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EDGE

Source: Electric tractor and Agri-PV installation at ZHAW Grüental (© Anja Schilling Hoyle, 2025)

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Executive summary

The overall EDGE objective is to provide evidence from a highly interdisciplinary and transdisciplinary perspective with the aim to support fast-tracking the growth of locally-sourced decentralized renewable energy in Switzerland. In year 5, the EDGE consortium has combined its previous bottom-up research studies with several overarching analyses on solar PV and wind power. A discussion paper was prepared with 16 research-based recommendations for policymakers and administrators at all federal levels, as well as for associations and companies on PV and wind power policies. A better understanding of the consequences of the currently fragmented Swiss policy landscape for PV growth at the municipal level was achieved, leading to further policy recommendations. In terms of electric vehicles as a source of flexibility, EDGE combined its earlier bottom-up work on electric vehicles to assess the role of unidirectional charging flexibility in the planning and operation of the whole Swiss electricity system, with the focus on the transmission level and more recently also on the distribution level. Finally, EDGE further advanced its work on distributional impacts of policies and regulations which are like the Model Energy Regulations of the Cantons (MuKEn), such as heating bans, and PV and retrofit obligations. This work identified the vulnerable societal groups and estimated the impact on public budget as well as other actor groups (construction companies, utilities etc.). Further ground was laid for the final EDGE year by massively improving and regionalising PV and wind power potential as a basis for the third model inter-comparison. The second population survey has confirmed the results from the first. For their KTT activities, EDGE organized the second Swiss conference on renewable energy, started a research-industry webinar series, and further disseminated its outputs through social and conventional media, achieving coverage also from large media, such as for example SRF or NZZ. Learnings from the case studies and demonstration projects included guidelines for improved wind power siting and a demonstrated potential for cost reduction and yield optimization in alpine PV plant construction.

Zusammenfassung

Das übergeordnete Ziel von EDGE besteht darin, Erkenntnisse aus einer stark interdisziplinären und transdisziplinären Perspektive zu liefern, um das Wachstum lokal erzeugter, dezentraler erneuerbarer Energien in der Schweiz beschleunigt voranzutreiben. Im fünften Jahr hat das EDGE-Konsortium seine bisherigen Bottom-up-Studien mit mehreren übergreifenden Analysen zu Solar-PV und Windkraft kombiniert. Es wurde ein Diskussionspapier mit 16 forschungsbasierten Empfehlungen für politische Entscheidungsträger und Verwaltungsfachleute auf allen föderalen Ebenen sowie für Verbände und Unternehmen zur PV- und Windkraftpolitik erstellt. Es gelang, ein besseres Verständnis für die Auswirkungen der derzeit fragmentierten politischen Landschaft in der Schweiz auf das Wachstum der Photovoltaik auf kommunaler Ebene zu gewinnen, was zu weiteren politischen Empfehlungen führte. Im Hinblick auf Elektrofahrzeuge als Flexibilitätsquelle kombinierte EDGE seine früheren Bottom-up-Arbeiten zu Elektrofahrzeugen, um die Rolle der Ladeflexibilität in eine Richtung bei der Planung und dem Betrieb des gesamten Schweizer Stromnetzes zu bewerten, wobei der Schwerpunkt zunächst auf der Übertragungs- und in jüngerer Zeit auch auf der Verteilungsebene lag. Schliesslich hat EDGE seine Arbeit zu den Verteilungswirkungen von politischen Massnahmen und Vorschriften, die den Muster-Energie-Verordnungen der Kantone (MuKEn) ähneln – wie beispielsweise Heizverbote sowie PV- und Sanierungsverpflichtungen – weiter vorangetrieben. Im Rahmen dieser Arbeit wurden die besonders betroffenen gesellschaftlichen Gruppen ermittelt und die Auswirkungen auf den öffentlichen Haushalt sowie auf andere Akteursgruppen (Bauunternehmen,

Energieversorger usw.) abgeschätzt. Für das letzte EDGE-Jahr wurden weitere Grundlagen geschaffen, indem das PV- und Windpotenzial als Basis für den dritten Modellvergleich massiv verbessert und regionalisiert wurde. Die zweite Bevölkerungsbefragung hat die Ergebnisse der ersten bestätigt. Im Bereich Wissens- und Technologietransfer organisierte EDGE die zweite Schweizer Konferenz zu erneuerbaren Energien, startete eine Webinar-Reihe für Forschung und Industrie und verbreitete seine Ergebnisse weiter über soziale und klassische Medien, wobei auch grosse Medien wie beispielsweise SRF oder NZZ darüber berichteten. Zu den Erkenntnissen aus den Fallstudien und Demonstrationsprojekten zählen Leitlinien für eine verbesserte Standortwahl bei Windkraftanlagen sowie ein nachgewiesenes Potenzial für Kostensenkungen und Ertragsoptimierung beim Bau von Photovoltaikanlagen in den Alpen.

Résumé

L'objectif général du projet EDGE est de fournir des données factuelles avec une perspective hautement interdisciplinaire et transdisciplinaire, dans le but de favoriser l'accélération du développement des énergies renouvelables décentralisées d'origine locale en Suisse. Au cours de la cinquième année, le consortium EDGE a combiné ses précédentes études de recherche bottom-up avec plusieurs analyses globales sur l'énergie solaire photovoltaïque et l'énergie éolienne. Un document de réflexion contenant 16 recommandations fondées sur la recherche a été rédigé à l'intention des décideurs politiques et des administrateurs à tous les niveaux fédéraux, ainsi que des associations et des entreprises impliquées dans les politiques en matière d'énergie photovoltaïque et éolienne. Une meilleure compréhension des conséquences du paysage politique suisse actuellement fragmenté sur la croissance du photovoltaïque au niveau communal a été obtenue, ce qui a conduit à de nouvelles recommandations politiques. En ce qui concerne les véhicules électriques en tant que source de flexibilité, EDGE a combiné ses travaux bottom-up antérieurs sur les véhicules électriques pour évaluer le rôle de la flexibilité de recharge unidirectionnelle dans la planification et l'exploitation de l'ensemble du système électrique suisse, en mettant l'accent sur le réseau de transport et, plus récemment, sur le réseau de distribution. Enfin, EDGE a poursuivi ses travaux sur les impacts distributifs des politiques et réglementations similaires aux Modèles de réglementation énergétique des cantons (MuKEn), telles que les interdictions de chauffage et les obligations en matière de photovoltaïque et de rénovation. Ces travaux ont permis d'identifier les groupes sociaux vulnérables et d'estimer l'impact sur le budget public ainsi que sur d'autres groupes d'acteurs (entreprises de construction, distributeurs d'énergie, etc.) Les bases ont été consolidées pour la dernière année du projet EDGE grâce à une amélioration considérable et à une régionalisation du potentiel photovoltaïque et éolien, qui ont servi de fondement à la troisième inter-comparaison de modèles. La deuxième enquête auprès de la population a confirmé les résultats de la première. Dans le contexte de ses activités KTT, EDGE a organisé la deuxième conférence suisse sur les énergies renouvelables, lancé une série de webinaires réunissant chercheurs et industriels, et continué à diffuser ses résultats via les réseaux sociaux et les médias traditionnels, ce qui lui a valu une couverture médiatique de la part de grands médias tels que la SRF ou la NZZ. Les enseignements tirés des études de cas et des projets de démonstration comprennent des lignes directrices pour un meilleur choix des sites éoliens et la mise en évidence d'un potentiel de réduction des coûts et d'optimisation du rendement dans la construction de centrales photovoltaïques alpines.

Riassunto

L'obiettivo generale di EDGE è quello di fornire dati e risultati da una prospettiva altamente interdisciplinare e transdisciplinare, con l'intento di favorire un'accelerazione della crescita delle energie rinnovabili decentralizzate di provenienza loc ale in Svizzera. Nel quinto anno, il consorzio EDGE ha integrato i suoi precedenti studi di ricerca eseguiti da collaborazioni fra i singoli membri del consorzio con molteplici analisi di ampio respiro relative all'energia fotovoltaica ed eolica. In particolare, è stato redatto un documento informativo contenente 16 raccomandazioni basate sulla ricerca e rivolte a responsabili politici e amministratori a tutti i livelli federali, nonché ad associazioni e aziende in materia di politiche sul fotovoltaico e sull'energia eolica. È stata raggiunta una migliore comprensione delle conseguenze dell'attuale frammentazione del panorama politico svizzero sulla crescita del fotovoltaico a livello comunale, che ha portato a ulteriori raccomandazioni politiche. Per quanto riguarda i veicoli elettrici come fornitori di flessibilità rivolta al sistema elettrico, EDGE ha utilizzato il precedente lavoro sui veicoli elettrici e lo ha integrato nello studio per la valutazione del ruolo della flessibilità di ricarica unidirezionale a supporto della pianificazione e del funzionamento dell'intero sistema elettrico svizzero, con particolare attenzione al livello di trasmissione e, più recentemente, anche a quello di distribuzione. Infine, EDGE ha ulteriormente approfondito il proprio lavoro sugli impatti distributivi di politiche e regolamenti simili ai Regolamenti energetici modello dei Cantoni (MuKEn), quali i divieti di riscaldamento e gli obblighi in materia di fotovoltaico e di riqualificazione energetica. Questo lavoro ha identificato i gruppi sociali vulnerabili e ha stimato l'impatto sul bilancio pubblico nonché su altri gruppi di attori (imprese di costruzione, servizi pubblici ecc.). Sono state gettate ulteriori basi per l'anno conclusivo del consorzio EDGE migliorando notevolmente e regionalizzando il potenziale fotovoltaico ed eolico da utilizzare come base per il terzo confronto tra modelli energetici nazionali. La seconda indagine conoscitiva sulla popolazione svizzera ha confermato i risultati della prima. Nell'ambito delle attività KTT, EDGE ha organizzato la seconda conferenza svizzera sulle energie rinnovabili, ha avviato una serie di webinar dedicati alla collaborazione tra ricerca e industria e ha ulteriormente diffuso i propri risultati attraverso i social media e i media tradizionali, ottenendo anche la copertura da parte di grandi testate giornalistiche, come ad esempio SRF o NZZ. Gli insegnamenti tratti dai casi di studio e dai progetti dimostrativi includono linee guida per una migliore localizzazione degli impianti eolici e un potenziale dimostrato di riduzione dei costi e ottimizzazione della resa nella costruzione di impianti fotovoltaici alpini.

1 Work programme overview

The overall EDGE objective is to provide evidence to fast-track the growth of locally-sourced decentralized renewable energy in Switzerland 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. Pathways towards largely electrified and multi-carrier energy systems are examined by analysing electricity, mobility, and heating sectors. In particular, the EDGE consortium aims to move beyond generic designs and national-level analysis of decentralized renewable systems in Switzerland to a regionalized analysis, providing high-resolution spatially-explicit energy modelling and social data analysis to derive region-specific insights for the Swiss cities, midlands, and the Alps.

The EDGE consortium also delivers collaborative, highly interdisciplinary and transdisciplinary expertise and provides corresponding recommendations, ranging from potential assessment and technology development to systems modeling, political science, management, economics, sustainability science, and energy practice, in order to identify the most efficient directions to unlock the full potential of decentralized renewable energy. EDGE brings together 19 research groups with 19 cooperation and 34 support partners from industry, public administrations, associations, and other sectors. It is jointly led by Prof. Michael Lehning at the École Polytechnique Fédérale de Lausanne and the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, and Prof. Evelina Trutnevyte at the University of Geneva.

The research component in EDGE is combined with specific case studies and implementation projects that cover the diversity of the Swiss regions, including urban, rural midlands, and Alpine projects. The mutual learning from these case studies and implementation projects ensures feedback loops between theory and practice, and ability to use the outcomes for delineating realistic pathways for successful implementation of nearly or fully renewable Switzerland by 2050.

The EDGE work plan consists of ten work packages that cover:

- WP1, WP2, WP3 conduct analysis of energy supply and demand, grid capabilities, business models and finance, as well as governance for Switzerland as a whole and specifically for the Swiss cities, midlands, and the Alps.
- WP4, WP5, and WP6 cover case studies and implementation projects in cities, midlands, and alpine settings respectively;
- WP7 develops country-wide scenarios and transition pathways for nearly or fully renewable Switzerland by 2050 to investigate the impact of high shares of renewable generation on the transmission, centralized generation and storage, transport sector, and European interconnection.
- WP8 works on policies, market design, market instruments, measures to mobilize finance and social acceptance, and distributional impacts in order to foster the uptake of decentralized renewable energy.
- WP9 and WP10 represent project management and knowledge and technology transfer.

In sum, the EDGE consortium aims to become the point of reference for scientific analysis and science-practice collaboration in Switzerland on integrating very high shares of renewable generation, taking into account the regionalized approach.

2 Progress of activities

In year 5, EDGE continued its work on ways to promote higher uptake of solar PV and wind power in Switzerland. First of all, EDGE synthesized selected research findings to prepare a discussion paper on policy measures for solar PV and wind power (Schmid and Stadelmann-Steffen 2025). This paper presented 16 overarching insights for the further development of policy measures and for communication with the voting public. These insights cover three areas: (i) opportunities to reduce political conflict, (ii) policy and implementation measures with stricter targets and standardization, and (iii) the promotion of local initiatives. These insights target policymakers and administrators at all federal levels, as well as for associations and companies. Second, two studies were completed to contribute to a better understanding of the consequences of the currently fragmented Swiss policy landscape for accelerating PV growth at the municipal level. It was shown that that the current policy mix in Switzerland does not incentivize solar PV where it is most useful from a security of supply perspective (Dukan et al. 2025). Changing the policy mix, especially the minimum feed-in tariff, would result in a better incentive structure. Stadelmann-Steffen et al. (2026) further documented that a high internal rate of return on investments is an important driver of accelerating PV growth, while cantonal policies are currently not able to sufficiently impact local PV growth. Third, deliverable 3.12 paper Stadelmann-Steffen et al 2025, under review) investigated how alpine PV projects and related processes can be designed to facilitate acceptance of these infrastructures by the municipalities in which they are located. Based on an empirical comparative statistical analysis of all 40 alpine PV projects that were subject to a popular vote between summer 2023 and the end of 2024, the main finding is that projects involving local co-owners and decided by public vote received significantly higher proportions of 'yes' votes than projects with exclusively 'distant' owners and secret voting. Importantly, a 'yes' outcome was found not to be possible to simply engineer by implementing public voting. Rather, the process encouraged considerations of the collective good and facilitated acceptance of projects that are well embedded in local structures and norms.

EDGE has also continued its work on electric vehicles and their role in an electricity system with high shares of renewable technologies. First, EDGE combined its earlier bottom-up work on passenger electric vehicles (EVs) to assess the role of unidirectional charging flexibility from EVs in the planning and operation of Switzerland’s electricity system, with the focus on the transmission level (Parajeles Herrera et al, 2026). The analysis leveraged previous modeling on charging behaviour and flexibility patterns and this high-resolution, bottom-up data were integrated into Nexus-e. The aim was to evaluate, from a central planner's perspective, the impacts of coordinated charging on generation capacity planning and national system dispatch in terms of system costs, electricity prices, and seasonal charging patterns, identifying use cases that deliver the greatest value to Switzerland. Further work was initiated to incorporate costs and operational constraints at the distribution network level. Second, progress has been made on analysing the business models for EVs as rolling storage for electrifying corporate fleets, and for the intersection of EV, solar PV, and storage. The results showed a range of adoption chain and co-innovation risks undermining the adoption potentials of corporate users for cross-sectoral business model innovations, leading to a number of policy recommendations, targeting the corporate end-user as a key stakeholder. Those include phasing out feed-in tariffs (FiTs), providing direct purchase subsidies for bi-directional charging infrastructure, introducing cost-reflective network tariffs (EU Publication Office, 2026), and promoting dynamic electricity pricing. As for the intersection of EV, solar PV, and storage, three dominant optimisation logics were identified for smart EV charging: «market-oriented», «grid-conscious», and «prosumer-driven» charging. Structuring the analysis around these logics revealed distinct trade-offs and

synergies between optimisation approaches, offering a novel lens to evaluate smart charging strategies and helping to implement the recommendations above.

EDGE further advanced its work on distributional impacts of policies, where two modelling studies quantify the distributional impacts of policy mixes to decarbonize the residential sector. The first study used microsimulation to evaluate various policy mixes with MuKEn-like regulations, such as heating bans, and PV and retrofit obligations (Torné and Trutnevyte 2026). The results showed that the lowest-income group, older people living alone, dwelling owners, rural households, and households from the less populated cantons would be the most economically burdened groups. A second study found that stricter regulations than proposed by the MuKEn 2025 that would force investments in heating systems, retrofits, and PV in the next decade can meaningfully contribute to meeting sectoral targets. However, depending on subsidies and protection measures, these regulations carry the risk of too high costs for some dwelling owners and households, especially for those living in houses rather than apartments, and a strain on public finances, shrinking business for utilities and leading to workforce bottlenecks, too. This modelling work by Torné and Trutnevyte (2026) has then been used to prepare two collaborative experiments in the second EDGE population survey. The first study investigates the extent to which communicating about policy effectiveness shapes public support and perceptions of fairness and financial affectedness toward these mixes. The second study tests how people perceive and use the distributional impacts of policies for their policy evaluation, namely policy support.

In year 5, EDGE laid new basis for further collaborative analyses to be completed by the end of the project. New potential estimates for wind and solar power resources have been generated with a particular focus on correctly representing the landscape units Alps, midlands and cities. This should facilitate predictions on where solar PV could be constructed and allow aggregation on a municipal level, which is a core objective of EDGE. Based on this updated input, the third model inter-comparison has been designed and started to provide results for the third EDGE Renewable Energy Outlook. The second EDGE population survey has been conducted reaching 1’899 respondents. A White Paper on distributional impacts and a White Paper on social acceptance have been started to synthesize various EDGE research findings for the practitioners.

In terms of Knowledge and Technology Transfer, in year 5 EDGE held the second Swiss conference on decentralized renewable energy, started a new and well-attended webinar series, and continued its usual dissemination activities of newsletters, social media (LinkedIn), and Youtube videos. Publication of the second Renewable Energy Outlook and other EDGE research publications also received a substantial media coverage, including RTS, RSI, Neue Zürcher Zeitung, and further news outlets.

3 Highlights of outputs

Research-based recommendations have been formulated in EDGE for the development of solar PV and wind power policy measures and for communication with the voting public. In terms of reducing political conflicts, EDGE shows the importance of communicating the effectiveness of the policy measures upfront, using the energy independence argument, fully involving local stakeholders and offering alternatives to the public rather than a simple yes/no decision on a project, and adopting measures to reduce political polarization in the wind power sector. For enacting policy and implementation measures with stricter targets and standardization, EDGE research recommends

uniform enforcement rules for large PV systems (usable building area of over 300 m²), a unified tax policy for PV systems, quick adoption of MuKEn 2025 regulations, increased visibility, transparency and possibly higher level of subsidies, further harmonization of planning and approval procedures for wind power beyond the acceleration decree, and transformation of the municipal veto right in wind power projects into a right to participate. In terms of promoting local initiatives, EDGE findings point to the importance of funding programs from municipalities and cantons that are more flexible, encouraging utilities to adopt green standards through public co-ownership, examining industrial zones and off-grid areas for wind power potential, integrating PV expansion criteria into the «Energiestadt» certification program, strengthening popular financial participation, and specifically promoting of simultaneous investments.

In terms of solar PV policies, current PV support overlooks production seasonality, risking a lock-in of projects optimized for annual production that is dominated by irradiation during the summer. Dukan et al. (2025) showed that seasonally differentiated feed-in tariffs would increase the economic incentives for winter electricity generation in the Swiss areas with the highest winter supply potential (Figure 3.1). Investment subsidies, which are resource agnostic, prove less effective in directing PV to high-resource locations. This analysis underscored the importance of regionally tailored policies to promote winter-adjusted PV plants.

The EDGE work on EVs found that incorporating EV charging flexibility into centralized planning would reduce total installed generation capacity needed in Switzerland, leading to lower investment costs, particularly in scenarios with restricted electricity trading (Figure 3.2). However, this flexibility would contribute primarily at the operational level by improving the dispatch of renewable and high-operating-cost generation, especially in systems with strong renewable targets. It would also enhance the value of electricity trading by enabling more efficient exchanges with neighbouring countries. Analysis of flexibility use shows consistently high utilization, with peaks in summer driven by abundant local solar PV generation. In winter, utilization declines as system operation becomes more dynamic, relying more on a combination of electricity imports and local peaking resources. This seasonal contrast with stable charging patterns in summer and more variable, system-responsive behaviour in winter, provides valuable insights into flexibility activation strategies.

In terms of distributional impacts from MuKEn-like regulations (heating bans, and PV and retrofit obligations), Torné and Trutnevyte (2026) showed that a requirement to install solar PV, combined with subsidies for PV, heat pumps, and envelope retrofits alongside would promote greater emission savings at limited public cost, while allowing for lower and more equally distributed heating and electricity costs to reduce the overall burden on households. Added to this mix, an ambitious requirement to deeply retrofit the worst insulated buildings can achieve further emission and energy savings, albeit at comparatively high public costs or with exacerbated inequalities without retrofit subsidies. Without special support, low-income, elderly, and rural households and dwelling owners risk bearing a higher economic burden to achieve collective emission savings.

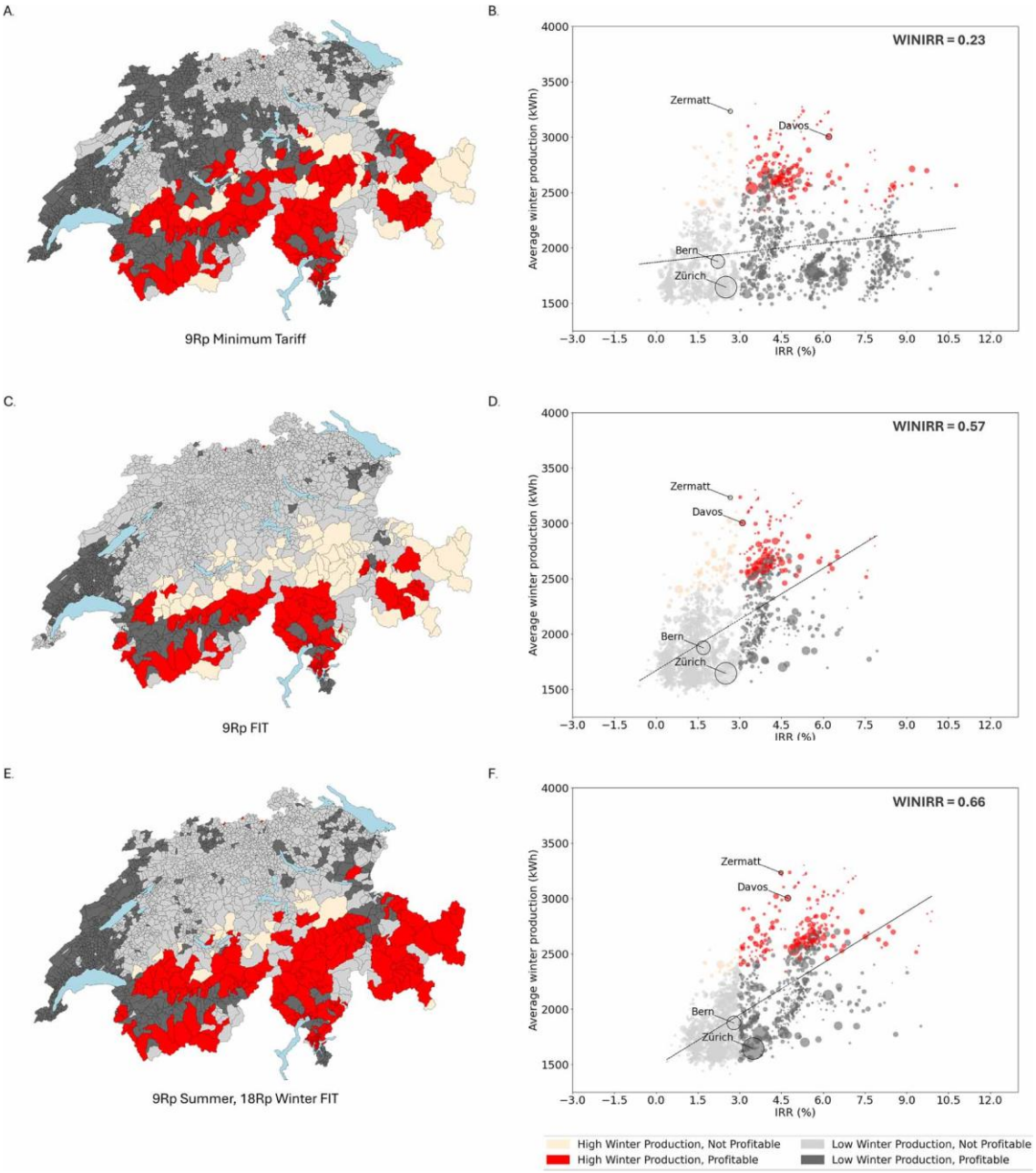

Figure 3.1: The impact of PV support policies on winter electricity production incentives. The considered policy options are 9Rp minimum tariff, 9Rp feed-in-tariff (FIT), and 9Rp summer and 18 Rp winter FIT. IRR is internal rate of return; WINIRR is the correlation between winter electricity production and IRR. Source: Dukan et al. 2025.

The intensive exchange between the research in WPs 1-3 and the corresponding demonstration projects and case studies in WPs 4-6 has generated important new actionable results. One prominent example is an improved understanding of how to overcome hurdles in Agri-PV installations by working with local farmers. The confirmation of both, attractive winter electricity production at a high-Alpine utility PV plant and the risk of production loss and damage by snow has been achieved at the Muttsee

installation and through the corresponding (Innosuisse funded) demonstration project. Furthermore, the differences of neighbouring wind turbines at the Gotthard pass could be explained and lead to the recommendation of very high resolution (model-based) wind assessments before wind farm construction in complex terrain. In general, the high and untapped potential of (winter) wind electricity production has been confirmed (van Schaik et al., 2025). Another notable result is the generation of an emulator of satellite-based radiation estimation at very high resolution, which allows accurate forecasting of PV yield with high accuracy at high elevations (Frischholz et al., 2026). With some high-Alpine PV plants being currently constructed, the Disentis public workshop has led to the important result that significant reduction in time of construction and therefore cost will be possible in future.

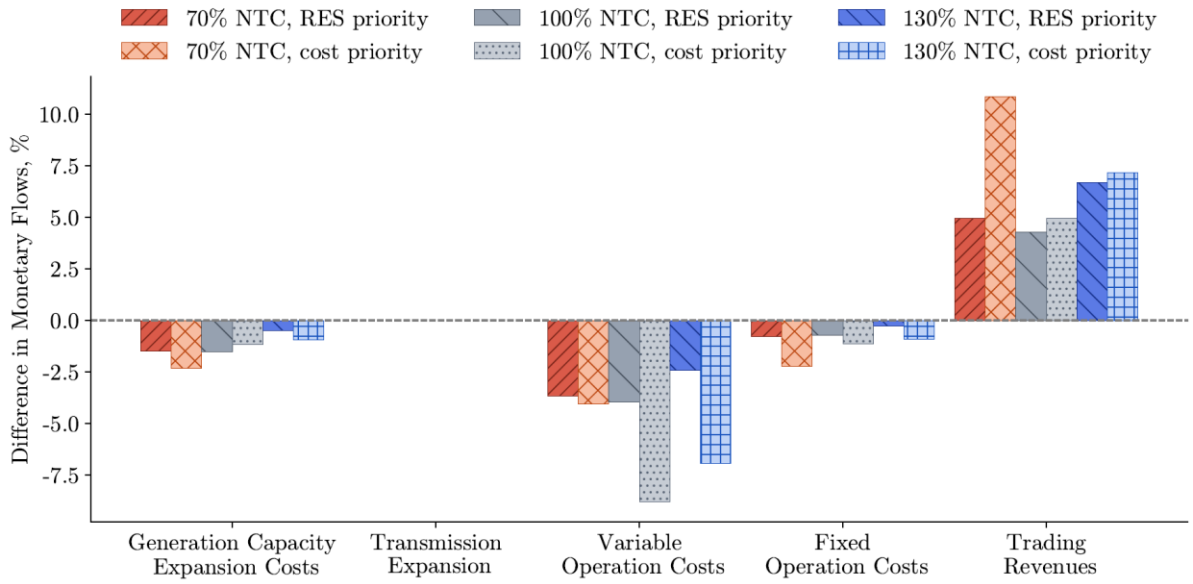

Figure 3.2: Difference in monetary flows between centralized investment and operation in the 2050 Swiss electricity system with and without EV charging flexibility. The legend indicates assumptions on net-transfer capacity availability and renewable energy targets. Source: deliverable 7.8.

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