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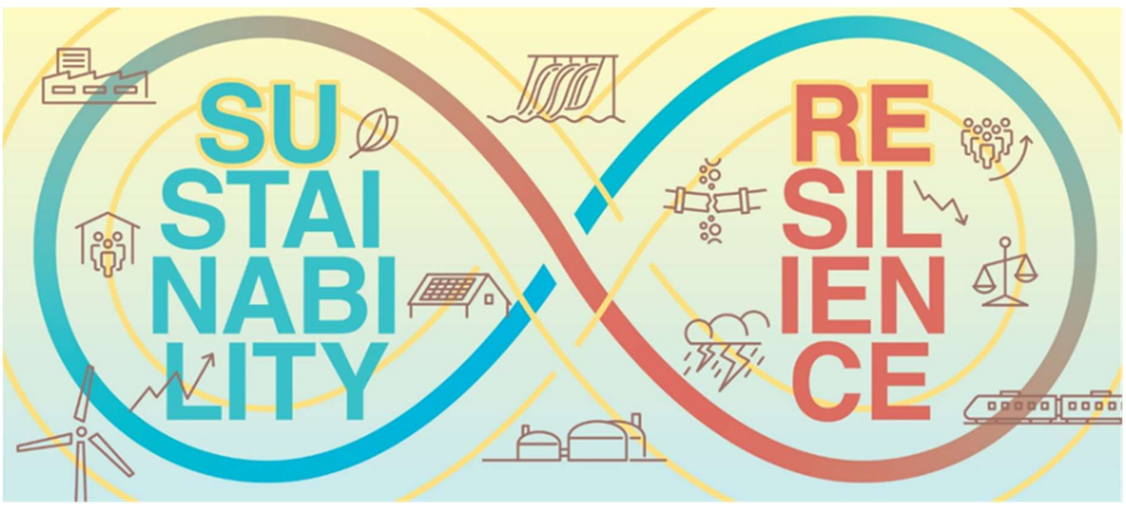
SURE



sweet swiss energy research for the energy transition

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Executive summary

The guiding research question of the SURE project is «How can resilience and sustainability criteria be reconciled with the primary goals of the Swiss energy sector transformation?» More specifically, the project investigates four primary objectives:

1. Assess the sustainability and resilience of the future renewable-based Swiss energy system.

2. Develop an integrated analytical framework based on modeling tools and indicator databases.

3. Engage stakeholders to evaluate indicators for four pathways and five shock scenarios.

4. Apply the framework to the national level and to regional and sectoral case studies.

The project aims to create a quantitative model- and data-based framework that combines holistic systems approaches with social and policy considerations. It analyzes resilience from a long-term perspective, focusing on 2035 and 2050, and evaluates four transition pathways and five disruptive events (shocks). The major achievements of the project, focusing on the past year, can be summarized as follows.

Cluster 1 developed a web-based Multi-Criteria Decision Analysis (MCDA) Decision Support System (DSS) that enables stakeholders to compare Swiss energy pathways across sustainability and resilience dimensions. Life cycle assessment indicators were calculated for all pathway-shock combinations, and the SURE Database comprises the project's central repository. **Cluster 2** explored the social, behavioural, and legal factors shaping acceptance of the energy transition. The serious game ENSURED ENERGY was publicly released as a key knowledge transfer instrument, and numerous activities were conducted. Legal analyses clarified the distribution of responsibility for energy supply security across governance levels and identified the potential value of permanent capacity mechanisms. **Cluster 3** quantified the performance of the four pathways across five shocks. Seven robust priority actions emerged, including accelerated building renovations, heat pump deployment, expanded solar power, and stronger grids. A key finding is that the 2025–2035 decade is critical: delayed action makes the transition significantly more costly. **Cluster 4** acts as the synthesis and translation layer, consolidating outputs from all other clusters into concrete policy recommendations. Its main output will be four policy briefs, which will be released towards the end of the project. **Cluster 5** demonstrated the SURE resilience framework through regional and topical case studies, each of which engaged directly with relevant stakeholders. The Ticino case study developed a prototype web-based tool to simulate the real-time impacts of policy. The Zurich case study completed its heat grid analysis and launched the interactive planning tool GridPLAN and a module of the spatial energy analysis toolbox SEAT. The SBB transport case study showed that optimized coordination of frequency converters can reduce peak loads in Swissgrid's network. The IWB case study yielded actionable insights for decarbonizing the industrial sector.

Together, the five clusters provide an integrated, openly accessible evidence base for Swiss energy policy. With the quantitative analysis now largely complete and the synthesis cluster preparing its policy-oriented outputs, SWEET SURE is well positioned to deliver concrete, decision-ready recommendations for Switzerland's energy transition in its final phase.

Zusammenfassung

Die übergeordnete Forschungsfrage des SURE-Konsortiums lautet: «Wie können Resilienz- und Nachhaltigkeitskriterien mit den primären Zielen der Schweizer Energiewende in Einklang gebracht werden?» Konkret untersucht das Projekt vier Hauptziele:

1. Bewertung der Nachhaltigkeit und Resilienz des zukünftigen Schweizer Energiesystems auf Basis erneuerbarer Energien.
2. Entwicklung eines integrierten analytischen Rahmens auf Basis von Modellierungswerkzeugen und Indikatordatenbanken.
3. Einbeziehung von Interessengruppen zur Bewertung von Indikatoren für vier langfristige Pfade unter fünf Schockszenarien.
4. Anwendung auf nationaler Ebene in der Schweiz sowie für mehrere regionale oder themenbezogene Fallstudien.

Das Projekt zielt darauf ab, einen quantitativen, modell- und datenbasierten Rahmen zu schaffen, der ganzheitliche Systemansätze mit gesellschaftlichen und politischen Überlegungen verbindet. Es analysiert Resilienz aus einer langfristigen Perspektive mit Fokus auf 2035 und 2050 und bewertet vier Transformationspfade sowie fünf disruptive Ereignisse (Schocks). Die wichtigsten Ergebnisse des Projekts, insbesondere im vergangenen Jahr, lassen sich wie folgt zusammenfassen.

Cluster 1 entwickelte ein webbasiertes Entscheidungsunterstützungssystem (DSS) für die multikriterielle Entscheidungsanalyse (MCDA), das es den Interessengruppen ermöglicht, Schweizer Energiepfade hinsichtlich ihrer Nachhaltigkeit und Resilienz zu vergleichen. Für alle Kombinationen aus Szenario und Schock wurden Ökobilanzindikatoren berechnet, und die SURE-Datenbank dient als zentrale Plattform des Projekts. **Cluster 2** untersuchte die sozialen, verhaltensbezogenen und rechtlichen Faktoren, die die Akzeptanz der Energiewende beeinflussen. Das Serious Game ENSURED ENERGY wurde als zentrales Instrument für den Wissenstransfer öffentlich veröffentlicht, und es fanden zahlreiche zugehörige Aktivitäten statt. Rechtliche Analysen klärten die Verteilung der Verantwortung für die Versorgungssicherheit über die verschiedenen Regierungsebenen hinweg und identifizierten den potenziellen Wert von Mechanismen zur Sicherung von Produktionskapazitäten. In **Cluster 3** wurde die Leistungsfähigkeit der vier Szenarien unter fünf verschiedenen Schocks quantifiziert. Es kristallisierten sich sieben wirksame vorrangige Massnahmen heraus, darunter beschleunigte Gebäudesanierungen, der Einsatz von Wärmepumpen, der Ausbau der Solarenergie und stabilere Stromnetze. Eine zentrale Erkenntnis ist, dass der Zeitraum 2025–2035 entscheidend ist: Verzögerungen bei den Massnahmen verteuern den Übergang erheblich. **Cluster 4** fungiert als Synthese- und Umsetzungsschicht und fasst die Ergebnisse aller anderen Cluster zu konkreten politischen Empfehlungen zusammen. Sein wichtigstes Ergebnis werden vier Policy Briefs sein, die gegen Ende des Projekts veröffentlicht werden. **Cluster 5** wandte das SURE-Resilienz-Framework auf regionale und themenbezogene Fallstudien an, in denen jeweils relevante Interessengruppen direkt einbezogen wurden. Im Rahmen der Fallstudie aus dem Tessin wurde ein prototypisches webbasiertes Tool entwickelt, um die Auswirkungen politischer Massnahmen in Echtzeit zu simulieren. Die Fallstudie aus Zürich schloss ihre Wärmenetzanalyse ab und lancierte das interaktive Planungstool GridPLAN und ein Modul der Räumlichen Energieanalyse Toolbox REAT. Die Fallstudie zum SBB-Verkehr zeigte, dass eine optimierte Koordination von Frequenzumrichtern die Spitzenlasten im Netz von Swissgrid reduzieren kann. Die IWB-Fallstudie lieferte umsetzbare Erkenntnisse zur Dekarbonisierung des Industriesektors.

Zusammen bilden die fünf Cluster eine integrierte, frei zugängliche Faktengrundlage für die Schweizer Energiepolitik. Da die quantitative Analyse nun weitgehend abgeschlossen ist und der Synthese-Cluster seine politikorientierten Ergebnisse vorbereitet, ist SWEET SURE gut aufgestellt, um in der Schlussphase konkrete, entscheidungsreife Empfehlungen für die Energiewende in der Schweiz zu liefern.

Résumé

La question de recherche centrale du projet SURE est la suivante : « Comment concilier les critères de résilience et de durabilité avec les objectifs principaux de la transformation du secteur énergétique suisse ? » Plus précisément, le projet s'articule autour de quatre objectifs principaux :

1. Évaluer la durabilité et la résilience du futur système énergétique suisse fondé sur les énergies renouvelables.
2. Développer un cadre analytique intégré, fondé sur des outils de modélisation et des bases de données d'indicateurs.
3. Impliquer les parties prenantes dans l'évaluation des indicateurs pour quatre trajectoires et cinq scénarios introduisant un choc.
4. Appliquer le cadre au niveau national ainsi qu'à des études de cas régionales et sectorielles.

Le projet vise à créer un cadre quantitatif fondé sur des modèles et des données, combinant des approches systémiques holistiques et des considérations sociales et politiques. Il analyse la résilience dans une perspective à long terme, en se concentrant sur 2035 et 2050, et évalue quatre voies de transition ainsi que cinq événements perturbateurs (chocs). Les principales réalisations du projet, en se concentrant sur l'année écoulée, peuvent être résumées comme suit.

Le cluster 1 a développé un système d'aide à la décision (SAD) en ligne, basé sur l'analyse décisionnelle multicritère (MCDA), qui permet aux parties prenantes de comparer les voies énergétiques suisses selon les dimensions de la durabilité et de la résilience. Des indicateurs d'analyse du cycle de vie ont été calculés pour toutes les combinaisons de trajectoires et de chocs, et la base de données SURE constitue le référentiel central du projet. **Le cluster 2** a exploré les facteurs sociaux, comportementaux et juridiques qui façonnent l'acceptation de la transition énergétique. Le jeu ENSURED ENERGY a été rendu public en tant qu'instrument clé de transfert de connaissances et de nombreuses activités ont été menées. Des analyses juridiques ont clarifié la répartition des responsabilités en matière de sécurité de l'approvisionnement énergétique entre les différents niveaux de gouvernance et ont identifié la valeur potentielle des mécanismes de capacité permanente. **Le cluster 3** a quantifié les performances des quatre trajectoires face aux cinq chocs modélisés. Sept actions prioritaires solides ont émergé, notamment l'accélération de la rénovation des bâtiments, le déploiement de pompes à chaleur, l'expansion de l'énergie solaire et le renforcement des réseaux électriques. Une conclusion clé est que la décennie 2025-2035 est cruciale : tout retard dans l'action rendra la transition nettement plus coûteuse. **Le cluster 4** fait office de couche de synthèse et de traduction, consolidant les résultats de tous les autres clusters en recommandations politiques concrètes. Son principal résultat sera la publication de quatre notes d'orientation vers la fin du projet. **Le cluster 5** a démontré le cadre de résilience SURE à travers des études de cas régionales et thématiques, chacune impliquant directement les parties prenantes concernées. L'étude de cas du Tessin a permis de développer un prototype d'outil en ligne pour simuler en temps réel les effets des politiques publiques. L'étude de cas de Zurich a achevé son analyse du réseau de chauffage et lancé l'outil de planification interactif GridPLAN et un module de la spatial energy analysis toolbox SEAT. L'étude de cas sur les transports de la CFF a montré qu'une coordination optimisée des convertisseurs de fréquence peut réduire les pics de charge sur le réseau de Swissgrid. L'étude de cas de l'IWB a fourni des enseignements exploitables pour la décarbonisation du secteur industriel.

Ensemble, les cinq groupes de travail fournissent une base factuelle intégrée et librement accessible pour la politique énergétique suisse. L'analyse quantitative étant désormais en grande partie achevée et le groupe de travail chargé de la synthèse préparant ses résultats orientés vers les politiques,

SWEET SURE est bien placé pour formuler des recommandations concrètes et prêtes à être mises en œuvre pour la transition énergétique de la Suisse dans sa phase finale.

Riassunto

La domanda di ricerca principale del progetto SURE è: «Come si possono conciliare i criteri di resilienza e sostenibilità con gli obiettivi primari della trasformazione del settore energetico svizzero?» Più nello specifico, il progetto indaga quattro obiettivi:

1. Valutare la sostenibilità e la resilienza del futuro sistema energetico svizzero basato su fonti rinnovabili.
2. Sviluppare un quadro analitico integrato basato su strumenti di modellizzazione e database di indicatori.
3. Coinvolgere gli stakeholder per valutare indicatori relativi a quattro scenari e cinque shock.
4. Applicare il quadro a livello nazionale e a studi di caso regionali e settoriali.

Il progetto mira a creare un quadro quantitativo basato su modelli e dati che combini approcci sistemici olistici con considerazioni sociali e politiche. Analizza la resilienza in una prospettiva di lungo periodo, concentrandosi sugli anni 2035 e 2050, e valuta quattro scenari di transizione e cinque eventi dirompenti (shock). I principali risultati del progetto, con riferimento all'ultimo anno, possono essere riassunti come segue.

Il **Cluster 1** ha sviluppato un Sistema di Supporto alle Decisioni (DSS) basato sul web e fondato sull'Analisi Decisionale Multi-Criterio (MCDA), che consente agli stakeholder di confrontare gli scenari energetici svizzeri secondo le dimensioni di sostenibilità e resilienza. Sono stati calcolati indicatori di analisi del ciclo di vita per tutte le combinazioni scenario-shock, e il database SURE costituisce il repository centrale del progetto.

Il **Cluster 2** ha esplorato i fattori sociali, comportamentali e giuridici che influenzano l'accettazione della transizione energetica. Il gioco ENSURED ENERGY è stato pubblicamente rilasciato come strumento chiave di trasferimento delle conoscenze, e sono state svolte numerose attività. Le analisi giuridiche hanno chiarito la distribuzione delle responsabilità per la sicurezza dell'approvvigionamento energetico tra i diversi livelli di governance e hanno individuato il potenziale valore di meccanismi permanenti di capacità.

Il **Cluster 3** ha quantificato le prestazioni dei quattro scenari rispetto a cinque shock. Sono emerse sette azioni prioritarie robuste, tra cui l'accelerazione delle ristrutturazioni edilizie, la diffusione delle pompe di calore, l'espansione dell'energia solare e il rafforzamento delle reti. Un risultato chiave è che il decennio 2025–2035 è critico: ritardare l'azione rende la transizione significativamente più costosa.

Il **Cluster 4** funge da livello di sintesi e traduzione, consolidando i risultati degli altri cluster in raccomandazioni politiche concrete. Il suo principale output sarà costituito da quattro policy brief, che verranno pubblicati verso la fine del progetto.

Il **Cluster 5** ha dimostrato il quadro di resilienza SURE attraverso casi studio regionali e tematici, ciascuno dei quali ha coinvolto direttamente gli stakeholder pertinenti. Il caso studio del Ticino ha sviluppato un prototipo di strumento web per simulare in tempo reale gli impatti di diverse politiche. Il caso studio di Zurigo ha completato l'analisi della rete di teleriscaldamento e lanciato lo strumento interattivo di pianificazione GridPLAN. Il caso studio sui trasporti SBB ha mostrato che una coordinazione ottimizzata dei convertitori di frequenza può ridurre i carichi di picco nella rete di Swissgrid. Il caso studio IWB ha fornito indicazioni operative per la decarbonizzazione del settore industriale.

Nel complesso, i cinque cluster forniscono una base di evidenze integrata e accessibile pubblicamente per la politica energetica svizzera. Con l’analisi quantitativa ormai in gran parte completata e il cluster di sintesi impegnato nella preparazione dei risultati orientati alle politiche, SWEET SURE è ben posizionato per fornire raccomandazioni concrete e immediatamente utilizzabili per la transizione energetica della Svizzera nella sua fase finale.

1 Work programme overview

The overarching research question of the SURE project is how resilience and sustainability criteria can be reconciled with the primary goals of the Swiss energy transition. It aims to (1) assess the sustainability and resilience of the future Swiss energy system, (2) develop an integrated analytical framework based on modeling tools and indicator databases, (3) engage stakeholders to evaluate indicators for long-term pathways under shock scenarios, and (4) apply the framework at the Swiss national level and for several case studies. The research is organized along five main clusters.

Cluster 1 evaluates the sustainability and resilience of the four long-term SURE pathways under five shock scenarios. It develops a Multi-Criteria Decision Analysis (MCDA) framework that incorporates stakeholder interaction throughout the process, fostering transparency, reproducibility, and an understanding of trade-offs to reach consensus. Additionally, the environmental impacts of Swiss production and consumption are examined through Life Cycle Assessment and Circular Economy methods, with a reconciled uncertainty quantification approach based on surrogate modeling. Lastly, the SURE Database, providing the project's data repository, was developed in the last year.

Cluster 2 investigates the social, legal, and political framework of the SURE pathways and shocks. Central objectives include developing indicators on the legal and political adaptation needs and the social acceptance of pathways to inform SURE modeling. Additionally, the cluster activities involve creating a serious game to gather data on how the population perceives and potentially behaves in different future energy systems, and to evaluate how the SURE game can enhance players' awareness of the energy transition and influence attitudes and behavioral intentions.

Cluster 3 translates Switzerland's energy policy choices into integrated scenario analysis. Four pathways were examined, of which three aimed at achieving climate neutrality by 2050 and one aligned with current policy. They differ in the pace of global climate action and the speed of domestic renewable deployment. Five disruptive shock events were defined: financial, societal, nuclear power reintroduction, heat wave, and cold spell. The cluster completed shared scenario definitions and common data exchange rules across all models, and quantified impacts of the shocks, enabling consistent analysis across energy, economy, buildings, regions, and networks. Seven robust priority actions emerged, including accelerated building renovations, heat pump deployment, and expanded solar power. A key finding is that the 2025–2035 decade is critical: delayed action makes the transition significantly more costly.

Cluster 4 consolidates the outputs of the other clusters into concrete recommendations for Switzerland's energy transition. Its central activity is the development of four Policy Briefs addressing (1) energy imports and independence, (2) critical materials and supply chain resilience, (3) policy influence and technology uptake, and (4) a cross-cutting synthesis of pathways and shocks. The release is planned towards the project's end, accompanied by dedicated dissemination activities.

Cluster 5 includes three case studies assessing resilience within the SURE framework through regional investigations with public and industry partners. The cantonal study focuses on sustainable energy pathways for Ticino, utilizing a System Dynamics simulation model to evaluate policies and compare transitions. A regional case study in with City of Zurich examines district heating's role in urban energy system resilience, analyzing heat grid planning across various levels. Two sectoral studies evaluate challenges to reducing heat-related CO_2 emissions in industry, while the other analyzes the resilience of the electric power grid in public transport.

2 Progress of activities

The SWEET SURE project is built on a complex framework (**Figure 1**), yet a simple, powerful idea. Sound energy policy requires not only rigorous technical analysis of what is possible, but also an honest understanding of the social and legal conditions that determine what is feasible, and robust tools to evaluate which options are preferable. The five clusters reported here each address one of these questions, and their outputs are designed to feed into one another.

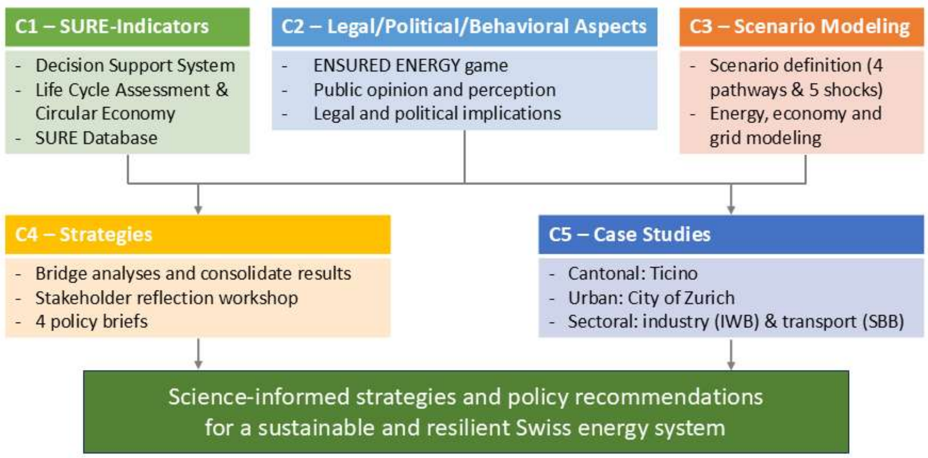

Figure 1: Overview of the SURE-Framework – from scenarios to policies.

Building the evidence base: What futures are possible? Cluster 3 served as the quantitative backbone of the project, translating Switzerland's energy policy choices into integrated scenario analysis. Four pathways were examined: three aimed at achieving climate neutrality by 2050, and one aligned with current policy. These pathways differed in the pace of global climate action, the openness of international energy markets, and the speed of domestic renewable deployment. Furthermore, five disruptive events (i.e., shocks) were defined: financial, societal, nuclear power reintroduction, heat wave, and cold spell. The performance of each pathway was then evaluated under different shocks and at three shock intensities. A significant achievement was the establishment of shared scenario definitions and common data exchange rules across models, enabling consistent analysis across energy, economy, buildings, regions, and networks. Seven priority actions emerged as essential across all pathways, including accelerated building renovations, heat pump deployment, stronger grids, and early investments in hydrogen and carbon management infrastructure. Notably, the timeframe of 2025–2035 is critical, as delayed actions could significantly raise costs and limit options.

Understanding the conditions: Who decides, and under what rules? Quantified pathways alone cannot dictate policy. Cluster 2 explored the social, behavioral, and legal factors that influence whether the transition is accepted or resisted. A key output was the public release of the ENSURE ENERGY serious game, developed for knowledge transfer and educational purposes. Surveys linked to the game are providing insights into how citizens view the trade-offs between competing energy pathways and how public opinion regarding the energy transition is shaped. Additionally, a legal analysis examined regulatory frameworks' ability to balance energy security and sustainability, suggesting the potential value of permanent capacity mechanisms. This research also clarified the distribution of responsibility for energy supply security across governance levels and between the state and industry, while specifically addressing the legal aspects of wind energy acceptance and identifying regulatory adaptations to support Switzerland's renewable energy expansion targets.

Turning evidence into decisions: How resilient are the pathways? With quantifiable scenarios and a better understanding of societal conditions, Cluster 1 developed the evaluative tools needed to transform this evidence into structured, multi-criteria decision support. A major achievement was the completion of a web-based Multi-Criteria Decision Analysis (MCDA) Decision Support System, enabling stakeholders to effectively compare Swiss energy pathways across sustainability and resilience dimensions. Life cycle assessment indicators were calculated for all scenarios (pathway × shock) using data from a centralized online database (SURE Database). Additional work examined the critical raw-material dependencies embedded in future energy infrastructure and advanced scenario-based policy analysis to reduce embodied emissions in the Swiss built environment. The SURE database serves as the project's data repository to ensure consistency, transparency, and reproducibility. It also automatically generates the indicator data needed for the MCDA and provides diverse data visualizations.

From evidence to policy: Strategies and roadmaps. Cluster 4 is the SURE synthesis and translation layer. It consolidates the quantitative, societal, and evaluative outputs of the preceding clusters into concrete policy recommendations for Switzerland's energy transition. A dedicated core group comprising representatives from across the consortium was established and met regularly to design the process for developing four Policy Briefs. This resulted in the identification of four policy brief topics, each with designated lead and contributing authors, and a shared implementation timeline. To align content with current policy needs, several exchanges with SFOE are held. The four forthcoming Policy Briefs address: energy imports and energy independence; critical materials and supply chain resilience; policy influence and technology uptake; and a cross-cutting synthesis of pathways and shocks. Their release is planned towards the end of the project, targeting federal and cantonal decision-makers, the energy industry, and the broader public.

Demonstrating resilience in practice: Regional and sectoral case studies. Cluster 5 demonstrates the SURE resilience framework through dedicated topical and regional case studies. Each case study has engaged directly with relevant stakeholders, ensuring that findings deliver practical impact, as reflected in a number of follow-up activities initiated. At the cantonal level, the Ticino case study developed a prototype web-based tool to assess the real-time impact of policy measures on the energy system. At the city level, the Zurich case study completed its quantitative heat grid analysis and focused the reporting period on dissemination, including the interactive grid planning tool GridPLAN. In the transport and industry case studies, completed quantitative modeling demonstrated that flexibility in SBB's frequency converters could reduce peak loads in Swissgrid's network by 6-27%. An industry workshop with IWB generated ground-level insights to inform policy measures for decarbonizing the industry sector.

Toward policy-relevant synthesis. Together, the five clusters will provide an integrated, openly accessible evidence base that connects technical feasibility, societal acceptance, multi-criteria evaluation, real-world implementation, and policy translation in a single coherent framework. With the quantitative analysis now largely complete and the synthesis cluster preparing to deliver its outputs, SWEET SURE is well positioned to provide concrete, decision-ready recommendations for Swiss energy policy in its final phase.

3 Highlights of outputs

1) How to relieve the Swiss electricity grid using flexibility between SBB and Swissgrid

SBB's frequency converters have a broad bidirectional power range and are located throughout Switzerland (**Figure 2**). This flexibility motivates the use as a virtual redispatch device for the Swissgrid network, which is currently not systematically performed. To provide a first estimate of the potential benefit of such a flexibility measure, the SURE grid simulation tool was adopted for a topical investigation including the SBB frequency converters.

The computational framework includes a link to the full range of scenario pathways, shocks and grid security indicator computation of the SURE modeling chain. Furthermore, a new optimization framework has been created to investigate the effectiveness of different control approaches of the SBB frequency converters. The result are actionable insights, how an increased coordination between SBB and Swissgrid can relieve congestions in the Swissgrid network: By using an optimized coordination of the frequency converters, an average reduction of the peak loading in the Swissgrid network by 6 to 14 % (in extreme cases up to 27%) can be observed. The results of the peak loading reduction are robust over a broad range of flow conditions, scenarios, years, seasons and hours of the day. The benefit tends to increase in later years of the energy transition, as grid loading rises from increased electrification and transit flows. The benefit is also robust to varying overall SBB demand while respecting the power limits of the frequency converters.

In the context of SURE, the case study has shown how the resilience of the electricity grid can be improved without new investments in the grid infrastructure or a new flexible power plant. A broad dissemination workshop with technical, regulatory, and legal experts from SBB, Swissgrid, and ElCom has been held. The technical potential has been recognized, but reductions of the potential may arise from constraints within the SBB grid, as well as organizational and legal hurdles, motivating further investigations with the stakeholders. For a full description of the results, see the report D15.6 (**Link**).

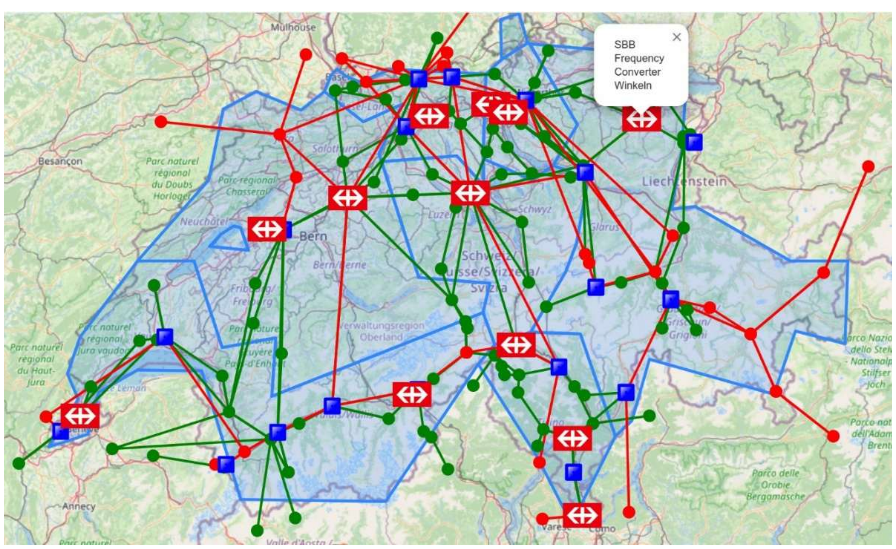

Figure 2: Illustration of the Swiss transmission grid with the locations of the SBB frequency converters.

2) Implementation feasibility of achieving solar PV targets

In Year 5, SURE has also estimated how feasible it is to achieve the solar PV deployment levels from the four SURE scenarios (SPS1-4). In SPS1, green strategies are implemented gradually worldwide, while in SPS2, economic volatility is higher, and energy security concerns increase. In SPS3, regions are more fragmented and implement climate policies at different rates. SPS4 describes business as usual, similar to today. The spatially-explicit electricity sector model EXPANSE was used first to estimate the required PV capacities and locations at the level of 143 sub-national districts. The probabilistic technology diffusion model PROWIDE was then used to assess the implementation feasibility at district and national levels, assuming current, weaker, and stronger PV policies. The SPS4 scenario, which is the least ambitious in terms of solar PV uptake (17.5 TWh), was found to have a high likelihood (81% probability) of being achieved if current conditions continue (**Figure 3**). The most ambitious SPS2 scenario (47 TWh), however, was found to ve rather unrealistic (11% probability). Central and southwestern Switzerland is more likely to achieve higher PV levels. The results overall highlight the importance of strengthening policy support for PV to reach the levels depicted in the SURE scenarios.

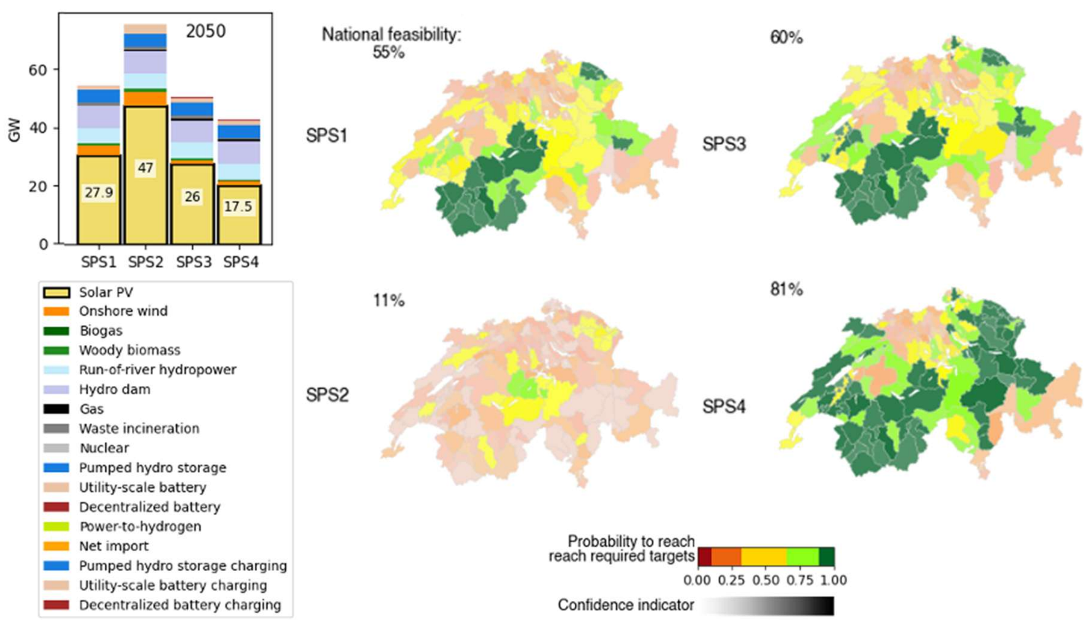

Figure 3: The district- and national-level feasibility of implementing solar PV targets according to the PROWIDE model (left) for the four SWEET SURE scenarios SPS1-4 in 2050 represented in the EXPANSE model (right). The implementation feasibility is estimated as the probability of reaching the needed PV level, based on the probabilistic technology growth modeling if the current trend and contextual conditions continue. Five colors represent the probability to reach the required targets depending on the quantile in which the target is located. For each color, different gradient represents the confidence indicator to show how uncertain (wide) the probabilistic projections are. The darker the color – the higher the confidence, indicating more certain projection.

4 References

Fuchs, A., Demiray, T. (2025) Report on SBB-related scenario analysis and resilience indicators (D15.6, **Link**)

Huang, R. Corrente, S., Siskos, E., Burgherr, P. (2026a) The Multi-Level Cards method: Weights elicitation, consistency checking and restoration for hierarchical criteria. Omega, Volume 138, 103438. **https://doi.org/10.1016/j.omega.2025.103438**

Huang, R., Kadziński, M., Rui Figueira, J., Corrente, S., Siskos, E., Burgherr, P. (2026b) A Modular Simos-Roy-Figueira framework for tailored weight elicitation in multi-criteria decision aiding, Expert Systems with Applications, Volume 311, 131315. **https://doi.org/10.1016/j.eswa.2026.131315**

Müller, L. (2025) Die Energieversorgungssicherheit im Kontext der Artikel 6–8 des Energiegesetzes (EnG). DIKE Verlag AG, Zürich, Schweiz. **https://doi.org/10.3256/978-3-03929-085-7**

Müller, R.P. (2025).Kapazitätsmechanismen: Zwischen Resilienz und Nachhaltigkeit, Jusletter 15. Dezember 2025. **https://doi.org/10.38023/1e67e061-0564-439d-a768-012764ebee2f**

Palucci, M., Tardif, J. M., Medici, V., Sansavini, G. (2026) "Energy Communities foster PV diffusion and distributive justice: insights from a Socio-Technical Energy Transition model", under review in *Energy Research and Social Science*. **http://dx.doi.org/10.2139/ssrn.6101809**.

Rubino, G., Wallinger, S., Trutnevyte, E. (2026) Key uncertainties for hydrogen in Switzerland: insights from global sensitivity analysis and Plackett-Burman design, International Journal of Hydrogen Energy, Volume 216, 153822. **https://doi.org/10.1016/j.ijhydene.2026.153822**.

Singhvi, A., Mottet, C., Bitard, L., Binder, C.R. (2025a) Circular decarbonisation? Material and waste implications of the transition to low-carbon technologies in Switzerland. Journal of Physics: Conference Series, Volume 3140, Circularity - Urban metabolism and regenerative planning. **https://doi.org/10.1088/1742-6596/3140/15/152009**

Singhvi, A., Sirenko, M., Athanassiadis, A., Binder, C.R. (2025b) Mapping operational and embodied emissions in relation to household and ownership profiles with bottom-up building stock analysis: The case of Vaud, Switzerland, Resources, Conservation and Recycling, Volume 221, 108431. **https://doi.org/10.1016/j.resconrec.2025.108431**.

Wallinger, S., Zielonka, N., Sasse, J.-P., Trutnevyte, E. (2025) Spatially-resolved optimisation of coupled hydrogen and electricity systems: Abundant and niche hydrogen scenarios in Switzerland, International Journal of Hydrogen Energy, Volume 121, Pages 96-110. **https://doi.org/10.1016/j.ijhydene.2025.03.345**.