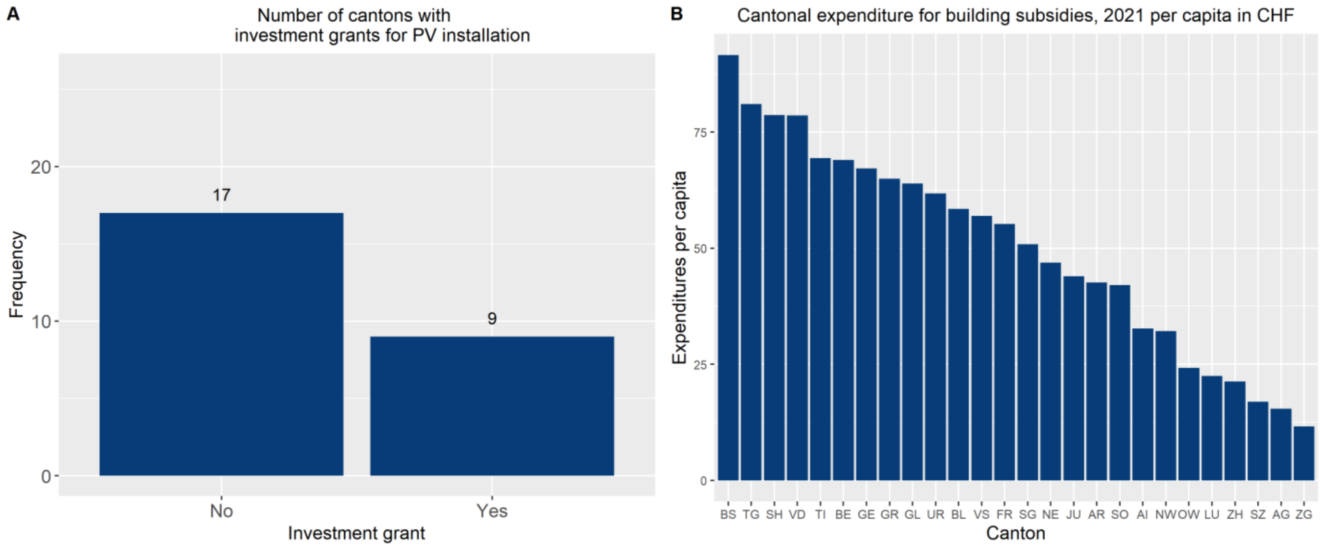

Figure 3: Cantonal subsidies for rooftop solar PV. Left panel: own data collection based on cantonal documents. Right panel: Source: BFE 2022, Building subsidies spent by the cantons per capita (incl. potential subsidies beyond the building program), including global contributions by the Federation in CHF.

How solar PV plants are considered for the calculation of income and property taxes can also generate positive or negative investment incentives. Two aspects are relevant: a) how solar PV installations affect the taxation of individuals and b) how revenues from solar PV production are taxed.

Regarding the ***taxation of individuals***, cantons must consider solar PV installations as an additional asset, which thereby increases the personal tax amount (Vereinigung der Schweizer Steuerbehörden, 2020: 10). In most cantons, a solar PV installation increases the official property value of the building, whereas the PV installation needs to be declared as "other assets" where it does not affect the official property value. In the cantons of GE, VD, FR, SO and SG, built-up PV systems are both included in the property value and additionally subject to property taxes (Lüthi & Russi, 2021).

Cantonal differences are more relevant with respect to the way ***revenues from PV production are taxed***. Ten cantons, using the "gross principle", tax all revenue generated, which can be considered a relevant negative incentive for private PV production. Conversely, the "net principle", used by 14 cantons, taxes the revenue after balancing it with the electricity bill and therefore provides more advantageous conditions. As long as the household spends more on electricity than it earns from remuneration, zero taxes are paid. Only in two cantons, Valais and Vaud, the first 10'000 kWh per year are tax-free (Lüthi and Russi 2021: 5f.).[14]

2.2.2 Governance

As Figure 4 illustrates, cantons vary considerably with respect to how much they invest in energy governance. On the one hand, this concerns the

[13] Schweizer Bundesgericht, 2C_727/2012 18.12.2012 (bger.ch).

[14] There is a pending parliamentary initiative (Pa-IV 21.529) requesting harmonization of how revenues from PV plants are taxed.

resources assigned to the cantonal energy office, which is considered a relevant indicator capturing the willingness but also the possibilities to effectively implement cantonal policies (e.g., Strebel, 2011). On the other hand, as (co-)owners of energy utilities, cantons could have a say also beyond the administrative sphere. Panel B in Figure 4 illustrates that several cantons fully own an energy utility, meaning that these utilities are public enterprises. Other cantons, in turn, do not participate at all in utilities. While strong participation implies the potential of cantons to steer the activities of the energy providers, the data do not tell us anything about whether and how much the cantons make use of this powerful position.[15]

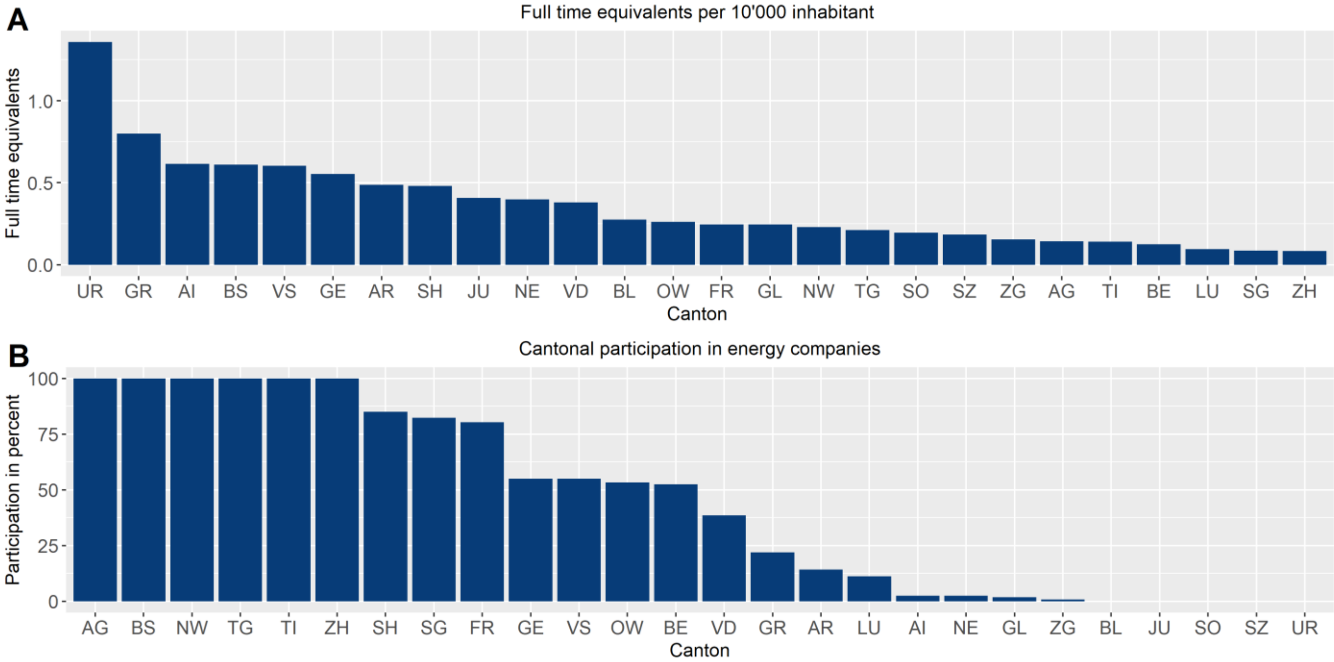

Figure 4: Cantonal governance in energy policy. Panel A: Source: own calculation based on (BFE, 2022); Panel B: Highest share held by a canton in an energy company (not capturing participation in multiple energy companies), data based on publicly available documents.

2.3 Policy instruments on the municipal level

On a municipal level, further differences influence the deployment of solar PV. While the nation-wide one-time subsidy provides a spatially evenly distributed support (350CHF + 380 CHF/kWp), there are certain municipalities in which projects receive additional support. Figure 5 shows a map of all available local investment grants (subsidies) in 2022 that are known to EnergieFranken.ch (EKZ, 2022). There are a total of 390 municipalities which additionally support solar PV installations. The support mechanisms vary in requirements and increments, Figure 5 only shows a snapshot of rooftop mounted PV systems with a size of 10 kWp (p stands for peak capacity). The support does not automatically change proportionally for differently sized PV systems in different municipalities. Vaux-sur-Morges, for example, remunerates an additional 8'300 CHF for a 10 kWp system, anything larger than 10 kWp would be decided on a case-to-case basis. Furthermore, five municipalities incentivize PV investments with a feed-in tariff. On top of that, in 126 municipalities investors receive financial relief in form of a subsidy if they invest in a battery-system.

[15] This focus on cantonal participation may in some cases underestimate the "public ownership" because municipalities rather than the canton importantly participate in energy companies. Moreover, we also do not include participation of energy providers at other energy providers, which can imply an indirect participation of a canton.

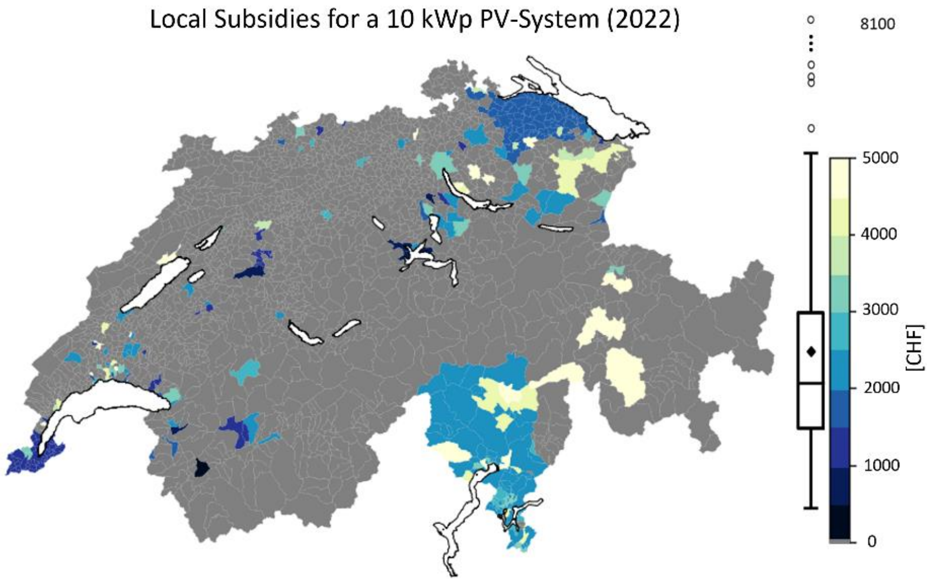

Figure 5: Subsidies received for a 10 KWp PV system (additionally to the KLEIV) per municipality. The Boxplot shows the average PV tariff as point and the median as line. The box indicates the first and third quartile and the whiskers the range of data without outliers. Data-Source: (EKZ, 2022)

While not being support policies per se, PV tariffs and electricity prices are set by the local energy provider, which in 90% of cases are owned by public authorities such as cantons, as described above (Vuilleumier, 2022). The end-consumers' electricity price depends on the electricity market and the energy provider's ability to produce electricity[16]. The more dependent the energy provider is on the electricity market the higher the impact of market changes on electricity prices for its end consumers. While energy providers are obliged to set the minimal PV tariff to their procurement electricity price[17], some offer a higher remuneration at the grey electricity price level at the electricity market.

The PV tariffs differ substantially on the municipal level, as shown for 2022 in Figure 6. The Data was obtained from Vese (Vese, 2022) and contains 490 energy providers. The median PV tariff in 2022 was 9.9 Rp/kWh, with a range from 5 to 22 Rp/kWh. Two of the most prominent energy providers, BKW and CKW remunerated at around 18.5 Rp/kWh, which increases the average to over 11 Rp/kWh.

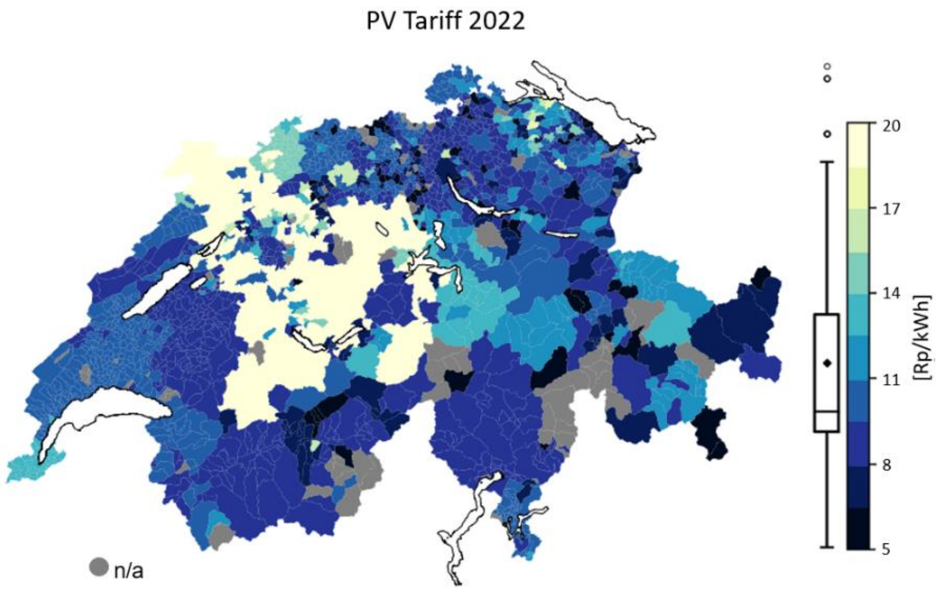

Figure 6: Renumeration shown for each municipality in Switzerland in 2022. The boxplot displays the average with a point and the median with a line. The box indicates the first and third quartile and the whiskers the range of data without outliers. Data-Source: (Vese, 2022)

[16] Around 70% of energy providers do not produce their own electricity (Vuilleumier, 2022).

[17] EnV Art. 12 https://www.fedlex.admin.ch/eli/cc/2017/763/de

3 The role of policy fragmentation for the profitability of rooftop solar PV deployment

Having identified a substantial policy fragmentation on all three governance levels above, here, we aim to understand how this policy fragmentation affects the profitability of PV installations for households. While solar PV investment decisions of households depend on a multitude of factors (see Petrovich 2021 for a recent analysis in Switzerland), the profitability is a key determinant. Put differently, even if further barriers might impede the adoption, it is unrealistic to assume large-scale deployment of the technology without a minimum level of profitability.

3.1 Modelling Methodology

We analyze the investment landscape in Switzerland on the municipal level with a techno-economic model, using real values, i.e., before inflation. We calculate the optimal combination of PV and battery for four residential buildings for each municipality. The model simulates a PV-/Battery system over its lifetime, calculating yearly cash flows. The model uses the Internal Rate of Return (IRR) to compare the performance of different systems within and between municipalities. The IRR indicates the discount rate at which a project returns a Net Present Value of Zero (Braeley & Myers, 2000). A higher IRR indicates a higher profitability.

We use four use cases to exemplify the diverse residential building stock with large solar potential in Switzerland. One single-family house (SFH) vs one multi-family house (MFH), that each are heated with gas (or other non-electrified heating systems) vs heat pumps[18], resulting in four different use cases. The SFH is occupied by a working couple[19] and the MFH by a total of nine people, spread across four apartments. Figure 7 summarizes all use cases with their respective annual electric energy consumption.

	Space & Water Heating	
	Gas	**Heat Pumps**
Single Family House (SFH) 2x	**3'200** kWh/year	**7'900** kWh/year
Multi Family House (MFH) 9x	**14'800** kWh/year	**23'000** kWh/year

Figure 7: The four use cases simulated in the techno-economic model and their annual electricity consumption

The techno-economic model optimizes the combination of PV and battery capacity for each use case in each municipality. The PV capacity is limited by the roof size and ranges from 0 to 12 kWp for the SFH and from 0 to 16 kWp for the MFH. The model calculates the IRR for all possible PV and battery combinations for all use cases in all municipalities and outputs the best performing combination for each use case in each municipality. A detailed explanation of the chosen use cases and the methodology can be found in the Appendix Section 7.1.

For the model to calculate the IRR, the following additional inputs were necessary: yearly load profiles of the households, PV- and battery costs and system specifications, irradiation, electricity prices (to calculate avoided grid electricity costs), PV tariff, tax rate, and local subsides. A detailed description of all inputs can be found in the Appendix Section 6.2.

The maps showing the local subsidy and the PV tariff are found in Section 2.3. The electricity cost for 2022 is shown in Figure 8. The data was obtained from ElCom (ElCom, 2022) and was adapted using the high demand tariffs of 29 of the largest DSOs to represent the cost during production hours of a PV system. Note that our optimization never identified a system where the installation of a battery system was economical (i.e., increasing the IRR beyond that of a system without battery), see below. The median electricity price lies at 22 Rp/kWh. Half of the municipalities charge prices between 20.3 and 22.5 Rp/kWh with outliers in the range of 12 to 34 Rp/kWh.

[18] We exclude the costs of the heating systems from the profitability calculation. Only the electricity demand of the heat pumps are considered.

[19] The average household size in Switzerland is 2.2 people (FSO, 2022)

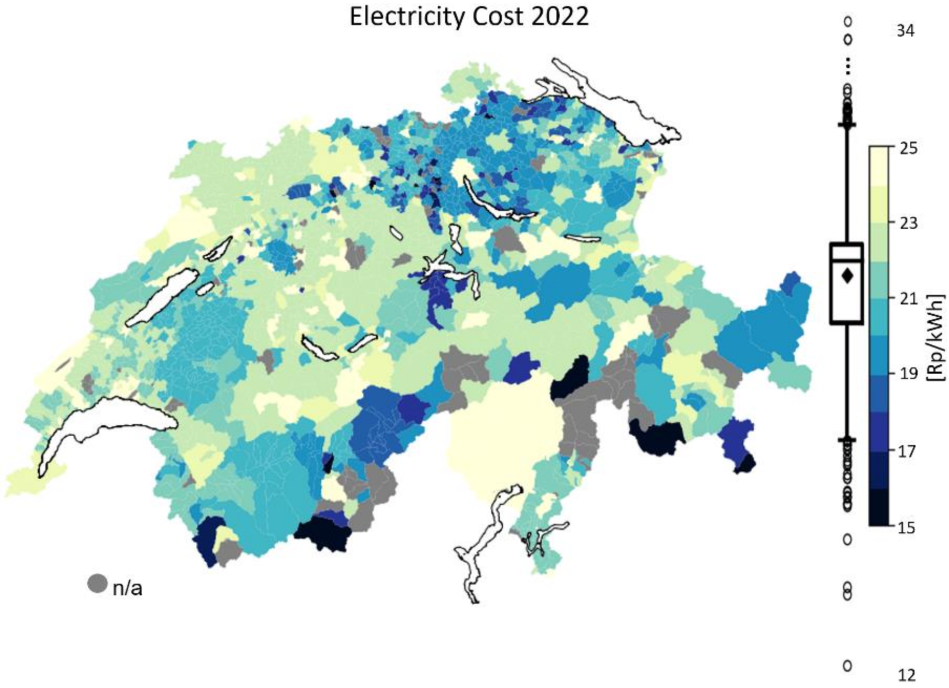

Figure 8: Electricity cost (high tariff) shown for each municipality in 2022. The boxplot displays the average with a point and the median with a line. The box indicates the first and third quartile and the whiskers the range of data without outliers.

3.2 Simulation of household PV profitability

Figure 9 shows the results of the techno-economic model for all four use cases. We calculated the IRR for 2'067 municipalities. 81 municipalities had insufficient data and are shown as n/a. The use case with the lowest electricity consumption, a single-family house using gas, results in IRRs ranging from 0 to 10.4% (median 3.2%). For higher electricity consumption, as in the case of a multi-family house using heat pumps, the IRRs lie between 2.1 and 22.4% (median 10.5%). The larger energy consumption leads to a higher share of self-consumed electricity (14% for case 1 and 63% for case 4). Self-consumed electricity is valued at the electricity price level, which would have been paid for electricity consumption in absence of a PV installation. Since electricity prices are generally higher than PV tariffs, the average produced kWh has a higher value and the investment becomes more attractive.

With an investment threshold of an IRR of 3%[20], 972 municipalities would be considered unattractive for the first use case. For the second use case, 443 municipalities lie below the 3% threshold, whereas for the third and fourth use cases, only three and two municipalities, respectively, are below the threshold.

[20] Interviews with investors performed in other tasks of SWEET EDGE show a required Weighted Average Cost of Capital (WACC) of around 2 to 4% for private individuals.

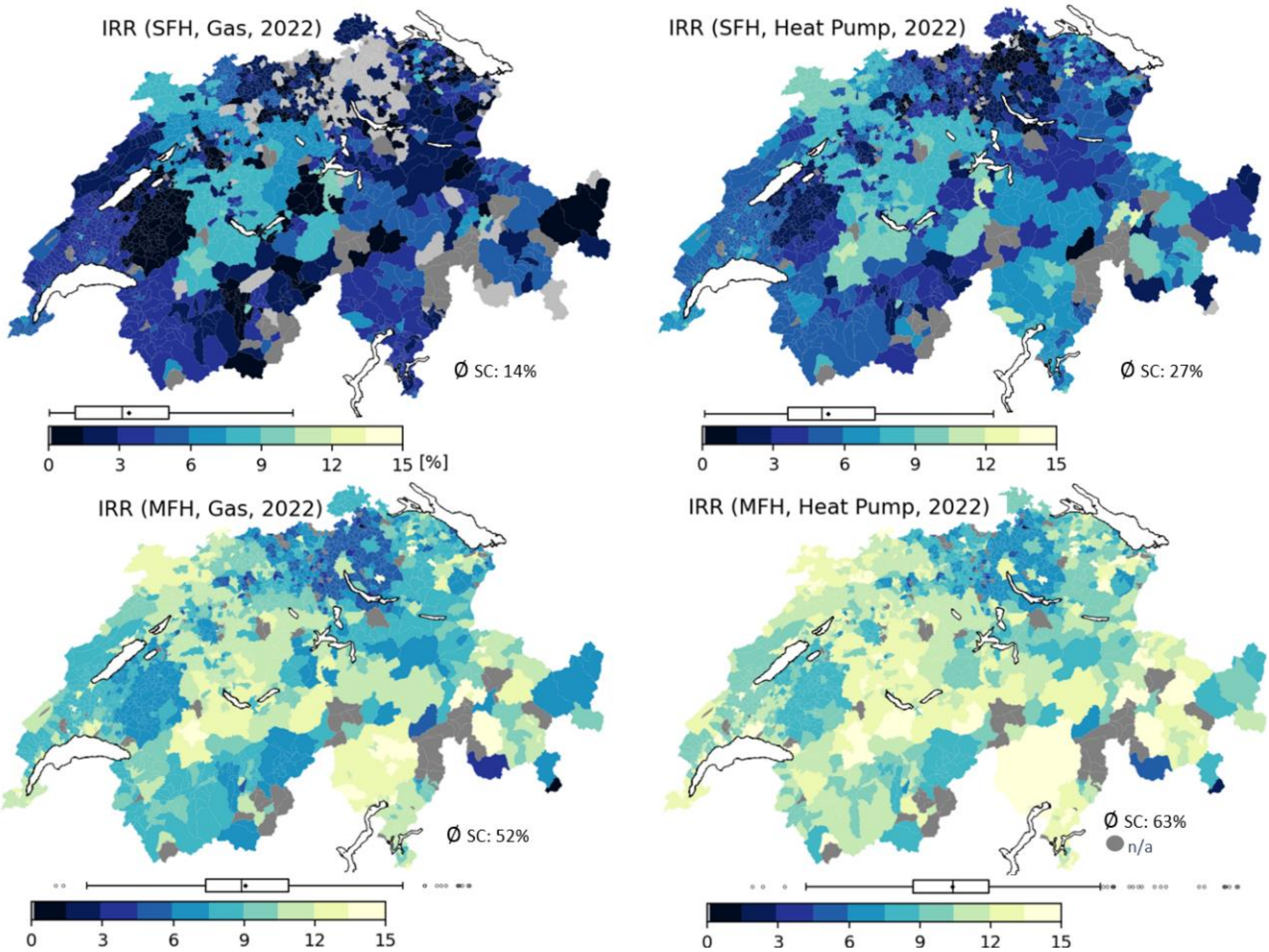

Figure 9: Results of modelling – Spatial differences in IRR for all four use cases. The boxplots displays the average with a point and the median with a line. The box indicates the first and third quartile and the whiskers the range of data without outliers. Values of zero are shown as light grey. Incalculable municipalities are shown in dark grey. SC = Self-Consumption

According to our results, no batteries would be installed. The battery price is too high to reach a break-even point during the system's lifetime (See Appendix Figure A.6 for detailed price information). In reality, however, nearly one in four new PV systems is paired with a battery storage in Switzerland in 2021 (Hostettler & Hekler, 2022), indicating that there are other variables that impact the choice to install batteries besides their economic profitability (customers value the increased resilience or independence). Furthermore, a variance in battery prices could lead to some battery investments being profitable. In the model, however, we use an empirically calibrated cost curve which renders batteries unprofitable across Switzerland. Note that due to increased demand for battery packs from the transport sector and supply bottlenecks, battery systems face increasing costs at the moment, which is likely to change in the next few years.

Since the model's outputs are the results of the best performing PV system in each municipality (details in the Appendix Section 6.1), not all resulting PV systems have the same size[21]. For the first use case - a single-family house with gas heating - there are 1'632 municipalities in which a PV system with a capacity of 12 kWp is installed, the maximum size for a PV system on a single-family house we assume in the model. A histogram with the PV sizes is shown in Figure 10. The second most common capacity for this use case is 6 kWp. A smaller PV system produces less electricity which leads to less energy being fed into the grid and a higher share of self-consumption. If the PV tariff is low, feeding into the system is not lucrative, and a smaller system achieves a higher IRR.

[21] Note that we optimize the PV system in 2 kWp increments.

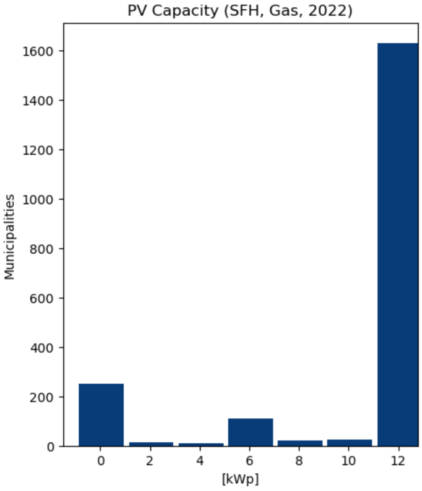

Figure 10: results of modelling – Resulting PV capacities for the use case SFH gas in each municipality. If a capacity of zero is chosen, no PV system is installed since it would lead to a negative IRR. The histograms of the other three use cases are found in Appendix Figure A.3.

To investigate the influence of the rising energy prices in 2023, a scenario analysis was conducted. We applied the electricity prices and PV tariffs from the years 2022 (referred to as low-price level[22]) and 2023 (referred to as high-price level) throughout different years of the PV systems lifetime. Since the high-price level data is only available for the 28 largest energy providers, the scenario analysis covers 1'349 municipalities. In Scenario "2022" and "2023", the low and high-price levels are applied respectively on the entire 30 years of the systems lifetime. In five additional scenarios, we assume the high-price level and a reversion to a low-price level after 1, 2, 5, 10, and 20 years, respectively, to analyze the impact of a short lived (1 and 2 years) and a mid- to long lived (5, 10, and 20 years) price increase.

Figure 11 shows the box plots of all scenarios. Depending on their electricity provider, investors experience a different IRR increase. If the provider is procuring electricity from the spot market and is exposed to market changes, the IRR increases faster since the electricity price and the PV tariff increase, resulting in a more profitable remuneration for electricity produced by the PV system. The increase in the median IRR of 1% in the 2-year scenario (Sc02) illustrates this finding. On the other hand, providers that cover their electricity demand with own production are more resilient to market changes, resulting in the average IRR moving slower than the median in the scenarios. Overall, it can be seen that in some municipalities the high-price level significantly improves the performance of the PV system even if the high price exists only in the first two years (Sc02) of the project, while for other municipalities the change between high- and low-price level is not as drastic.

As stated above the scenario analysis is done for the 28 most prominent energy providers. If smaller energy providers are more reliant on the whole-sale electricity price, they would likely be even more affected by the price level changes than what we see in our results.

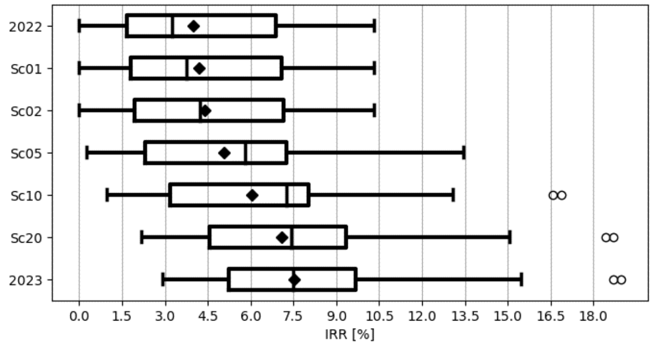

Figure 11: Results of modelling – IRR box plots of different price scenarios. ScXX = Scenario with a change from high to low price after XX years of operation. The boxplots displays the average with a point and the median with a line. The box indicates the first and third quartile and the whiskers the range of data without outliers.

Furthermore, we examined the cash flows over a PV system's lifetime in different cities for the first use case (single-family house heated with gas) to see how the difference of prevailing factors influences the profitability in different cities. Figure 12 shows the cash flows over a PV system's lifetime in Zurich, Bern, Lausanne, and Lucerne. The cashflows are shown at a real discount rate of 3% (i.e. on top of inflation). If the PV system's IRR is below 3%, the project will be unprofitable. In most cases, the PV tariff revenue is the largest positive cash flow and has the largest impact on the systems profitability. In most of the presented cities a local subsidy exists, which additionally supports PV, but some of the projects still fail to be profitable.

For an investor in Zurich, the model optimizes for the installation of a small PV system amounting to 4 kWp. Since the PV tariff is too low, feeding more electricity into the grid reduces the IRR. A low system capacity increases the share of self-consumption and, therefore, the share of electricity valued at the electricity price level. A project in Zurich receives relatively to the initial investment the highest combined capital relief in form of KLEIV, local subsidies, and tax deductions compared to the other cities. However, it still fails to reach a positive Net Present Value (NPV) since the PV tariff is at 7.9 Rp/kWh and too low to pay off the system. On the other hand, investors in Lucerne receive the least investment support compared to the other cities; the investment into the PV system is not tax-deductible, and the additional local subsidy is small. Nevertheless, the PV tariff is at 14.4 Rp/kWh, enough to cover the initial investment by itself.

[22] A main assumption is that the prices from 2022, which have been stable over at least the last 4 years, are a realistic price level for the next 30 years.

While in Zurich, Bern and Lucerne the "gross principle" is applied to tax the revenue, Lausanne uses the "net principle" (see Section 2.2.1).

Subsequently, the main factors for a financially attractive PV investment, as shown for the case of Lucerne, seem to be the PV tariff for systems with a low share of self-consumption and the electricity price for systems with a high share of self-consumption. High subsidies and low taxation contribute to the financial success of a project but cannot mitigate insufficient remuneration for the produced electricity.

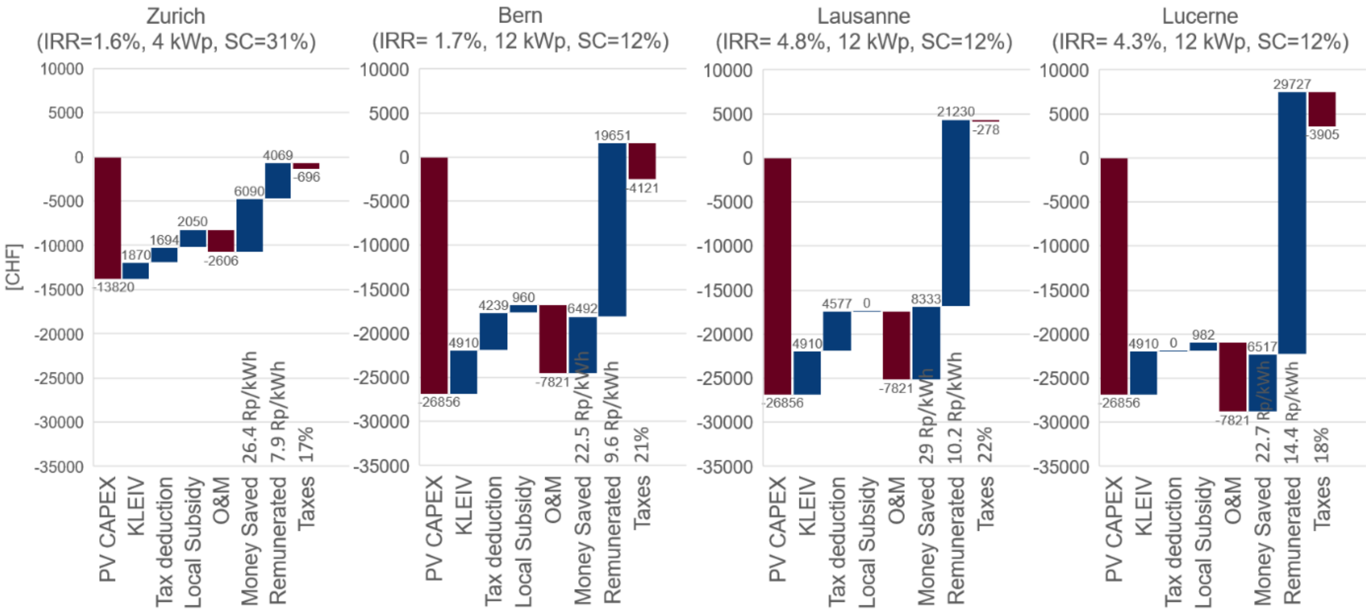

Figure12: Cashflow during the lifetime of a PV system with a discount rate of 3%. SC = Self-Consumption

4 Conclusion and policy implications

In this White Paper we discussed how the Swiss energy policy landscape targeting household PV is geographically fragmented across federation, cantons, and municipalities and functionally split across several policy instruments. We show that there is a high variance in cantonal and municipal policy environments targeting rooftop solar PV. Furthermore, to understand how this fragmentation of the PV policy landscape affects PV investment incentives, we simulate the profitability of a solar PV-Battery system for different household types in all municipalities.

According to economic and public policy literature (for an overview, see e.g., OECD 2016), policy and consequently market fragmentation has ups- and downsides. On the one hand, it enables innovation and experimentation with new policies, technologies and business models in niches, which – if successful – can then diffuse to other jurisdictions/markets (sometimes called the California effect, though keep in mind that California's market size is a multiple of that of entire Switzerland) (Vogel, 1997). On the other hand, policy/market fragmentation (especially if as extreme as in Switzerland) increases search and transaction costs, raises entry barriers for new businesses, thereby reducing competition, reduces economies of scale, and generally limits the efficient allocation of capital. These reasons led the EU to enforce a common electricity market (EU, 2019).

We find that, in the Swiss system that provides the cantons with ample autonomy to decide about and implement PV policies according to their preferences, a majority of the cantons do not use their leeway for innovative or ambitious policies but rather tend towards the minimal requirement. This is particularly true at the level of regulative policy. An illustrative example is the MuKEn 2014, which have included a PV obligation for several years, which are still not implemented in some cantons. Moreover, while currently debated in the canton of Zurich, no canton has so far introduced a requirement to install solar PV on existing buildings in the case of renovations. At the same time, it is noteworthy that a minority of the cantons, with respect to subsidies, indeed makes use of the cantonal autonomy to go beyond horizontally agreed standards and complement the national KLEIV and GREIV with additional cantonal subsidies. This is particularly interesting against the background that horizontal coordination of the cantons (HFM 2015) does explicitly no longer include PV subsidies.

To understand how this geographic and functional policy fragmentation affects the profitability of household PV systems in Switzerland, we use a techno-economic model to estimate variance in the IRR and analyze policy drivers. Our results show that most municipalities and use cases create a favorable investment environment. The primary drivers behind the profitability of PV systems are the initial cost of investment, the irradiation, and, depending on whether the share of self-consumption of produced electricity is high or low, electricity cost or PV tariff, respectively. The extensive range of PV tariffs and electricity prices, resulting from a semi-liberated energy market paired with variable revenue taxation systems, leads to a highly fragmented investment landscape for all four analyzed use cases. Both variables have a tremendous influence on the profitability of household PV installations. In extreme cases, the electricity tariff of neighboring municipalities varies by over 10 Rp/kWh or about 60%. The remuneration for PV electricity can even vary up to 20 Rp/kWh between neighboring municipalities. It is implausible that the value of one kWh of PV-generated electricity should be about 5 times higher in one than in the neighboring municipality. High electricity prices as in 2023 increase the profitability of PV systems but also exacerbate this fragmentation effect. The same is true for policies that reduce the costs of investments.

To secure the increasing deployment of rooftop solar PV, continuing support of policymakers is required. Based on the results presented in this White Paper, we derive the following implications and recommendations:

- **Increasing ambition and harmonization.** Based on our findings, we recommend a reduction of the fragmentation through a harmonization and ratcheting-up process. Given that power sector reform (e.g., resulting in liberalization and consequently strong consolidation) is unlikely in the short to mid-term, the largest harmonization potential lies in the support policies. The federalist structure of Swiss Energy policy would – in theory – allow cantons and municipalities to go for innovative and far-reaching instruments and practices. However, the findings reveal that this subnational autonomy and the informal horizontal coordination between cantons has not been able to generate dynamics towards more ambitious cantonal policies. In other words, fragmentation has created economic cost while not creating ambition. In order to enhance harmonized and ambitious regulative structures across Swiss cantons, more formal (potentially top-down) legislation might be necessary (see also Wittwer et al. (2022) for a similar conclusion). An alternative would be binding intergovernmental cooperation at higher ambition levels. Individual cantons could also top the federal investment grant with a further upfront payment. Not only may this convey the important message that the canton really aims at higher PV deployment, but higher investment subsidies may also still facilitate the installation of rooftop PV for (less affluent) house owners.

- **Getting rid of unnecessary regulative barriers.** The findings also suggest that the current treatment of PV in the tax system might be a barrier for the rapid deployment of rooftop solar PV. Required by federal law and decisions by the federal court, cantons must consider solar PV installations as additional asset that needs to be taxed. However, one way to maximize incentives for house owners to invest in solar PV would be to exempt PV installations from these taxes. A similar point concerns the practice to only allow for tax deduction for PV investments if the building is older than five years. While installing a PV system during construction of the building is certainly most efficient, there might be many reasons – including current delivery problems but also liquidity considerations – why house owners want or need to install a PV plant only a few years later. The current practice, consolidated by a Federal Court decision, is therefore an unnecessary regulation. Again, the number of installations that is effectively delayed as a result of the rule may be small, but the more symbolic message of this negative incentive should not be underestimated.

In sum, the White Paper suggests that a targeted harmonization of the highly fragmented energy policy landscape, aiming at more ambitious minimal standards, is key for an accelerated deployment of solar PV, and thus for reaching the targets of Switzerland's Energy Strategy 2050 and reaching a net-zero economy.

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SWEET EDGE

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7 Appendix

No construction permit required beyond RPG Art. 18a	e. g., in the following cantons	Obligation to install solar PV on newly built buildings: Substitutes	e. g., in the following cantons	Investment grants conditional on…	e. g. in the following cantons
On facades in certain building zones	BS	Substitute fee instead of PV system	BS, LU, NW, OW, SG	no condition	AR
Balcony railings up to 12m2	OW	Compensation through additional energy efficiency measures	AI, SH, TG	winter power generation	GR, UR
Working zones	TG	Investments in other PV plants in own canton	FR, NW	additionally installing PV when renovating the building envelope	BS, GE, TG, UR
Solar plants on the ground or on facades up to 8m2	VD	Exemption if too little solar irradiation	GR, SZ	Only for large PV systems	SH, TG
Flat roof	VS	No installation necessary if protective measures taken on site or if the performance of the plant would be insufficient.	JU	Only for systems co-financed by crowdfunding of at least 20 people.	VD
On facades in industrial, handicraft, and commercial zones with area of at least 100m2 or 30 percent of façade area	VS	No PV necessary if the weighted energy consumption of a building is 20% below the threshold for that type of building.	ZH	Battery storage system	SH, TG
Solar plants in industry-, or trade areas also when not sufficient adapted in industrial and commercial zones	ZH			Conditional on purchase of energy from cantonal energy supplier	GE
		Other regulations related to the obligation to install solar PV on new constructed buildings	**e. g., in the following cantons**	Only with simultaneous promotion of thermal solar energy	GL
		Only for new constructed buildings that are heated, ventilated, cooled or moistened	LU	Bonus if simultaneous construction of heat put system	SH, TG
		Possibility to reduce requirement by means of weighted energy requirement	SG	Only if constructed by companies based in Switzerland	TI
		Obligation to install solar PV on new constructed buildings can be met by a joint project of several buildings	SG	Only for PV plants without KEV	TI

Table A.1.: Conditions and exceptions at the cantonal level

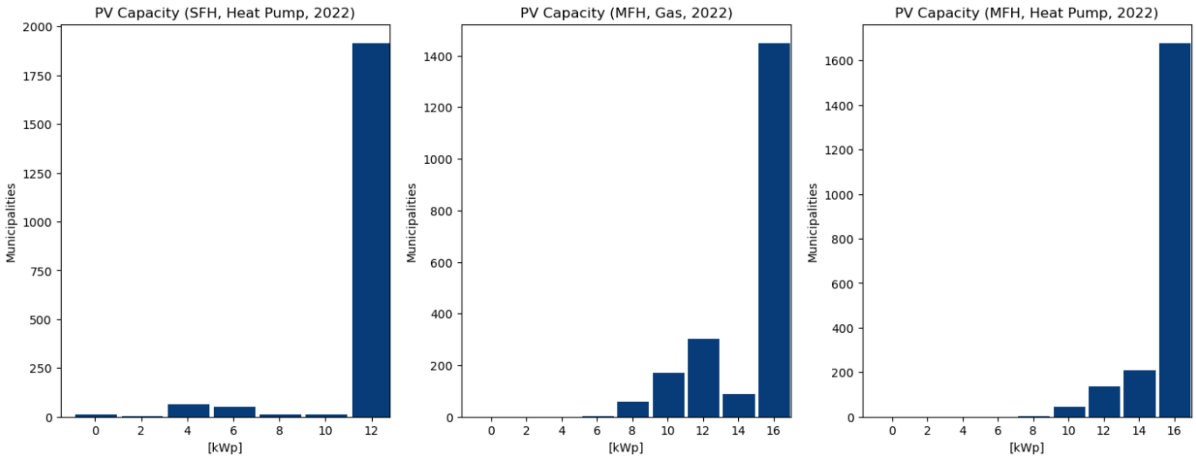

Figure A.3.: Histogram of use case 2, 3 and 4 showing the distribution of chosen PV capacities. Nate that the scales differ. A trend of increasing system sizes for use cases with higher electricity consumption becomes apparent. The higher electricity consumption leads to a larger share of self-consumption. Self-consumed electricity is valued at an electricity price level which is generally higher than remuneration levels. Therefore, each kWh produced has a higher average value, incentivizing for a larger system.

7.1 Use Cases

With alpine-PV in its cradle phase and ground-mounted systems not being relevant in Switzerland, this model focuses on rooftop-mounted PV. Solar rooftop PV is currently a major pillar of renewable energy in Switzerland, yet its potential is not exhausted. Residential buildings, namely Single-Family Houses (SFHs) (23%) and Multi Family Houses (MFHs) (19%), account for 42% of all rooftop potential in Switzerland. The other 58% are shared by mixed-use, industrial, agricultural, and public buildings (Siwssolar, 2020). This thesis focuses on rooftop PV on single and multi-family houses in combination with a storage device. 36% of Swiss homes are owned by their residents (FSO, 2022) and two-thirds of residential buildings are owned by a natural person (FSO, 2022). The model assumes that all revenue goes to the initial investor, which represents the truth for homeowners living in their own property but not necessarily for rental buildings.

Swiss residential buildings are nearly two-thirds SFHs. MFHs with four apartments or less sum up to 21% of buildings. Consequently, to represent the Swiss building stock, a SFH and a four-apartment MFH are chosen to be used in the model.

The average Swiss household consists of 2.19 people, with single and two-person households being the most dominant, at a 36.8% and a 32.7% share, respectively (FSO, 2022). Furthermore, the widest part in the age pyramid of Switzerland is at around 60 years old (FSO, 2022). A large share of the population will retire in the years to come (FSO, 2022). This is translated to the model by assigning a working couple, a one-child family and two retired couples to the MFH, resulting in an average household size of 2.25. Five of the nine people have at least a partial daily occupation, while the four retirees stay at home. For the SFH, a childless working couple was chosen, which represents a household with a relatively low self-consumption.

Two different water- and space-heating options are used in the model, either gas or heat pumps. The latter increases the yearly electricity consumption and operates with a Coefficient of Performance (COP) of three. The figure provides an overview of all four use cases. The consumption of the SFH is 3’200 kWh/year and aligns well with the analysis of Swissolar (EnergieSchweiz, 2021), which reports an energy consumption of 2’900 kWh/year for a two-person SFH. The MFH has slightly over four times the consumption of the SFH, since four of its residents do not have daily occupations.

The sizes of the PV- and battery-system, here referred to as the system capacities, need to be defined. An Analysis by T. Hostettler (Hostettler & Hekler, 2022) of 20’200 installed PV-systems on SFHs revealed an average Power of 10.9 kWp. Assuming the available space limits most installed systems on the roof, a maximal power of 12 kWp has been chosen for the modelled SFH to represent an appropriate space availability of around 82 m2 on a rooftop. Since MFH tend to be larger than SFH, their maximal PV capacity is increased to 16 kWp (or 112 m^2). For batteries, the same maximal capacity has been used in both cases. Figure A.4 show the resulting capacity matrix.

PV-Capacity [kWp]

<table>
<tr><th>Battery-Capacity [kWh]</th><th>0</th><th>2</th><th>4</th><th>6</th><th>8</th><th>10</th><th>12</th><th>14</th><th>16</th></tr>
<tr><td>0</td><td>0|0</td><td>2|0</td><td>4|0</td><td>6|0</td><td>8|0</td><td>10|0</td><td>12|0</td><td>14|0</td><td>16|0</td></tr>
<tr><td>2</td><td>0|2</td><td>2|2</td><td>4|2</td><td>6|2</td><td>8|2</td><td>10|2</td><td>12|2</td><td>14|2</td><td>16|2</td></tr>
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<tr><td>6</td><td>0|6</td><td>2|6</td><td>4|6</td><td>6|6</td><td>8|6</td><td>10|6</td><td>12|6</td><td>14|6</td><td>16|6</td></tr>
<tr><td>8</td><td>0|8</td><td>2|8</td><td>4|8</td><td>6|8</td><td>8|8</td><td>10|8</td><td>12|8</td><td>14|8</td><td>16|8</td></tr>
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<tr><td>14</td><td>0|14</td><td>2|14</td><td>4|14</td><td>6|14</td><td>8|14</td><td>10|14</td><td>12|14</td><td>14|14</td><td>14|16</td></tr>
<tr><td>16</td><td>0|16</td><td>2|16</td><td>4|16</td><td>6|16</td><td>8|16</td><td>10|16</td><td>12|16</td><td>14|16</td><td>16|16</td></tr>
</table>

Figure A.4.: The matrix shows the capacities of the SFH in blue and the additional capacity of the MFH in green. For each combination, the model calculates the IRR, and the best-performing combination is used in the result.

7.2 Techno-Economic Model

Table 2 Overview of all inputs to the techno-economic model.

		Source
Irradiation	Variable [kWh/kWp per hour]	(Pfenninger & Staffel, 2016)
PV Tariff	Variable [CHF/kWh]	(Vese, 2022)
Electricity Cost	Variable [CHF/kWh]	(ElCom, 2022)
Tax rate	Variable [%]	(FTA, 2022)
Local Subsidies	Variable	(EKZ, 2022)
Yearly Load Profile Single-family House gas Single-Family House Heat Pump Multi-Family House Gas Multi-Family House Heat Pump	 3'200 kWh/year 7'900 kWh/year 14'800 kWh/year 23'000 kWh/year	(Pfugradt, 2016)
PV Capex	$y = \frac{5523}{x^{0.4862}} + 156.2 \cdot e^{-0.2321 \cdot x} + 578.4$ [CHF/kWp] $with\ y = Price\ per\ kWp$ $x = Size\ in\ kWp$	(Guillaume, Sauter, & Jacqim, 2021)
PV OPEX	33.25 CHF/kWp p.a.	(SFOE, 2017)
PV Characteristics Lifetime Degradation	 30 years 0.5 % p.a.	 (SFOE, 2021) (SFOE, 2021)
Battery CAPEX	$y = 3095.7 \cdot x^{-0.424}$ [CHF/kWh] $With\ y = Price\ per\ kWh$ $x = Size\ in\ kWh$	
Battery OPEX	4 CHF/kWh p.a.	(Cole, Frazier, & Augustine, 2021)
Battery Characteristics Lifetime Degradation Round trip efficiency Discharge Depth	 15 years 1.5% p.a. 0.9 1 (price reflects usable capacity)	 (Cole, Frazier, & Augustine, 2021) (Tesla, Inc., 2017) (Cole, Frazier, & Augustine, 2021)

The techno-economic model uses multiple inputs to calculate the Internal Rate of Return (IRR) of different PV and battery capacity combinations for each municipality in Switzerland. The code takes the use cases and the system capacities described above. A capacity matrix is created in which each combination of PV and battery size is present. The yearly cash flow for each municipality and capacity combination is calculated for the system's entire lifetime. Following Equation is solved to calculate the IRR (Brealy & Myers, 2000). The highest IRR decides the system capacities for each municipality.

$$\sum_{n=0}^{N} \frac{c_n}{(1+IRR)^n} = 0$$

$$\begin{aligned} \text{with } c &= \textit{cashflow} \\ N &= \textit{Lifetime of project and investment year} \\ n &= \textit{Year} \\ IRR &= \textit{Internal Rate of Return} \end{aligned}$$

Since the model compares systems of different sizes, the IRR was chosen as the measurement of choice. In reality, investors choose the option with the highest Net Present Value (NPV) as long as the IRR is above the given cost of capital. People would invest in larger systems than the model predicts based on the IRR. However, to compare the best-performing combinations of systems, the IRR must be used. Based on ongoing work from the Sweet Edge project, a threshold of 3% IRR has been chosen to determine whether a system is of interest to a private investor

Since electricity costs and PV tariffs experience significant changes between 2022 and 2023, they pose a considerable uncertainty factor. The model analyses several scenarios. In the first scenario, prices were held at the 2022 level for the entirety of the system's lifetime. A second scenario kept prices stable at 2023 levels. There are three more scenarios simulating prices that return to today's price level after 2023. Sc05 returns to 2022 prices in the fifth year of operation, Sc10 does so in the tenth year and Sc20 in the 20^{th}

The inputs to the code can be divided into two groups, general and municipal inputs. General inputs are applied nationwide; each municipality receives the same inputs. The following are general inputs and will be explained in more detail in this chapter:

- Yearly load profile
- PV CAPEX & OPEX
- PV panel characteristics
- Battery CAPEX & OPEX
- Battery characteristics

The municipal inputs differ on a municipal level and are the driver behind the spatial heterogeneity of the attractiveness of PV systems in the model. They consist of the following inputs:

- Irradiation
- Electricity Cost
- PV tariff
- Taxes
- Local Subsidies

Yearly Load Profile

The yearly load profiles for the use cases were calculated using the LoadProfileGenerator application (Pfugradt, 2016). The application models load profiles based on preset behaviour and household appliances on a minute resolution. The hourly sums were calculated to match the time resolution with the irradiation. The inputs used to generate each load profile can be found in Table A.3.

Table A.3.: Inputs for the LoadProfileGenerator

	Single Family House	Multi Family House
House types	HT06	HT11
Temp. Profile	Dresden	same as SFH
Location	Munich	same as SFH
Tot. Energy cons. per year	15000	20000
Heating temperature	15	same as SFH
Room Temperature	20	same as SFH
Heat pump system	Warm Water Mixer Hot Water – Continuous Flow Heat Pump COP3 Space Heating – Continuous Flow Heat Pump COP3	same as SFH
Gas system	Warm Water Mixer Hot Water – Continuous Flow Gas Water Boiler Space Heating – Continuous Flow Gas Heater	same as SFH
Residents	CHR01	CHR01, CHR03, CHR16, CHR51
Charging station settings	Charge at Work	same as SFH

PV CAPEX & OPEX

Energieschweiz (Guillaume, Sauter, & Jacqim, 2021) analysed over 3'000 solar panel installations in Switzerland in 2020. They provide a function for the price of installations depending on their size. The data includes prices of realised projects and offers from installers and is depicted in Figure A.5. Integrated solar systems are excluded. Therefore, the data only consists of prices of roof-mounted systems. They state that installations on new buildings and flat rooftops tend to be cheaper than on existing and gable roofs. Following Function was used in the model to calculate the cost for each PV capacity.

$$y = \frac{5523}{x^{0.4862}} + 156.2 \cdot e^{-0.2321 \cdot x} + 578.4$$

$$\text{with } y = Price\ per\ kWp$$
$$x = Size\ in\ kWp$$

Additionally, the government grants a subsidy to PV systems smaller than 100 kWp, called Einmalvergütung für Kleine Photovoltaikanlagen (KLEIV). The KLEIV reimburses 350 CHF as a base contribution, and 380 CHF per kWp installed (Pronovo, 2022). The model assumes the subsidy to be received in the same year as the installation is done.
A SFOE report from 2017 (SFOE, 2017), which is still referred to by BFE in 2021 (SFOE, 2021), sets the operation and maintenance (O&M) cost at around 3-4 Rp/kWh. This cost includes the replacement of the inverter. Using the interim results of the authors (Baumgarnter, Toggweiler, Sanchez, Maier, & Schär, 2015) and their assumption of 950 kWh/kWp, the cost was translated to 28.5-38 CHF/kWp and year. For the model, the mean of 33.25 CHF/kWp was used, which is around 1.5 per cent of the capital investment for a 10 kWp system.

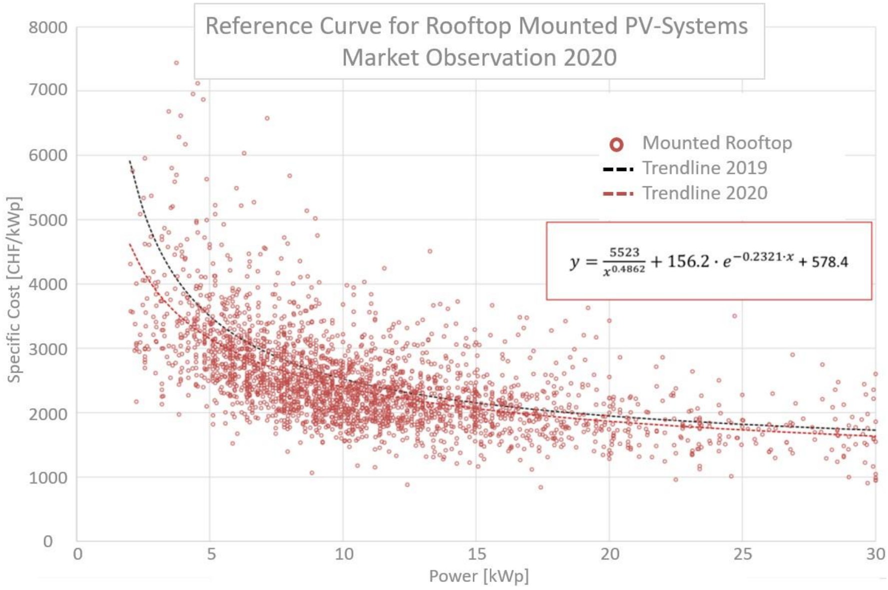

Figure A.5.: Scatter plot of all data points of 2020 installation prices. The x-axis is the size of the installed system, and the y-axis is the specific cost in CHF/kWp. (Guillaume, Sauter, & Jacqim, 2021)

PV Panel Characteristics

The system's lifetime was set to 30 years (SFOE, 2021). Over its lifetime, the PV system experiences degradation, decreasing its yearly output. SFOE uses a degradation of 0.5% (SFOE, 2021), which is also the median degradation reported by NREL studies (Jordan & Kurtz, 2012; NREL, 2018). They report the average degradation at 0.8% per year for silicon panels and the median at 0.5%. In the model, the median degradation of 0.5% per year was used, resulting in a 14% performance loss by the end of the PV system's lifetime.

Battery CAPEX & OPEX

The cost of batteries for the end consumer in Switzerland seems to be poorly documented. A 2017 publication from EnergieSchweiz shows the specific cost of stationary energy storage systems in Switzerland (SFOE, 2019). However, since the data is over five years old, it was used as reference data, and 30 installers of PV and battery systems in Switzerland were asked about their respective prices for battery systems in the range of 0 to 20 kWh when installed alongside a rooftop PV system. From a total of five responses, two sent data differentiating between the battery being installed individually and alongside a PV system. The data points of the 2017 report and the replies from the industry are depicted in Figure A.6. The data from the industry was used to derive the power trend line describing the cost of a battery per kWh:

$$y = 3095.7 \cdot x^{-0.424}$$

$$with\ y = Price\ per\ kWh$$
$$x = Size\ in\ kWh$$

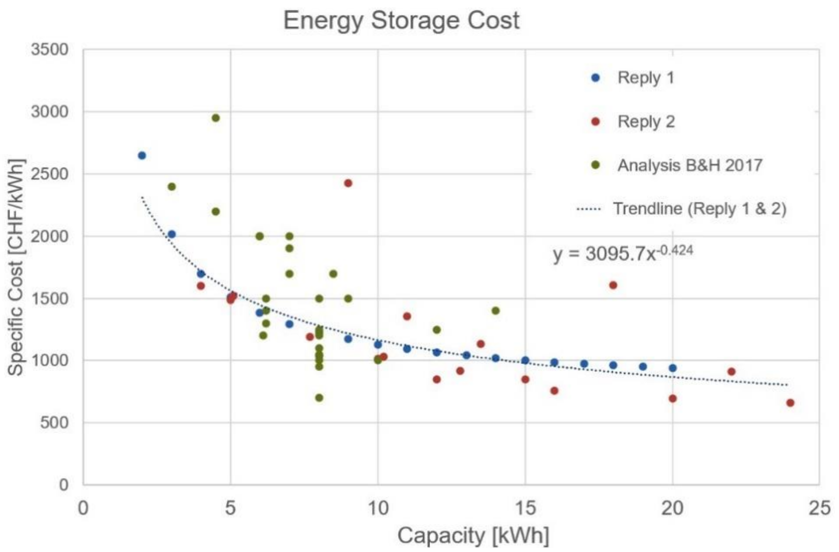

Figure A.6.: Scatter plot of all data points received from battery installers (Reply 1 and Reply 2) and data from a report from 2017 [51] as a comparison. The trend line was created using the data points from Reply 1 & 2.

Since the battery life is shorter than the PV lifetime, a replacement battery must be purchased. The price of the replacement was set using the data provided by the installers. Expenditures for a first-time installation were subtracted from labour and battery cost to get the cost per capacity. A cost reduction factor of 0.6 was applied for the year 2037 to account for learning effects (Cole, Frazier, & Augustine, 2021; Bloomberg, 2020). The O&M costs were set to 4 CHF per installed kWh for a system including degradation (Cole, Frazier, & Augustine, 2021).

Battery Characteristics

The lifetime of the battery was set to 15 years (Cole, Frazier, & Augustine, 2021), after which it needs to be replaced. The round-trip efficiency was set to 0.9 (Cole, Frazier, & Augustine, 2021), and the discharge depth was modelled as one since the prices reflect the actual usable capacity. The degradation was set to 1.5% per year to reach a similar capacity fade by the end of its lifetime as the Tesla Powerwall's warranty guarantees after ten years (Tesla, Inc., 2017). The model uses an implicit assumed C-rating of one, meaning the battery can be fully emptied in an hour.

Irradiation

The irradiation data stems from RenewablesNinja (Pfenninger & Staffel, 2016). The coordinates were set to the centroids of all municipality polygons. As angle inputs for tilt and azimuth, 35° and 180° were used, respectively. Furthermore, the panel size was set to 1 kWp, so the data can be multiplied by the system capacity to get the final power output. The yield of a 1 kWp PV system with a degradation of

0.5% is around 950 kWh/year in Switzerland according to SFOE (SFOE, 2021). This can be translated to

a yield of 1'010 kWh during its first year of operation. To get a similar average power output in the first year across all Swiss municipalities, the system loss was set to 0.3, which resulted in an average energy yield of 1'059 kWh/year. The satellite data was set to merra2.

Electricity Cost

Elcom publishes a list of energy providers and their yearly electricity prices in CHF/kWh each year (ElCom, 2022). For the years 2022 and 2023, those lists already show in which municipalities those prices are applied. For the years 2020 and 2021, the 2022 list was used to link Distribution System Operators (DSOs) to their respective municipalities. The given electricity prices are averaged values for given user profiles. An electricity price includes four variable rates; the energy price, the grid costs, and a municipal and national tax. Often a monthly or yearly flat rate must be paid as well. Furthermore, the energy price and the grid costs are often split into a high and a low tariff. Energy providers set their schedules differently, with high tariffs applied during the daytime on working days and sometimes at weekends. A price close to the high tariff must be used to calculate savings achieved by a PV system. Elcom's category H8 was chosen as a basis to calculate the high tariffs since it represents a highly electrified apartment with a high share of electricity consumed during the daytime. However, since ElCom assumes a consumption profile, the grid costs and the energy price already include a fixed ratio of high and low tariffs and the flat rate, respectively. To correct for those inaccuracies, the online available energy price and the grid costs of 29 of the largest DSOs, (partially) covering 70% of municipalities, were compared to the costs provided by ElCom's H8 category (see Table A.4). The H8 data set was adjusted using the average deviation found or, if possible, replaced by the gathered data. The median electricity tariff used to value the self-consumed electricity from the PV system lies at 22 Rp/kWh. 50% of municipalities have tariffs between 20.3 and 22.5 Rp/kWh with outliers in the range of 12 to 34 Rp/kWh.

PV tariff

Vese keeps a list of DSOs and the PV tariff they offer for solar electricity (Vese, 2022). Using Elcom's electricity cost list, the feed-in-tariff data can be linked to the municipalities via their DSO-number. In some cases, there are one or more fitting DSO per municipality. If so, the average electricity price and feed-in tariff were used. If none of the DSOs listed to be responsible for a municipality can be found in Elcom's electricity cost list, the model cannot calculate any results for the municipality. For 2022, Vese's data includes the PV tariffs of around 490 energy providers. For the year 2023, the PV tariff data is available for the 30 most prominent energy providers (Fischer, 2022).

The median PV tariff in the year 2022 is 9.9 Rp/kWh, with 50% of municipalities receiving between 9.3 and 13.1 Rp/kWh and the total range being 5 to 22 Rp/kWh. Two of the largest energy providers, BKW and CKW remunerative at around 18.5 Rp/kWh, which increases the average to over 11 Rp/kWh.

Table A.4.: Difference between the Elcom H8 Data and public tariff information of DSOs

	2022					2023						
Name	H8	High Tariff	Low Tariff	Avg. Feed in	Diff. to H8	H8	High Tariff	Low Tariff	Avg. Feed in	Diff. to H8	Covered Municip.	Size Ranking
BKW Energie AG	20.04	17.00	17.00	17.00	-3.04	20.34	17.30	17.30	17.30	-3.04	322	1
Romande Energie SA	16.80	17.56	12.80	16.88	0.08	27.79	30.40	18.10	28.64	0.86	260	2
Groupe E SA	17.79	17.53	8.75	16.28	-1.52	21.99	21.48	11.90	20.11	-1.88	146	3
Elektrizitätswerke des Kantons Zürich EKZ	13.77	15.84	11.21	15.18	1.41	18.57	21.02	16.71	20.40	1.84	132	4
AEW Energie AG	16.34	17.01	12.76	16.40	0.07	21.23	22.21	17.36	21.52	0.29	73	5
Centralschweizerische Kraftwerke AG CKW	17.55	18.50	14.80	17.97	0.42	25.65	25.90	22.20	25.37	-0.28	71	6
Elektra Baselland	17.44	20.30	15.20	19.57	2.13	21.43	18.86	15.66	18.40	-3.02	55	7
Aziende Industriali di Lugano SA AIL	15.68	15.26	15.26	15.26	-0.42	22.62	21.66	21.66	21.66	-0.96	51	8
Primeo Energie	17.78	18.51	13.91	17.85	0.07	27.65	29.41	22.46	28.42	0.77	48	9
Services Industriels de Genève SIG	16.34	19.45	12.55	18.46	2.12	20.68	24.45	15.85	23.22	2.54	44	10
Società Elettrica Sopracenerina SA (Ticino)	18.89	17.96	17.96	17.96	-0.93	23.48	22.91	22.91	22.91	-0.57	38	11
St.Gallisch-Appenzellische Kraftwerke AG SAK	16.81	16.86	12.90	16.29	-0.52	23.25	14.61	18.16	15.12	-8.13	38	12
Repower AG	19.86	17.46	17.46	17.46	-2.40	22.66	20.26	20.26	20.26	-2.40	33	13
Elektrizitätswerk Obwalden	16.54	16.96	12.31	16.30	-0.24	24.93	25.26	21.11	24.67	-0.26	30	14
Elektrizitätswerk des Kantons Schaffhausen AG EKS	16.30	19.19	15.20	18.62	2.32	20.97	22.04	17.29	21.36	0.40	25	15
OIKEN SA	15.60	16.73	11.69	16.01	0.41	26.40	27.27	22.07	26.53	0.13	24	16
Genossenschaft Elektra, Jegenstorf	16.39	14.86	14.86	14.86	-1.53	28.19	26.96	16.96	25.53	-2.66	22	17
Eniwa AG	17.52	18.06	14.46	17.55	0.02	23.04	26.37	19.46	25.38	2.35	17	18
Société des Forces Electriques de la Goule	20.36	20.73	14.08	19.78	-0.58	20.79	18.48	16.48	18.19	-2.60	17	18
EWA-energieUri AG	18.53	18.21	12.07	17.33	-1.19	26.29	25.81	19.36	24.89	-1.40	16	20
Kantonales Elektrizitätswerk Nidwalden	14.34	13.66	11.60	13.37	-0.97	15.14	14.46	12.46	14.17	-0.97	11	23
Regionale energie Lieferung Leuk AG	15.72	16.71	11.11	15.91	0.20	19.49	19.36	13.06	18.46	-1.03	11	23
WWZ Netze AG	17.53	19.34	11.00	18.15	0.62	25.87	26.56	21.26	25.80	-0.07	11	23
ewz	17.35	21.97	10.77	20.37	3.02	17.94	21.10	10.35	19.56	1.62	9	28
Gruyère Energie SA	16.35	17.78	11.23	16.84	0.50	24.78	26.50	19.42	25.49	0.71	9	28
Services Industriels de Lausanne SIL	17.74	20.14	13.69	19.22	1.48	24.27	27.37	19.38	26.23	1.96	7	33
Industrielle Werke Basel IWB	18.63	22.36	15.21	21.34	2.71	21.90	25.76	18.36	24.70	2.81	3	50+
Energie Wasser Bern ewb	16.26	15.96	15.96	15.96	-0.30	20.51	20.11	20.11	20.11	-0.40	1	50+
Stadtwerk Winterthur	18.02	18.78	12.93	17.94	-0.08	24.30	25.58	19.18	24.67	0.37	1	50+
Average	17.21	17.93	13.49	17.29	0.14	22.95	23.00	18.13	22.30	-0.48		
As Percentage of H8				100.47	0.82				-0.03	-0.02		
Std. Derivation				0.09	1.48				0.10	2.26		

Taxes

The Federal Tax Administration provides a geographical comparison of tax burden statistics for variable inputs (FTA, 2022). The variables were set to represent the largest group in Switzerland within each category: married couple (FSO, 2022), no kids (FSO, 2022), single income and roman catholic (EDA, 2022). The average Swiss household income in 2019 was around 115'000 CHF per year (FSO, 2022). The tax calculation tool provides a predetermined choice of income, of which 100'000 CHF was chosen as yearly income for the households. The tax data for an income per year between 50'000 and 100'000 CHF with an increment of 10'000 CHF, is used to account for a tax deduction of the PV investment. The tax per municipality was extracted from those five tables of different gross incomes, and the possible savings were calculated. Ex.: With the assumption that a household earns 100'000 CHF, a deductible investment of 20'000 CHF would be equal to the household earning 80'000 CHF. The difference in owed taxes of those two incomes is the amount saved by the investor. Since the amount deducted from the gross income (insurance premiums and other mandatory expenditures) to calculate the taxable income is higher for larger incomes, the difference in taxable income between the sets is smaller than the difference in gross income. This leads to a slight underestimation of the actual saving from the deduction of the PV system. Since the steps between sets are 10'000 CHF and investments can fall anywhere within that 10'000 CHF, the savings were linearly interpolated between the sets. According to Swissolar (Swissolar, Vese, EnergieSchweiz, 2021), the investment in battery often cannot be separated from the PV investment due to non-transparent billing. Therefore, the battery cost was added to the PV investment. In some cantons (AG, BE, OW, SZ, SG and ZH), the addition of batteries can even be deducted after the PV installation. In one canton, Lucerne, neither the Battery nor the PV investment is deductible. The model assumes that the KLEIV and local subsidies are rewarded in the same year the investment was made. Therefore, the subsidies are subtracted from the deductible amount.

The revenue created by the PV tariff is taxed as additional income at the tax rate in the highest tax bracket. The revenue is taxed with the highest marginal tax rate into which the household's income reaches. Since the dataset only provides the average tax rate, the tax generated by the last earned 10'000 CHF was calculated and used for the PV revenue. Not every canton uses the same taxation system for PV revenue. The Nettoprinzip, used by 14 cantons (AG, AR, BL, GR, JU, LU, NE, NW, SG, SH, TG, TI, UR and ZG), taxes the revenue after balancing it with the electricity bill. As long as the household spends more on electricity than it earns from the PV tariff, it will pay zero tax. Cantons using the Bruttoprinzip (AI, BE, BS, FR, GE, GL, OW, SO, SZ, ZH) tax all revenue generated. In the cantons of Valais and Vaud, the first 10'000 kWh are tax-free. The tax rate on the last 10'000 CHF of a 100'000 CHF income shown in Figure A.7 is an indicator of the differences in tax deduction and is used to tax the revenue from the PV tariff. As mentioned above, there are three systems in how the revenue is taxed, which also influences the heterogeneity of the tax situation in Switzerland. The lowest tax rate is in Zug, with tax rates as low as 7.5% and the highest in Geneva and Neuchâtel at 27%.

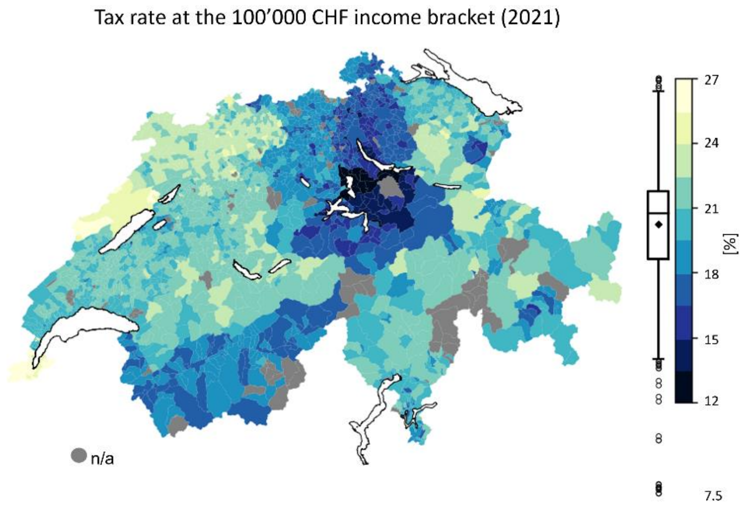

Figure A.7.: Tax rate at the 100'000 CHF income bracket for each municipality. The boxplot displays the average with a point and the median with a line. The box indicates the first and third quartile and the whiskers the range of data without outliers

Local Subsidies

The Elektrizitätswerke des Kanton Zürichs (EKZ) provides a list of PV-related subsidies all across Switzerland (EKZ, 2022). This list uses postal codes to link the subsidies to their respective regions. To use the list in the model, the postal codes must be translated to municipality numbers. A 2019 publication of the Swiss Federal Office of Statistics (BFS) (FSO, 2019) was used to accomplish this. Federal postal codes stand in a non-exclusive n:m relation with municipalities. All entries of postal codes appearing on the list more than once and covering less than 10% of all buildings in a municipality were disregarded to reduce falsely covered areas. In a second step, all communal merges since 2019 were corrected (SFO, 2022). Subsidies for PV systems differing from the ones used in this simulation or with additional conditions were excluded. Certain subsidies have limited funding and are not paid throughout the whole year. In the model, the assumption is made that all subsidies are available.

In addition to the national subsidy system KLEIV, 390 municipalities receive local subsidies. The subsidies vary in type and amount of remuneration. Figure 5 shows the local one-time subsidies for a 10 kWp PV system. Five municipalities receive a FIP, and 126 receive subsidies for battery systems.