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Highlights Report Year 2

EDGE

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sweet swiss energy research for the energy transition

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EDGE

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

Highlights

EDGE was fully running in year 2, including various collaborative and individual research activities:

- The first EDGE White Paper showed a very high degree of fragmentation and a rather low ambition level in Swiss policy on household PV. This policy fragmentation creates massive variance in PV profitability. The White Paper proposed a strategy to reduce this policy fragmentation while increasing ambition by means, such as harmonizing the taxation of profits from solar PV 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. The EDGE Policy White paper received substantial media visibility with over 130 press articles.

- A representative population survey with over 4'900 respondents was completed. The survey included questions on policy goals and preferences, solar PV adoption, open-space PV, socio-demographics etc. The survey will be a crucial database for many subsequent EDGE activities and for providing information on what the public thinks regarding various elements of the Energy Strategy 2050.

- The first EDGE model inter-comparison benchmarked three models (Expanse, Nexus-e, and OREES) to produce spatially-explicit electricity scenarios for Switzerland. All three models aligned on high capacities of solar PV in 2035, but there was flexibility whether PV is placed on roofs and facades in densely populated areas or also in the Alpine areas. Other technologies, such as wind power or biomass, could complement PV and massively reduce import. Electricity interconnection with Europe remained key because any increases in electricity demand or lower deployment of renewable generation were compensated by electricity import.

Many other research and implementation frontiers were pushed by collaboration between EDGE teams, for example, by building a recommender tool for the Swiss municipalities, by estimating the financial needs for key renewable technologies, by building new modelling capabilities, in particular for EV penetration and supply security, and by revising estimates of high-Alpine wind and solar resources. On the latter, during WEF 2022, a successful demonstration of the potential of high-Alpine PV to Swiss politicians from the Federal Council could be made. This demonstration showed a potential solution for a high share of winter energy production, a topic that was also picked up by the Swiss legislation (Solarexpress).

Faits marquants

EDGE a fonctionné à plein régime au cours de la deuxième année, avec diverses activités de recherche collaboratives et individuelles :

- Le premier livre blanc d'EDGE a montré un degré très élevé de fragmentation et un niveau d'ambition plutôt faible dans la politique suisse en matière de photovoltaïque domestique. Cette fragmentation de la politique crée de larges variations dans la rentabilité de l'énergie photovoltaïque. Le livre blanc propose une stratégie visant à réduire cette fragmentation tout en augmentant l'ambition par des moyens tels que l'harmonisation de l'imposition des bénéfices provenant de l'énergie solaire photovoltaïque au niveau cantonal. De part leur propriété des services publics d'électricité, les municipalités et les cantons devraient également s'efforcer de réduire les différences géographiques flagrantes entre les tarifs de rachat et les prix de l'électricité. Le livre blanc sur la politique d'EDGE a bénéficié d'une grande visibilité dans les médias, avec plus de 130 articles.

- Une enquête représentative de la population a été réalisée auprès de plus de 4 900 personnes. L'enquête comprenait des questions sur les objectifs et les préférences politiques, l'adoption de l'énergie solaire photovoltaïque, les parcs photovoltaïques au sol, les données sociodémographiques, etc. L'enquête constituera une base de données essentielle pour de nombreuses activités EDGE ultérieures et pour fournir des informations sur ce que le public pense des différents éléments de la stratégie énergétique 2050.

- La première comparaison des modèles EDGE a évalué trois modèles (Expanse, Nexus-e et OREES) afin de produire des scénarios d'électricité spatialement explicites pour la Suisse. Les trois modèles s'alignent sur des capacités élevées d'énergie solaire photovoltaïque en 2035, mais proposent différentes réponses à la question de savoir si l'énergie solaire photovoltaïque est placée sur les toits et les façades dans les zones densément peuplées ou également dans les zones alpines. D'autres technologies, telles que l'énergie éolienne ou la biomasse, pourraient compléter l'énergie photovoltaïque et réduire massivement les importations. L'interconnexion électrique avec l'Europe est restée essentielle, car toute augmentation de la demande d'électricité ou tout ralentissement du déploiement de la production d'énergie renouvelable a été compensé par l'importation d'électricité.

La collaboration entre les équipes EDGE a permis de repousser de nombreuses autres frontières en matière de recherche et de mise en œuvre, par exemple en construisant un outil de recommandation pour les municipalités suisses, en estimant les besoins financiers pour les principales technologies renouvelables, en développant de nouvelles capacités de modélisation, en particulier pour la pénétration des VE et la sécurité de l'approvisionnement, et en révisant les estimations des ressources éoliennes et solaires dans les Alpes. Sur ce dernier point, au cours du Forum Économique Mondial 2022, une démonstration réussie du potentiel de l'énergie photovoltaïque dans les Alpes a pu être faite à des politiciens suisses du Conseil fédéral. Cette démonstration a montré une solution potentielle pour une part importante de la production d'énergie en hiver, un sujet qui a également été repris par la législation suisse (Solarexpress).

Highlights

EDGE war im zweiten Jahr umfassend aktiv, mit verschiedenen kollaborativen und individuellen Forschungsaktivitäten:

- Das erste EDGE White Paper zeigt einen sehr hohen Grad an Fragmentierung und eher schwache Ambitionen der Schweizer Politik im Bereich der Photovoltaik für Haushalte. Die Fragmentierung der Strategien und Massnahmen der Politik führt zu massiven Unterschieden in der Rentabilität der Photovoltaik. Das EDGE White Paper schlägt eine Strategie vor, um diese Fragmentierung zu verringern und gleichzeitig die Zielvorgaben zu erhöhen, z.B. durch die Harmonisierung der Besteuerung von Gewinnen aus der Photovoltaik auf kantonaler Ebene. Gemeinden und Kantone, die als Eigentümer von Unternehmen der Elektrizitätsversorgung fungieren, sollten auch darauf hinarbeiten, die starken geografischen Unterschiede bei den Einspeisetarifen und Strompreisen zu verringern. Das EDGE Policy White Paper fand mit über 130 Presseartikeln ein grosses Medienecho.

- Eine repräsentative Bevölkerungsumfrage mit über 4'900 Teilnehmenden wurde durchgeführt. Die Umfrage enthielt Fragen zu politischen Zielen und Präferenzen, zur Einführung von Photovoltaik, zu Freiflächen-PV, zu soziodemografischen Merkmalen usw. Die Umfrage bildet eine wichtige Datenbasis für viele nachfolgende EDGE-Aktivitäten und gibt Aufschluss darüber, was die Öffentlichkeit über die verschiedenen Elemente der Energiestrategie 2050 denkt.

- Im ersten EDGE-Modellvergleich wurden die drei Modelle Expanse, Nexus-e und OREES miteinander verglichen, um räumlich explizite Stromszenarien für die Schweiz zu erstellen. Alle drei Modelle gingen von hohen PV-Kapazitäten im Jahr 2035 aus, aber es bestand Flexibilität, ob die Photovoltaik auf Dächern und Fassaden in dicht besiedelten Gebieten oder auch in den alpinen Gebieten installiert werden sollte. Andere Technologien wie Windkraft oder Biomasse könnten die Photovoltaik ergänzen und die Stromimporte massiv reduzieren. Der Stromverbund mit Europa ist nach wie vor von zentraler Bedeutung, da jeder Anstieg der Stromnachfrage und jeder geringere Einsatz erneuerbarer Energien durch Stromimporte kompensiert werden muss.

Durch die Zusammenarbeit zwischen den einzelnen EDGE-Teams wurden viele andere Forschungs- und Umsetzungsmöglichkeiten vorangetrieben, so zum Beispiel die Entwicklung eines Empfehlungstools für die Schweizer Gemeinden (Recommender Tool), die Abschätzung des Finanzbedarfs für die wichtigsten erneuerbaren Technologien, der Aufbau neuer Modellierungskapazitäten, insbesondere für die Elektromobilität und die Versorgungssicherheit, sowie die Überarbeitung der Schätzungen der hochalpinen Wind- und Solarressourcen. Während des WEF 2022 konnte das Potenzial der hochalpinen Photovoltaik den Schweizer Politikern des Bundesrats erfolgreich demonstriert werden. Diese Demonstration zeigte Lösungswege für eine hohe Produktion erneuerbarer Energie im Winter, ein Thema, das auch in der Form von der Schweizer Gesetzgebung aufgegriffen wurde (Solarexpress).

Punti salienti

Il consorzio EDGE è stato pienamente operativo nel secondo anno, includendo varie attività di ricerca sia collaborative che individuali. In particolare,

- Il primo Libro Bianco (White Paper) di EDGE ha evidenziato un elevato grado di frammentazione e un livello di ambizione piuttosto basso nelle politiche concernenti il fotovoltaico domestico in Svizzera. Questa frammentazione delle politiche crea una forte variazione nella redditività del fotovoltaico nazionale. Il Libro Bianco ha proposto una strategia per ridurre la frammentazione delle politiche e aumentare il loro livello di ambizione, ad esempio armonizzando la tassazione dei profitti del fotovoltaico a livello cantonale. Attraverso la proprietà delle aziende elettriche, i comuni e i cantoni dovrebbero inoltre adoperarsi per ridurre le forti differenze geografiche nelle tariffe onnicomprensive (Feed in Tariff) e nei prezzi dell'elettricità. Il Libro Bianco di EDGE concernente queste politiche ha ottenuto una notevole visibilità mediatica con oltre 130 articoli sui mezzi di comunicazione di massa.

- È stato completato un sondaggio rappresentativo della popolazione inclusivo di oltre 4.900 intervistati. L'indagine ha incluso domande relative agli obiettivi e alle preferenze concernenti le politiche energetiche, l'adozione del solare fotovoltaico, il fotovoltaico in spazi aperti, i dati socio-demografici, ecc. Il sondaggio costituisce una solida base di dati cruciale per molte attività EDGE successive e per fornire informazioni concernenti l'opinione pubblica in merito a vari elementi della Strategia Energetica 2050.

- La prima comparazione sistematica tra i modelli di EDGE ha messo a confronto tre modelli computazionali (Expanse, Nexus-e, e OREES) per produrre scenari elettrici con forte connotazione spaziale per la Svizzera. Tutti e tre i modelli si sono allineati sulle alte capacità del solare fotovoltaico nel 2035, ma c'è stata una certa flessibilità nel collocare il fotovoltaico su tetti e facciate nelle aree densamente popolate o anche nelle aree alpine. Altre tecnologie, come l'energia eolica o la biomassa, potrebbero integrare il fotovoltaico e ridurre in modo massiccio le importazioni elettriche. L'interconnessione elettrica con l'Europa si è rivelata fondamentale, perché questi modelli concordano che qualsiasi aumento della domanda di elettricità o il minore impiego di generazione rinnovabile sono necessariamente compensati dall'importazione di elettricità.

Molte altre frontiere della ricerca e dell'implementazione sono state spinte dalla collaborazione tra i team EDGE, ad esempio costruendo uno strumento di raccomandazione per i sistemi energetici utilizzabile dai comuni svizzeri, stimando il fabbisogno finanziario per le principali tecnologie rinnovabili, costruendo nuove capacità di modellazione teorica e computazionale, in particolare relative alla penetrazione dei veicoli elettrici e alla sicurezza delle reti di approvvigionamento e distribuzione elettrica, e rivedendo le stime delle risorse eoliche e solari presenti nelle Alpi. Per quanto riguarda quest'ultimo aspetto, durante il WEF 2022 è stato possibile dimostrare con successo il potenziale del fotovoltaico d'alta quota ai politici svizzeri del Consiglio federale. Questa dimostrazione ha rivelato una potenziale soluzione per garantire un elevato volume di produzione elettrica durante il periodo invernale, un tema che è stato ripreso anche dalla legislazione svizzera (Solarexpress).

1 Highlights of the reporting period

The overall SWEET EDGE objective is to fast-track the growth of locally sourced decentralized renewable energy in Switzerland, considering techno-economic as well as socio-political perspectives, and to ensure that by 2035 and 2050, when ambitious shares of renewable energy are reached, the Swiss energy system is designed and operated in a technically and economically optimal, as well as secure way, and that it is well positioned in the European markets. At the end of year 2, SWEET EDGE was fully running and included both collaborative interdisciplinary activities (*Collaborative research highlights #1-3*) and individual research on specific topics (*Individual research highlights*).

Collaborative research highlight #1: The **first SWEET EDGE White Paper** focused on the fragmentation of the policy landscape in the field of household solar PV. The paper combined an analysis of policies related to PV at the federal, cantonal and municipal level and a techno-economic model to analyse the profitability of PV in different types of houses. The findings showed a very high degree of fragmentation and a rather low ambition level in PV policy. Besides policies, the electricity costs and PV feed-in tariffs, which are set and regularly changed by the distribution grid operators (and which households cannot evade due to the non-liberalized retail market for small consumers), are very heterogeneous (figure 1). Overall, there was 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. The results regarding PV profitability showed a patchwork of municipalities, where this fragmentation was indeed shown to create a massive variance in PV profitability – one of the key determinants of technology deployment. As a result, the White Paper proposes a strategy to reduce this policy fragmentation while increasing ambition by means of targeted harmonization of selected policy instruments to create stronger incentives 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. A stronger role of the federal government was suggested, too, to reduce this extreme level of fragmentation by more formal (potentially top-down) legislation. An alternative would be binding intergovernmental cooperation at higher ambition levels. The EDGE Policy White paper received substantial media visibility with over 130 media articles.

Collaborative research highlight #2: A representative, large-n SWEET EDGE population survey was launched in year 2 by a collaboration of four social science teams, and with the support from technical research teams. Over 4’900 respondents finished the survey with a high response rate of over 36 %. The survey included questions on general climatic and environmental attitudes, environmental behaviour patterns, policy goals and preferences, conjoint choice experiment, solar PV adoption, open-space solar PV systems, energy policy attitudes, personal political attitudes, and socio-demographics (figure 2). The survey contained several methodologically innovative elements, such as experimental approaches. The survey will be a crucial database for many subsequent research activities within EDGE. It will also provide information about how the public thinks and behaves regarding different elements of the Energy Strategy 2050, and will therefore inform about the implementation barriers and successful pathways for the Swiss energy transition.

Collaborative research highlight #3: The first SWEET EDGE model inter-comparison was fully completed in year 2 on spatially-explicit electricity scenarios for Switzerland, using Expanse, Nexus-e, and OREES models (**link**). The three models ran a set of harmonized scenarios in terms of assumptions on electricity demand, battery storage, natural gas availability as well as different renewable electricity targets of 17

TWh/year or 25 TWh/year of domestic new renewable electricity or 25 TWh/year of solar PV. All three models aligned on high capacities of solar PV in 2035 as the key technology for reaching the three targets, but there was flexibility where PV can be placed to achieve the targets: either on roofs and facades in densely populated areas (Expanse, Nexus-e) or also in the Alpine areas (OREES). While Nexus-e relies most heavily on solar PV, OREES demonstrates how the Swiss electricity system could profit from a much higher share of wind installations, and Expanse shows the most diversified electricity mix. Electricity interconnection with Europe remains of key importance in Switzerland because any increases in electricity demand or lower deployment of new renewable generation are compensated for by electricity import in the models. This inter-comparison proved to be an important learning exercise for the three modelling teams, and it is the first-of-its-kind benchmarking of spatial models in Switzerland that will enable the preparation of the policy-relevant Renewable Energy Outlook in year 3.

Individual research highlights: Many other energy research frontiers were pushed in year 2 by the teams; only a few selected highlights are mentioned here. First, the recommender tool for Swiss municipalities on ways to increase the shares of renewable energy in electricity and heat supply was created for Basel, Chur, Luzern, Küssnacht (SZ), Wädenswil, Richterswil, Pontresina, Saanen, and Sarnen (HSLU). Second, the financial needs for key renewable energy technologies in Switzerland were determined, including cost of capital estimates for new technologies like Alpine PV (f.e. **here**) (ETHZ-E). Third, for renewable energy solutions in the Alps, the earlier estimates of high-Alpine solar resources were updated, taking into consideration that the new law would allow large installations outside of already existing building zones (EPFL-C, Sunwell). New methods for estimating wind potential in very complex terrain have been developed. Demonstration projects in the Alps are providing first insights from real-scale implementation at Muttsee (project: Innosuisse_47985.1 IP-EE) and La Stadera (funding through Armasuisse) (EPFL-C). Fourth, for the midlands' demonstration project in Wittenbach, the planning of a novel biogas plant using wood pyrolysis as a source of process heat, showed that carbon-negative biogas, electricity, and soil-enhancing biochar can be produced locally, while retaining local value creation and closing nutrient cycles. The implementation of this exact solution is subject to the success of a variety of investigated efficiency measures (ZHAW). Finally, new energy modeling capabilities were further developed: for example, developing Swiss-specific electric grid models (ETHZ-R) and incorporating electric mobility at a distribution grid level and later at a national system level (ETHZ-P), to quantify supply security considerations better (ETHZ-R), and to analyse better links between the Swiss and the European electricity systems and policies (UNIGE).

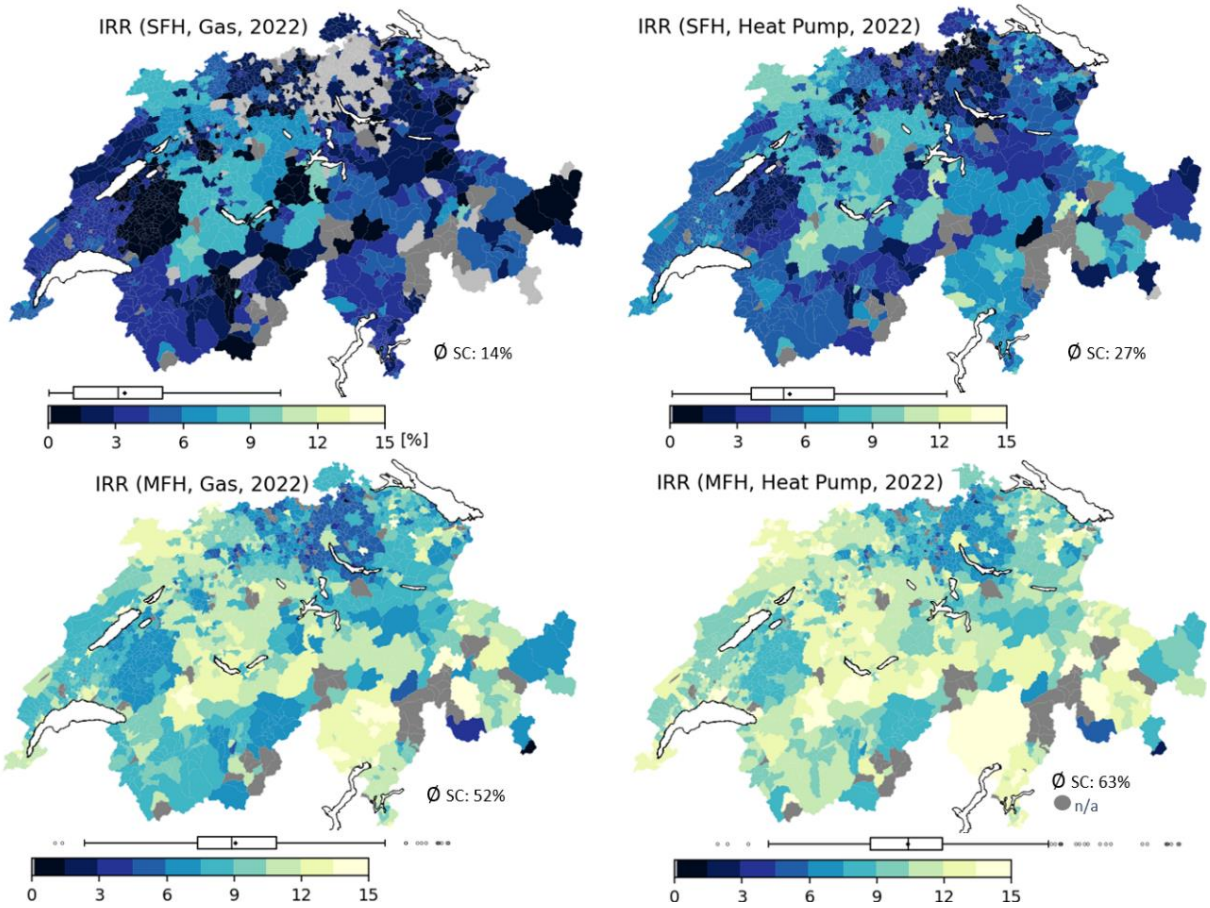

Figure 1: Spatial differences in Internal Rate of Return (IRR) of solar PV installations. The boxplots display the average with a point and the median with a line. The box indicates the first and third quartile and the whiskers the range of data without outliers. Values of zero are shown as light grey. Incalculable municipalities are shown in dark grey. SC = Self-Consumption. (Source: EDGE Policy White Paper)

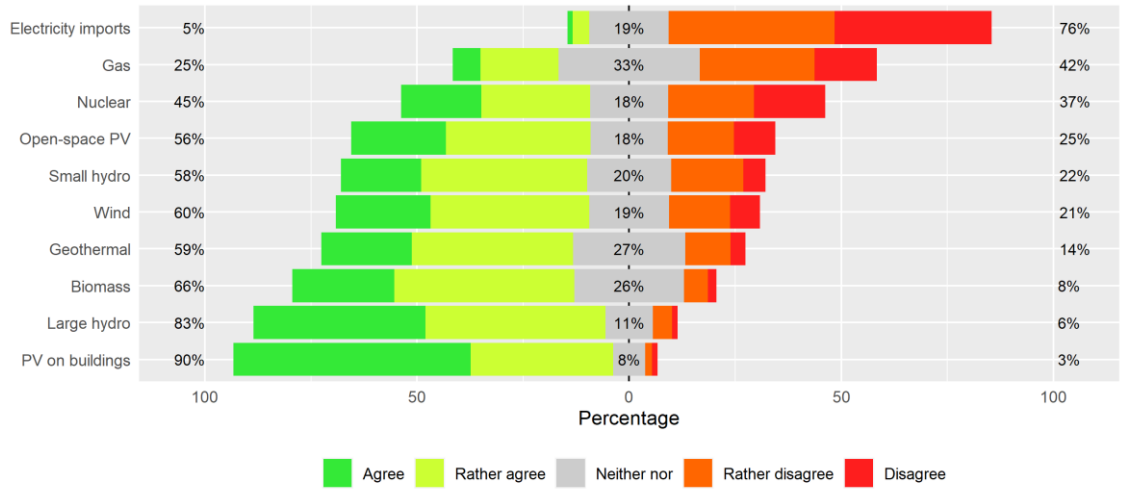

Figure 2: Preliminary results on the survey respondents' view (N=4'900) about which energy sources should be part of the future Swiss electricity mix. (Source: EDGE Survey)

2 Outputs of the reporting period

Peer-reviewed publications

Author(s), title, journal name, year	**doi/link**
Brückmann G, Berger S, Caviola H, Hahnel UJJ, Piana V, Sahakian M, Stadelmann-Steffen I (2023). Towards more impactful energy research: The salient role of social sciences and humanities. PLOS Clim 2(2): e0000132	**https://doi.org/10.1371/journal.pclm.0000132**
Gillianne Bowman, Thierry Huber, Vanessa Burg (2023). Linking Solar and Biomass Resources to Generate Renewable Energy: Can We Find Local Complementarities in the Agricultural Setting? Energies, February 2023.	**https://doi.org/10.3390/en16031486**
Anders Fremstad, Matto Mildenberger, Mark Paul, Isabelle Stadelmann-Steffen (2022). The role of rebates in public support for carbon taxes, IOP Science, August 2022.	**https://doi.org/10.1088/1748-9326/ac8607**
Paolo Gabrielli, Philipp Hilsheimer, Giovanni Sansavini (2022). Storage power purchase agreements to enable the deployment of energy storage in Europe, iScience, August 2022.	**https://doi.org/10.1016/j.isci.2022.104701**
Verena Heinisch, Jérôme Dujardin, Paolo Gabrielli, Pranjal Jain, Michael Lehning, Giovanni Sansavini, Jan-Philipp Sasse, Christian Schaffner, Marius Schwarz, Evelina Trutnevyte (2023). Inter-comparison of spatial models for high shares of renewable electricity in Switzerland, Applied Energy, Volume 350, November 2023.	**https://doi.org/10.1016/j.apenergy.2023.121700**
Sasse J.-P., Trutnevyte E. (2023). Low-carbon electricity sector in Europe risks sustaining regional inequalities in benefits and vulnerabilities. Nature Communications 2023.	**https://www.nature.com/articles/s41467-023-37946-3**
Ueli Schilt, Braulio Barahona, Roger Buck, Patrick Meyer, Prince Kappani, Yannis Möckli, Markus Meyer, Philipp Schütz (2023). Low-Cost Sensor Node for Air Quality Monitoring: Field Tests and Validation of Particulate Matter Measurements, Sensors, January 2023.	**https://doi.org/10.3390/s23020794**
Armin Siegrist, Gillianne Bowman, Vanessa Burg (2022). Energy generation potentials from agricultural residues: The influence of techno-spatial restrictions on biomethane, electricity, and heat production, Applied Energy, October 2022.	**https://doi.org/10.1016/j.apenergy.2022.120075**
Andrej Stankovski, Blazhe Gjorgiev, Giovanni Sansavini (2022). Multi-zonal method for cascading failure analyses in large interconnected power systems, IET Generation, August 2022.	**https://doi.org/10.1049/gtd2.12565**

Steffen, B., & Patt, A. (2022). A historical turning point? Early evidence on how the Russia-Ukraine war changes public support for clean energy policies. Energy Research & Social Science, 91, 102758.	**https://doi.org/10.1016/j.erss.2022.102758**
Bjarne Steffen, Paul Waidelich, (2022). "Determinants of cost of capital in the electricity sector", IOP Science.	**DOI 10.1088/2516-1083/ac7936**

Policy briefs, white papers

Author(s), title, channel or type of publication, year
Schmidt, Tobias; Stadelmann-Steffen, Isabelle; Dukan, Mak; Giger, David; Schmid, Nicolas; Schneuwly, Valentin (2023). Quantifying the degree of fragmentation of policies targeting household solar PV in Switzerland. White Paper No 1, January 2023. **https://doi.org/10.3929/ethz-b-000596612**

Other non-peer-reviewed publications (working papers, press articles, etc.)

Author(s), title, channel or type of publication, year
Brückmann, Gracia; Stadelmann-Steffen, Isabelle (2023). Energy policy support increases through policy goal communication, Paper presented at Annual Conference of the Swiss Political Science Association, Working Group Public Policy, February 2-3, 2023, Basel.
Lukas Nussbaumer (2022). So wird im Kanton Luzern geheizt – und wie es ökologischer ginge, zugerzeitung.ch / Zuger Zeitung Online, 29.10.2022
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Trutnevyte E. (2022). Produire localement plus de courant renouvelable : les options de la Suisse, ARE Forum 2022/02, 2022
NA (2022). Machine Learning für die Jagd nach Ölheizungen, myscience.ch / mySCience Schweizer Forschung/Innovation, 12.10.2022
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NA (2022). Die Jagd nach Ölheizungen, Surseer Woche, 20.10.2022
NA (2022). Architektur+Technik, Machine Learning für die Jagd nach Ölheizungen, 05.11.2022
NA (2022). Jagd nach Ölheizungen, Phase 5, 14.12.2022

Invited talks (scientific or broad audience)

Presenter(s), title, name of the event and location, year
Gracia Brückmann, Stadelmann-Steffen, Isabelle (2022). Policy preferences in the presence of policy, presented at EPG Online, 1 December, 2022, online.
Gracia Brückmann, Stadelmann-Steffen, Isabelle (2022). Proposing a Policy Design Exercise to Assess Preferences for Future Policy Goals and Policies to Achieve these, presented at POLMETH EUROPE 2022, 11 June, 2022, Hamburg (DE).
Jérôme Dujardin, Fanny Kristianti, Bert Kruyt, Andrew Clifton, Michi Lehning (2023). AlpEnForce Energieforschungsgespräche, Warum wir neben hochalpiner PV auch auf den (Gebirgs-)Wind setzen sollten, Disentis, 25.01.23.
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Martin Schlumpf (2022). Smart-Meter-Daten als Grundlage für einen Energieverbund mit Photovoltaik in einem Wohnquartier, 2022.

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Other outputs

Brief description
Citizen Science Event Turgi (**https://ribb.ch/e-anlass/17-11-2022-e-partizipation/**), 2022
Educational activity and a card game on the Swiss electricity mix at the Nuit de la Science in Geneva, 9-10 July 2022.

Appendix

Deliverable report for year 2

In year 2, one deliverable report was due to be submitted:

D2.1 – Report with the results on small-scale biogas systems and on combined biomass and solar energy (Gillianne Bowman et al, November 2022) (**https://drive.switch.ch/index.php/s/Cal2Uj5DK29bPIO**)