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# SWEET Call 1-2020 – SURE

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## Abbreviations

| Abbreviation | Description |
|---|---|
| ANOVA | Analysis of Variance |
| BSM | Building Stock Model |
| CECB | Certificat énergétique cantonal des bâtiments |
| COMEXT | Statistical database on trade of goods managed by Eurostat, the Statistical Office of the European Commission |
| D&C plan | Dissemination & Commmunication plan |
| DSM | Demand Side Management |
| DSS | Decision Support System |
| EEG | Energy Economics Group |
| ENTSO-E | European Network of Transmission System Operators for Electricity |
| ENTSO-G | European Network of Transmission System Operators for Gas |
| EPG | Energy Performance Gap |
| GAEK | Gebäudeenergieausweis der Kantone |
| GIS | Geographical Information System |
| GSA | Global Sensitivity Assessment |
| GTAP | Global Trade Analysis Project |
| IEA | International Energy Agency |
| IMF | International Monetary Fund |
| IO | Input-Output |
| KTT | Knowledge and technology transfer |
| LCA | Life Cycle Analysis |
| LCOE | Levelized cost of energy |
| LIC | Low-Invest-Cost |
| LICS | Potenziale von Low-Invest-Cost Sanierungslösungen |
| MCDA | Multi-Criteria Decision Analysis |
| MFH | Multi Family House |
| MISTEE | Motivations for Investment in Smart Technologies and Energy Efficiency |
| ML | Machine Learning |
| MLP | Multi-Level Perspective |
| NUTS | Nomenclature of Territorial Units for Statistics |
| PV | Photovoltaic |
| PyPSA | Python for Power System Analysis |
| SAM | Social Accounting Matrix |
| sBSM | Spatial Building Stock Model |
| SCCER JA | Joint Activity of the Swiss Competence Centers for Energy Research |
| SCCER-FURIES | Swiss Competence Centers for Energy Research. - Future Swiss Electrical Infrastructure |
| SFH | Single Family House |
| SFOE | Swiss Federal Office of Energy |
| SIO | Semi-Input-Output |

| | |
|---|---|
| STEM | Swiss TIMES Energy System Model |
| SURE | Sustainable and Resilient Energy for Switzerland |
| SWEET | Swiss Energy research for the Energy Transition |
| TIMES | The Interated MARKAL EFOM System |
| TYNDP | Ten Year Network Development Plan |

## Summary

The themes of sustainability and resilience are important dimensions of the energy transition, and they have become even more relevant with the recent developments in the Ukraine crisis that increased attention on geopolitical and market aspects in the general energy debate, while ambitious environmental goals are still to be met. The project SURE (Sustainable and Resilient Energy for Switzerland) explicitly deals with the question of how to reconcile resilience and sustainability criteria with the main goals of the Swiss energy sector transformation and the climate change mitigation targets aiming at net-zero greenhouse gas emissions by 2050.

The SURE project started in May 2021, with the kick-off meeting on the 4th of May 2021. The project team has been successfully established, and all research partners have been onboarded. The work packages scheduled to start in the first year became operational. For some work packages, the hiring of new personnel represented a challenge with minor implications for the work programme as a whole.
In the first year, research in SURE focused on the following major topics:

- Conceptualisation, methodological and data advancements of several analytical tools, including energy models, Life Cycle Assessment (LCA), indicator-based Multi-Criteria Decision Analysis (MCDA), machine learning (ML) for uncertainty analysis and the gaming-based approach.
- Identification of links between the several analytical tools comprising the SURE modelling toolbox and development of a common understanding of the entire SURE framework
- Development of a common understanding of the related scenario-based analyses, including the first definition of long-term pathway scenarios and disruptive events (so-called shocks).
- Conceptualisation of the case studies.
- Engagement in the SWEET-CROSS activity regarding the definition of common pathway scenarios and designing the interfaces between the SWEET-CROSS and SURE data platforms

The methodological improvements for several modelling tools performed in the first year resulted in five scientific publications (some of them under review) and one deliverable report. This work provides the foundation for the advanced model-based sustainability and resilience analysis to be conducted in the next phases of the project. Highlights of the model advancements refer to innovative approaches for analysing emission mitigation options in industry, improved representation of consumer preferences related to the deployment of low-carbon options for the buildings sector and mobility, as well as impacts of digitalisation on daily life. The analytical tool for grid modelling has been advanced by applying an open and very detailed modelling framewoth with Euopean scope. Regarding uncertainty analysis tools, the work on global sensitivity analysis for LCA and the ML-approach are to be highlighted. The research partners from the social sciences were closely involved in conceptual work, for instance in the design of the game as the set-up of long-term pathways and disruptive events.

The SURE stakeholder forum, to which initially 16 cooperation partners were committed, has been expanded by additional representatives from industry and other energy and climate-related organisations. The value of the stakeholder forum has been demonstrated in the first SURE stakeholder meeting on the 7th of April 2022, which was dedicated to setting the long-term pathways and disruptive events. The discussions with stakeholders comprise essential inputs to define pathways and disruptive events that have high relevance for a broad range of interest groups. Feedback and stakeholders' input will be used to define and characterise the scenarios for later application in the modelling work packages. It is also expected that the outcomes of the participatory processes foreseen in SURE will contribute to the definition of common scenarios across several SWEET projects.

PSI was actively engaged in the SWEET-CROSS activity in the first year, providing model specifications and input to the definition of common SWEET scenarios. This contribution is expected to support the coordination across the diverse modelling activities of the SWEET projects and to allow a better understanding of the various modelling outcomes. Besides, the interface between the SURE and CROSS data platforms is designed.

Knowledge & Technology Transfer (KTT) in SURE has been operationalised by creating the SURE website and several dissemination activities during the first year, including press releases, interviews, a project brief, and a video. The planned future activities are specified in the corresponding KTT plan and will be implemented and developed continuously. In addition to the KTT Plan, the risk and data management approaches have been stipulated and documented accordingly. The Scientific Advisory Board (SAB) has been set-up with four renowned international experts covering the areas of resilience and sustainability assessment as well as energy modelling.

## Résumé

Les thèmes du développement durable et de la résilience sont essentiels pour une transition énergétique réussie. Ceux-ci sont devenus d'autant plus pertinents avec les récents développements en Ukraine qui ont accru l'attention sur les aspects géopolitiques et de marché dans le débat général sur l'énergie, alors que des objectifs environnementaux ambitieux doivent encore être atteints. Le projet SURE (Sustainable and Resilient Energy for Switzerland, en anglais) traite explicitement de la conciliation entre d'une part les critères de résilience et de développement durable avec les principaux objectifs de la transformation du secteur énergétique suisse, et d'autre part les objectifs climatiques visant à atteindre des émissions nettes de gaz à effet de serre nulles d'ici 2050.

Le projet SURE a débuté en mai 2021 avec la réunion de lancement le 4 mai 2021. L'équipe du projet a été mise en place avec succès et tous les partenaires de recherche ont été intégrés. Les modules de travail dont le lancement était prévu en cours de première année sont devenus opérationnels, tandis que pour d'autres modules de travail, l'embauche de nouveau personnel a représenté un défi.
Au cours de la première année, la recherche au sein du projet s'est concentrée sur les principaux sujets suivants:

- Conceptualisation, avancées méthodologiques et données de plusieurs outils analytiques, notamment les modèles énergétiques, l'analyse du cycle de vie (ACV), l'analyse décisionnelle multicritères (ADMC) basée sur des indicateurs, l'apprentissage machine (ML) pour l'analyse des incertitudes et l'approche basée sur les jeux (*gaming-based approach*, en anglais).
- Développement d'une compréhension commune du cadre analytique et des analyses basées sur des scénarios, y compris la définition des scénarios de cheminement et des événements perturbateurs (appelés chocs).
- Conceptualisation des études de cas.
- Engagement dans l'activité SWEET-CROSS.

Les améliorations méthodologiques apportées à plusieurs outils de modélisation au cours de la première année ont donné lieu à cinq publications scientifiques (dont certaines sont en cours d'examen) et à un rapport. Ce travail constitue la base de l'analyse avancée de la durabilité et de la résilience basée sur des modèles, qui sera menée dans la prochaine phase du projet. Les principales avancées en matière de modélisation concernent des approches innovantes pour l'analyse des options de réduction des émissions dans l'industrie, ainsi qu'une meilleure représentation des préférences des consommateurs concernant le déploiement d'options à faible teneur en carbone (en particulier le chauffage et la mobilité) et les impacts généraux de la numérisation sur la vie quotidienne. En ce qui concerne les outils d'analyse des incertitudes, il convient de souligner les travaux sur l'analyse de sensibilité globale pour l'ACV et l'approche ML (Machine Learning, en anglais).

Le forum des parties prenantes de SURE, auquel 16 partenaires de coopération s'étaient initialement engagés, a été élargi par des représentants supplémentaires de l'industrie et d'autres organisations liées à l'énergie et au climat. La valeur du forum des parties prenantes a été démontrée lors de la première réunion des parties prenantes de SURE en avril 2022, consacrée à l'élaboration de scénarios de trajectoires et d'événements perturbateurs. Les discussions avec les parties prenantes constituent des contributions essentielles pour établir des scénarios pertinents pour un large éventail de groupes d'intérêt. Le retour d'information et les contributions des parties prenantes seront utilisés pour définir et caractériser les scénarios pour une application ultérieure dans les paquets de travail de modélisation, et devraient contribuer à la définition de scénarios communs à plusieurs projets SWEET.

L'Institut Paul Scherrer a participé activement à l'activité SWEET-CROSS au cours de la première année, en fournissant des spécifications de modèle et en contribuant à la définition de scénarios SWEET communs. Cette contribution devrait favoriser la coordination entre les diverses activités de modélisation des projets SWEET et permettre une meilleure compréhension des différents résultats de la modélisation.

Le transfert de connaissances et de technologies (KTT, pour Knowledge & Technology Transfer en anglais) dans SURE a été mis en œuvre par la création du site web de SURE et par plusieurs activités de diffusion au cours de la première année, notamment des communiqués de presse, des interviews, une présentation du projet et une vidéo. Les activités futures prévues sont spécifiées dans le plan KTT correspondant et seront mises en œuvre et développées en permanence. En plus du plan KTT, les approches de la gestion des risques et de la gestion des données ont été stipulées et documentées en conséquence. Le conseil consultatif scientifique (SAB, pour Scientific Advisory Board en anglais) a été mis en place avec quatre experts internationaux renommés qui couvrent les domaines de l'évaluation de la résilience et du développement durable ainsi que de la modélisation énergétique.

## Zusammenfassung


Die Themen Nachhaltigkeit und Resilienz sind wichtige Dimensionen der Energiewende und haben durch die jüngsten Entwicklungen in der Ukraine-Krise, die die Aufmerksamkeit auf geopolitische und marktwirtschaftliche Aspekte in der allgemeinen Energiedebatte erhöht haben, noch an Relevanz gewonnen, während gleichzeitig ehrgeizige Umweltziele noch nicht erreicht sind. Das Projekt SURE (Sustainable and Resilient Energy for Switzerland) befasst sich explizit mit der Frage, wie Resilienz- und Nachhaltigkeitskriterien mit den Hauptzielen der Schweizer Energiewende und den Klimaschutzzielen, die auf eine Netto-Null-Emission von Treibhausgasen bis 2050 abzielen, in Einklang gebracht werden können.

Das SURE-Projekt begann im Mai 2021 mit dem Kick-off-Meeting am 4. Mai 2021. Das Projektteam wurde erfolgreich zusammengestellt, und alle Forschungspartner wurden in das Projekt einbezogen. Die Arbeitspakete, die im ersten Jahr anlaufen sollten, wurden umgesetzt. Bei einigen Arbeitspaketen stellte die Einstellung neuen Personals eine Herausforderung dar, die sich nur geringfügig auf das gesamte Arbeitsprogramm auswirkte.

Im ersten Jahr konzentrierte sich die Forschung im Rahmen von SURE auf die folgenden Hauptthemen:

- Konzeptualisierung, methodische und datentechnische Weiterentwicklung mehrerer Analysewerkzeuge, einschließlich Energiemodellen, Lebenszyklusanalysen (LCA), indikatorbasierter Multikriterien-Entscheidungsanalyse (MCDA), maschinellem Lernen (ML) für Unsicherheitsanalysen und dem spielbasierten Ansatz,

- Identifizierung von Verbindungen zwischen den verschiedenen analytischen Werkzeugen, die die SURE-Modellierungs-Toolbox bilden, und Entwicklung eines gemeinsamen Verständnisses des gesamten SURE-Rahmens,

- Entwicklung eines gemeinsamen Verständnisses der damit zusammenhängenden szenariobasierten Analysen, einschließlich der ersten Definition langfristiger Pfadszenarien und störender Ereignisse (sogenannter Schocks),

- Konzeption der Fallstudien,

- Beteiligung an der SWEET-CROSS-Aktivität hinsichtlich der Definition gemeinsamer Pfadszenarien und der Gestaltung der Schnittstellen zwischen den Datenplattformen SWEET-CROSS und SURE.

Die im ersten Jahr durchgeführten methodischen Verbesserungen für mehrere Modellierungswerkzeuge führten zu fünf wissenschaftlichen Veröffentlichungen (einige davon in der Begutachtung) und einem Bericht, der vorgelegt wurde. Diese Arbeit bildet die Grundlage für die fortgeschrittene modellbasierte Nachhaltigkeits- und Belastbarkeitsanalyse, die in den nächsten Phasen des Projekts durchgeführt werden soll. Höhepunkte der Modellfortschritte sind innovative Ansätze für die Analyse von Emissionsminderungsoptionen in der Industrie, eine verbesserte Darstellung der Verbraucherpräferenzen im Zusammenhang mit dem Einsatz von kohlenstoffarmen Optionen für den Gebäudebereich und die Mobilität sowie die Auswirkungen der Digitalisierung auf das tägliche Leben. Das Analysewerkzeug für die Netzmodellierung wurde durch die Anwendung eines offenen und sehr detaillierten Modellierungsrahmens mit europäischem Geltungsbereich weiterentwickelt, und bei den

Instrumenten für die Unsicherheitsanalyse sind die Arbeiten zur globalen Sensitivitätsanalyse für LCA und der ML-Ansatz hervorzuheben. Die Forschungspartner aus den Sozialwissenschaften waren eng in die konzeptionelle Arbeit eingebunden, z. B. in die Gestaltung des Spiels zur Festlegung langfristiger Pfade und disruptiver Ereignisse.

Das SURE-Stakeholder-Forum, an dem ursprünglich 16 Kooperationspartner beteiligt waren, wurde um zusätzliche Vertreter aus der Industrie und anderen energie- und klimabezogenen Organisationen erweitert. Der Wert des Stakeholder-Forums hat sich beim ersten SURE-Stakeholder-Treffen am 7. April 2022 gezeigt, bei dem es um die Festlegung der langfristigen Pfade und disruptiven Ereignisse ging. Die Diskussionen mit den Interessenvertretern liefern wesentliche Beiträge zur Festlegung von Pfaden und Störereignissen, die für ein breites Spektrum von Interessengruppen von großer Bedeutung sind. Das Feedback und die Beiträge der Interessengruppen werden zur Definition und Charakterisierung der Szenarien für die spätere Anwendung in den Modellierungsarbeitspaketen verwendet. Es wird auch erwartet, dass die Ergebnisse der in SURE vorgesehenen partizipativen Prozesse zur Definition gemeinsamer Szenarien für mehrere SWEET-Projekte beitragen werden.

Das PSI beteiligte sich im ersten Jahr aktiv an der SWEET-CROSS-Aktivität und lieferte Modellspezifikationen und Beiträge zur Definition gemeinsamer SWEET-Szenarien. Dieser Beitrag soll die Koordinierung der verschiedenen Modellierungsaktivitäten der SWEET-Projekte unterstützen und ein besseres Verständnis der verschiedenen Modellierungsergebnisse ermöglichen. Außerdem wird die Schnittstelle zwischen den Datenplattformen SURE und CROSS entwickelt.

Der Wissens- und Technologietransfer (WTT) im Rahmen von SURE wurde durch die Einrichtung der SURE-Website und verschiedene Verbreitungsaktivitäten im ersten Jahr umgesetzt, darunter Pressemitteilungen, Interviews, eine Projektbeschreibung und ein Video. Die geplanten künftigen Aktivitäten sind in dem entsprechenden WTT-Plan aufgeführt und werden kontinuierlich umgesetzt und weiterentwickelt. Ergänzend zum WTT-Plan sind die Ansätze für das Risiko- und Datenmanagement festgelegt und entsprechend dokumentiert worden. Das Scientific Advisory Board (SAB) wurde mit vier renommierten internationalen Experten aus den Bereichen Resilienz- und Nachhaltigkeitsbewertung sowie Energiemodellierung besetzt.

## Riassunto

I temi della sostenibilità e della resilienza sono fondamentali per una transizione energetica di successo. Essi sono diventati ancora più rilevanti con i recenti sviluppi in Ucraina, che hanno aumentato l'attenzione sugli aspetti geopolitici e del mercato nel dibattito energetico generale. Inoltre, ambiziosi obiettivi ambientali devono ancora essere raggiunti. Il progetto SURE ("Sustainable and Resilient Energy for Switzerland") affronta esplicitamente la questione di come conciliare i criteri di resilienza e sostenibilità con i principali obiettivi della trasformazione del settore energetico svizzero e gli obiettivi climatici che puntano a zero emissioni nette di gas serra entro il 2050.

Il progetto SURE è iniziato a maggio 2021 con la riunione di avvio del 4 maggio 2021. Il team di progetto è stato istituito con successo e tutti i partner di ricerca sono stati coinvolti. I work package previsti per l'inizio del primo anno sono diventati operativi mentre per alcuni work packages l'assunzione di nuovo personale ha rappresentato una sfida.

Nel primo anno, la ricerca in SURE si è concentrata sui seguenti argomenti principali:

- Concettualizzazione, aspetti metodologici e relativi ai dati per diversi strumenti analitici, inclusi modelli energetici, Life Cycle Assessment (LCA), Multi-Criteria Decision Analysis (MCDA) basata su indicatori, machine learning (ML) per l'analisi dell'incertezza e approcci basati sul gioco.

- Condivisione del quadro analitico e creazione di un linguaggio comune e delle relative analisi basate sugli scenari, inclusa la definizione di scenari su percorsi ed eventi dirompenti (i cosiddetti shock).

- Concettualizzazione dei casi studio.

- Impegno nell'attività SWEET-CROSS.

I miglioramenti metodologici per diversi strumenti di modellazione eseguiti nel primo anno hanno portato a cinque pubblicazioni scientifiche (alcune delle quali in fase di revisione) e a rapporto di progetto. Questo lavoro fornisce le basi per l'analisi avanzata di sostenibilità e resilienza basata su modelli che sarà svolta nelle fasi successive di progetto. Gli elementi salienti dei progressi nei modelli riguardano approcci innovativi per l'analisi delle opzioni di mitigazione delle emissioni nell'industria, nonché una migliore rappresentazione delle preferenze dei consumatori circa la diffusione di opzioni a basse emissioni di carbonio (in particolare, riscaldamento e mobilità) e gli impatti generali della digitalizzazione sulla vita quotidiana. Per quanto riguarda gli strumenti per l'analisi dell'incertezza, sono da evidenziare il lavoro sull'analisi della sensibilità globale per l'LCA e l'approccio ML.

Il forum degli stakeholder SURE, in cui inizialmente erano impegnati 16 partner di cooperazione, è stato ampliato con ulteriori rappresentanti dell'industria e di altre organizzazioni legate all'energia e al clima. Il valore del forum degli stakeholder è emerso chiaramente nel primo incontro degli stakeholder SURE dell'aprile 2022, dedicato all'identificazione di scenario e percorsi futuri ed eventi dirompenti. Le discussioni con le parti interessate hanno fornito input essenziali per identificare scenari che hanno un'elevata rilevanza per un'ampia gamma di gruppi di interesse. Il feedback e gli input delle parti interessate verranno utilizzati per definire e caratterizzare gli scenari ai fini della loro applicazione futura nelle attività di lavoro di modellazione. Si prevede inoltre che essi contribuiranno alla definizione di scenari comuni in diversi progetti SWEET.

PSI è stato attivamente impegnato nell'attività SWEET-CROSS nel primo anno, fornendo specifiche del modello e input per la definizione di scenari SWEET comuni. Questo contributo potrà supportare il coordinamento tra le diverse attività di modellazione dei progetti SWEET e consentirà una migliore comprensione dei vari risultati che emergeranno dalla modellazione stessa.

Il trasferimento di conoscenze e tecnologie (KTT) in SURE è stato reso operativo dalla creazione del sito web di SURE e da numerose attività di divulgazione svolte durante il primo anno, inclusi comunicati stampa, interviste, una sintesi del progetto e un video. Le attività pianificate e future sono specificate nel corrispondente piano KTT e saranno implementate e sviluppate continuamente. Oltre al piano KTT, sono stati definiti e documentati gli approcci per la gestione del rischio e la gestione dei dati. Lo Scientific Advisory Board (SAB) è stato istituito con quattro rinomati esperti internazionali che coprono le aree della resilienza e della valutazione della sostenibilità, nonché la modellizzazione energetica.

# 1 Consortium's objectives

**How to reconcile resilience and sustainability criteria with the main goals of the Swiss energy sector transformation?** This is the guiding question of SWEET-SURE.
Extending existing research in this field, SURE will develop and apply a novel quantitative model- and data-based framework based on combining holistic systemic approaches, comprehensive indicator databases, energy infrastructure and system modelling, and explicitly representing social and policy aspects.

The projects objectives concern specifically:

**Assessment of the sustainability and resilience** of the future renewable-based Swiss energy system with a long-term perspective focusing on 2035 and 2050

**Development of an integrated quantitative analytical framework** based on modelling tools and indicator databases

**Engagement of stakeholders** for the evaluation of indicators, as well as future energy pathways and their sustainability and resilience implications and related competing objectives

**Application of the tool box** on Swiss national level and for several regional or topic-focused case studies and develop strategies for the transition towards sustainable and resilient energy systems including roadmaps, strategy documents etc. jointly with corresponding stakeholders

## 2 Status of the work packages

| WP n° | WP title | Status *(X as appropriate)* | | | | | |
|---|---|---|---|---|---|---|---|
| | | Previously completed: Final report published on ARAMIS | Completed during the reporting period (RP): Final report submitted to be reviewed | Ongoing: Progress & next steps to be reviewed | Starting during the next RP: First steps to be reviewed | New: Proposal and budget to be reviewed and approved; notes to be reviewed | Starting after the next RP: not yet reviewed |
| 1 | Indicator assessment and stakeholder-based sustainability and resilience evaluation | | | X | | | |
| 2 | Model tool interaction and scenario definition | | | X | | | |
| 3 | Gaming-based analysis of behaviour related to system shocks | - | - | X | | | |
| 4 | Energy demand modelling | | | X | | | |
| 5 | Spatial modelling of renewable-based generation | | | X | | | |
| 6 | Energy grid modeling and security analysis | | | X | | | |
| 7 | Integrated energy systems modelling | | | X | | | |
| 8 | Macro-economic modelling | | | X | | | |
| 9 | Reconciled model-based uncertainty analysis | | | X | | | |
| 10 | Life Cycle Analysis and Circular Economy | | | X | | | |
| 11 | Political environment and regulatory aspects ("Facts to policy") | | | | X | | |
| 12 | Formulation of strategies and roadmaps for implementation | | | | | | X |
| 13 | Case study on cantonal level - Ticino: Modelling of Socio-technical systems (system dynamics) | | | X | | | |
| 14 | Case study on city level - evtl. Zürich | | | X | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 | Topical case studies on sustainability and resilience: industry and transport | | | X | | | |
| 16 | Consortium coordination & project and stakeholder management | | | X | | | |
| 17 | Stakeholder forum & KTT | | | X | | | |
| | | | | | | | |

# 3 Work performed and results of ongoing work packages

## 3.1 WP *1 Indicator assessment and stakeholder-based sustainability and resilience evaluation*

| | | | | |
|---|---|---|---|---|
| **Title** | ***Indicator assessment and stakeholder-based sustainability and resilience evaluation*** | | | |
| **Actual start** | *01/2021* | | **End** | *10/2026* |
| **TRL range** | **Starting at** | *n.a.* | **Ending at** | *n.a.* |
| **WP leader** | *Dr. Peter Burgherr, PSI LEA-TA, peter.burgherr@psi.ch* | | | |
| **Members and coop. partners** | *E. Siskos (PSI LEA-TA)*<br>*E. Panos (PSI LEA-EE)*<br>*A. Fuchs (ETHZ)*<br>*A. Athanassidis (EPFL)*<br>*R. Krause (USI)*<br>*M. Jakob (TEP)*<br>*F. Cellina (SUPSI)*<br>*I. Stadelmann (UniBe)*<br>*E. Trutnevyte (UniGe)*<br>*A. Abegg / G. Seferovic / R. Müller (ZHAW)*<br>*L. Paroussos (E3M)* | | | |

**Objectives**

WP1 develops a nexus approach, which allows to simultaneously examine interactions among competing objectives, multiple actors, sectors and scales, and to systematically evaluate trade-offs and synergies. Moreover, the joint consideration of long-term pathways and shock scenarios aims to create broad support for the targets and measures to implement the energy transition and to ultimately make it as shockproof as possible. Using facts-based, key performance indicators and decision support tools it creates a common knowledge base and thorough learning experience, which ultimately will enable decision and policy makers to develop adaptive energy policies. More specifically:

The indicator database of Task 1.1 will provide a central repository, established and quantified for the pathway and shock scenarios at the national level. Indicator values will be accompanied with their metadata to provide consistency and transparency. It is planned that the database feeds the MCDA problem of Task 1.2 and is directly connected to the assessment toolbox of Task 1.4.

Task 1.2 will develop an MCDA framework to combine a comprehensive set of key performance indicators and preference information from all relevant stakeholder groups. Through that it is aimed that the pathway and shock scenarios are evaluated and ranked.

The analysis in Task 1.3 aims to add a dynamic dimension to the evaluation of the pathways. Hence, optimal policy mixes are appraised and identified, considering political and legal priorities, as well as the constraints hindering their implementation.

Task 1.4 will attempt to develop an innovative, open source DSS tool to support users perform their personal evaluation of energy policies and pathways and facilitate stakeholder interaction and dialogue. It is envisaged that it provides advanced visualization tools and support the implementation of the SURE case studies, as well as aid decision maker in other MCDA evaluation problems.

## Work performed and results

### Task 1.1 – Indicator database

*Work performed and achieved results*

Task 1.1 already started in May 2021 (M1) instead of Nov 2021 (M7) because initial discussions with project partners showed that the work on indicators has to be closely linked to and harmonized with pathway and shock discussions to ensure consistency and to timely resolve potential issues. The work of this task was initialized by PSI (as the leading partner) proposing a procedure to build an inclusive database that consolidates knowledge from a broad spectrum of the global literature, as well as the diversified expertise of the SWEET-SURE partners. PSI suggested a categorization of the Sustainability and Resilience pillars into different dimensions (societal, environmental, etc.), which allows accommodating all the relevant indicators that fit into them. The consortium partners were then provided with a comprehensive xlsx. template, which included, among others, the indicator name, unit, direction, scale, description, its quantification method, data sources, etc. The partners filled all the required fields of the xlsx. file with details on the indicators they can quantify, using their modelling activities, work within other consortia and/or literature analysis.

PSI consolidated and cleaned all the input received from the partners, performing also a prescreening of the indicators, based on their relevance for this resilience-sustainability database and their ability to appropriately refer to the energy pathways and differentiate between the shocks. In the following, PSI presented the results of the work achieved so far to the partners, in the 1st Indicator meeting of consortium partners, conducted online on June 17th, 2021. According to the summary of the meeting, 127 quantitative, as well qualitative, indicators were proposed and categorized into the sustainability and resilience pillars.

Next, PSI worked further in accurately categorizing the proposed indicators into the 4 sustainability and 4 resilience dimensions, omitting duplications and identifying the responsible partner for the quantification of each. PSI also worked on some ideas and possibilities to be further discussed with partners concerning the exploitation and dissemination of the database, within the SWEET SURE project and beyond. These were discussed with the whole consortium in the 2nd Indicators meeting, conducted online on September 16th, 2021. It was discussed, in particular, to (i) directly use the database in the MCDA model of Task 1.2, (ii) interconnect it with the DSS of Task 1.4 and complement it with appropriate data visualization tools (iii) promote the database to feed the three SURE case studies (WPs 13-15), though the DSS tool and (iv) attempt interactions with Task 11.2 and enrich the database with a set of indicators, including the preferences of the political actors. Outside of the SURE project, it was proposed to integrate the indicator database to the SURE website, granting specific access to data depending on assigned user roles (i.e., SURE partners, SURE stakeholder forum, website visitors). On top of that, the database is envisaged to be further disseminated to bigger audiences, using other communication channels, such as scientific outreach, printed material and the press.

Subsequently, PSI enriched the database with additional missing indicators, covering and representing all the resilience and sustainability dimensions, based on the Model Reference Cards (see also **www.sweet-sure.ch/toolbox**), drafted by the modelling partners, as part of Task 2.1. At the same time, PSI pinpointed certain indicators, which are expected to be used in the MCDA evaluation of Task 1.2, in order to set the standards for the quantifiable model data that will be needed for them, as well as for the rest of the indicators (interval years, referring to a national level, pathways/shock level). These will be communicated to the partners in the 3rd indicators meeting, to be held in the summer of 2022 (date tbd). This meeting will also set the ground for the effective conduction of the meeting with stakeholders (fall of

2022, date tbd), who are expected to provide their feedback on the indicator database and endorse it, leading to the realization of the Milestone 1.1 in M18.

In summary, the earlier start of this task ensures that potential issues on indicators as well as their relationships with pathways and shock scenarios are anticipated and resolved in a timely manner, ensuring that Milestone 1.1 will be on time because this is essential for subsequent activities of WP1 and interactions with other WPs.

**Task 1.2 - Multi-Criteria Decision Analysis (MCDA) for integrated assessment**

Although Task 1.2 was not planned to have started before the end of the project's first year, some preliminary work has already been carried out. Specifically, PSI drafted a document describing the required procedures and data for the design of the multicriteria evaluation system of the Swiss energy pathways. This work was carried out, in order to ensure that the SURE partners get a common understanding of the objectives, details and requirements of this task. In this way, the adequate quantification of the indicators to feed the MCDA evaluation would be assured, safeguarding therefore the comprehensiveness and transparency of the MCDA assessment, and avoiding feedback loops to demand additional indicator data from the modelling partners.

The document providing the specifications and standards of the MCDA evaluation system, will be distributed to partners and be thoroughly discussed in the 3$^{rd}$ Indicators meeting, to be held in the summer 2022 (date tbd).

**Task 1.3 - Comparative dynamic analysis of pathways**

This task has not started yet.

**Task 1.4 - Interactive, web-based decision support tool**

This task has not started yet.

### *3.2* WP *2* Specification of model tool interaction and scenario definition

| **Title** | Specification of model tool interaction and scenario definition | | | |
|---|---|---|---|---|
| **Actual start** | *05/2021* | | **End** | *07/2024* |
| **TRL range** | **Starting at** | *X* | **Ending a*t*** | *X* |
| **WP leader** | *Evangelos Panos, PSI LEA-EE, Evangelos.panos@psi.ch* | | | |
| **Members and coop. partners** | Peter Burgherr, PSI LEA-TA, Turhan Demiray, ETHZ; Claudia Binder, EPFL; Rolf Krause, USI; Martin Jakob, TEP; Roman Rudel, SUPSI; Isabelle Stadelmann-Steffen, UNIBE; Evelina Trutnevyte, UNIGE; Andreas Abegg, ZHAW; Leonidas Paroussos, E3M | | | |
| **Objectives:** | | | | |
| • To establish common data protocols and procedures that facilitate the communication between the different modelling frameworks in SURE<br>• To provide a definition of long-term scenarios pathways and disruptive events | | | | |

The modelling toolbox of SURE contains several models that need to be coordinated and exchange information, in order to ensure the successful implementation of the project. This work package lays the ground for the coordinated collaboration of the different energy modelling tools as well as it ensures an early involvement of the project's stakeholders in the scenario development process. The following activities have been performed along the three main tasks.

**Task 2.1 Specification of interfaces of energy models and assessment tools and harmonisation of major input data**

Under the coordination of PSI, several project meetings with the modelling partners have taken place in order to classify and document the main specifications of the involved modelling tools in a systematic manner. The result of this process is made publically available through the model reference cards which are also displayed on the project's website (see **www.sweet-sure.ch/toolbox**). This work was coordinated with SWEET-CROSS where the structure of the SURE model reference cards served partly as a blueprint for the collection of model information across the different SWEET projects. The model reference cards of SURE were fed into the model characterisation database of SWEET-CROSS.

Beyond the specification of model features, considerable work was dedicated to the identification of model input and model output data and the discussion of linkage between models needed for the joint application of the entire analytical framework. The status quo of these discussions is displayed in Figure 1. The figure also includes possible linkages to non-modelling work packages relevant for the models' related data processing.

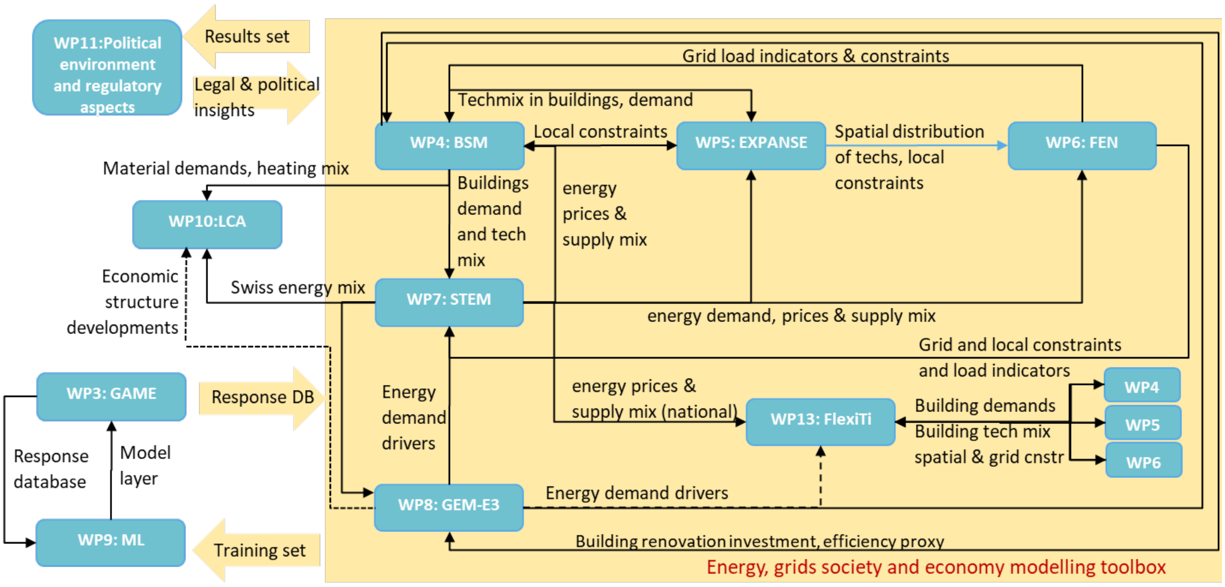



Figure 1: Overview of key interfaces between models

Besides the models' descriptions and identification of major input and output variables of the models, the model reference cards also provided insights on the sustainability and resilience indicators that can be provided by the different models. In this sense, they constitute an information source for WP1 too regarding the indicator database specification.

**Task 2.2 and Task 2.3 Definition of long-term pathway scenarios and scenarios related to disruptive events**

In SURE, two types of scenarios are analysed with the modelling framework: pathway scenarios and disruptive events (shock scenarios). The pathway scenarios represent overarching general long-term trends for the evolution of the energy systems with the assumption that these long-term trends or general conditions can be anticipated by the actors of the energy system. An example would be the existence and achievement of long-term climate policy goals. These pathway scenarios are complemented by scenarios representing disruptive events which aim at addressing also resilience issues on top of the sustainability dimensions. The scenarios for disruptive events – we also refer to them as shock scenarios – can have several desirable or undesirable systemic effects. Importantly, they distinguish from pathway scenarios in the sense that their anticipation by the actors of the energy system is limited or occur rather suddenly.

The work on this task was highly a collaborative effort between the partners (modelling partners and partners from social sciences and computational science) and facilitated by several consortium meetings in order to determine and agree on a common terminology and to collect relevant information for the definition of the pathway and shock scenarios. A valuable starting point for the discussion and formulation of long-term pathway scenarios are previous modelling project, such as SFOE's Energieperspekiven 2050+ as well as the scenarios developed in SCCER JA Scenarios and Modelling (Panos et al, 2021). These internal meetings served also to prepare the first SURE stakeholder workshop on the definition of pathway and shock scenarios, which took place on 7 April 2022 as a physical event at ETH Zürich. The workshop was well attended with representatives from the SURE cooperation partners, further interested stakeholders from industry and energy sector connected associations as well as from representatives from SFOE. Due to the COVID-19 restrictions and the necessity to hold such an interactive workshop as physical event to increase its outcome, the workshop was conducted two months later than originally planned in the proposal. The post-processing of the findings and outcomes of the workshop is on-going and will lead into deliverable D2.1 which has been shifted to October 2022.

The stakeholder workshop has revealed valuable insights into the stakeholders' perception on future developments of the energy system and possible disruptive events (Figure 2). The stakeholder workshop and internal discussion of pathway scenarios provide a basis for the description of the scenario narratives for SWEET-CROSS which are led by E. Panos.

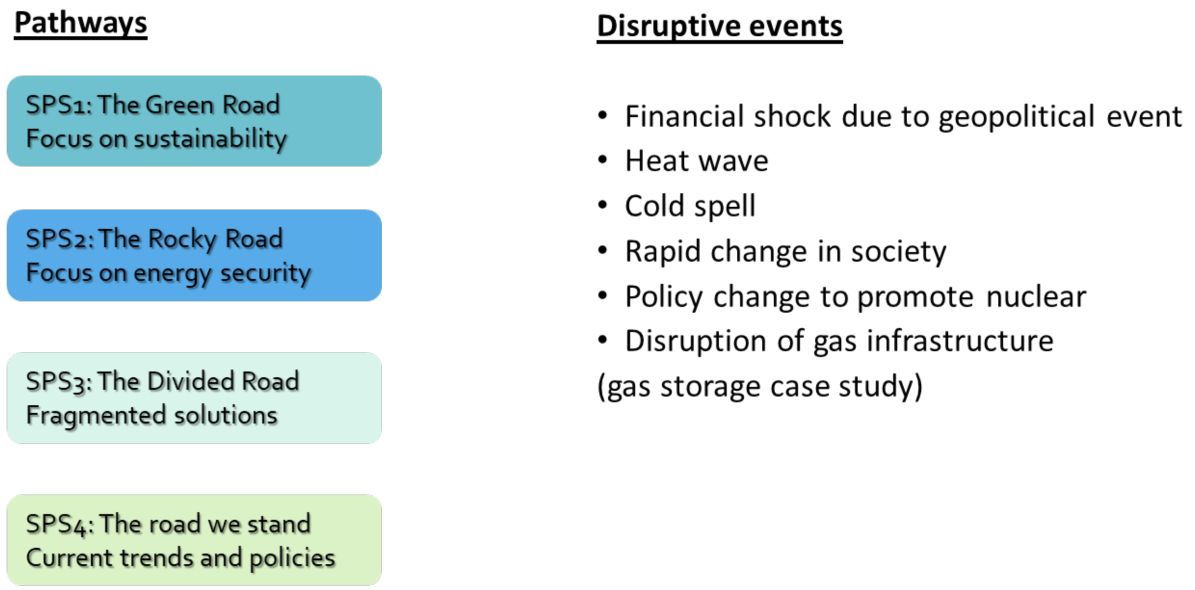



Figure 2: Current set-up of pathway scenarios and disruptive events

### 3.3 WP *3* Gaming-based analysis of behaviour related to system shocks

| | | | | |
|---|---|---|---|---|
| **Title** | Gaming-based analysis of behaviour related to system shocks | | | |
| **Actual start** | *05/2021* | | **End** | *03/2026* |
| **TRL range** | **Starting at** | | **Ending a***t* | |
| **WP leader** | *Rolf Krause, Università della Svizzera Italiana, rolf.krause@usi.ch*<br>*Michael Multerer, Università della Svizzera Italiana, michael.multerer@usi.ch* | | | |
| **Members and coop. partners** | *Benedikt Thelen, USI*<br>*Isabelle Stadelmenn, UNIBE*<br>*Gracia Brückmann, UNIBE*<br>*Sophie Ruprecht, UNIBE*<br>*Roman Rudel, SUPSI*<br>*Francesca Cellina, SUPSI* | | | |
| **Objectives** | | | | |
| *The objective of WP3 is the generation of a gaming environment to study User preferences, interactions and behaviour in the future energy context. The game additionally allows to generate additional input parameters for the models.* | | | | |

The work performed on the gaming environment ("The Game") has focused primarily on the design of the components, the players' goals, incentives, scoring metrics, game modality, and environment. A second focus was the connection to WP9 to obtain simulation results that are converted into the scores for a player's move. The core technical development is performed by USI with social science inputs from UNIBE and SUPSI for the extraction of survey and model data. The team of WP3 has held multiple meetings to develop the overall concept of the game based on member strengths.

In short, the current game design can be summarized as:

Players of the game will fill out a basic questionnaire on their knowledge and preferences of the current and future energy system in Switzerland as part of their profile generation. During gameplay the user will be presented with a realistic scenario where (s)he will be able to implement policy decisions, spend limited amounts of resources to improve the energy provision and consumption. The policy changes are fed to the simulation model from WP9 and produce a forecast upon which a score is calculated. The score can be tuned by us to incentivise goals. Scores of a round are added and supplied to a global leader board. Shocks are added randomly or in a targeted fashion to study the users' reaction and their compensation strategies. After playing multiple rounds, the questionnaire might be represented to users to investigate learnings and behaviour changes made by the users.

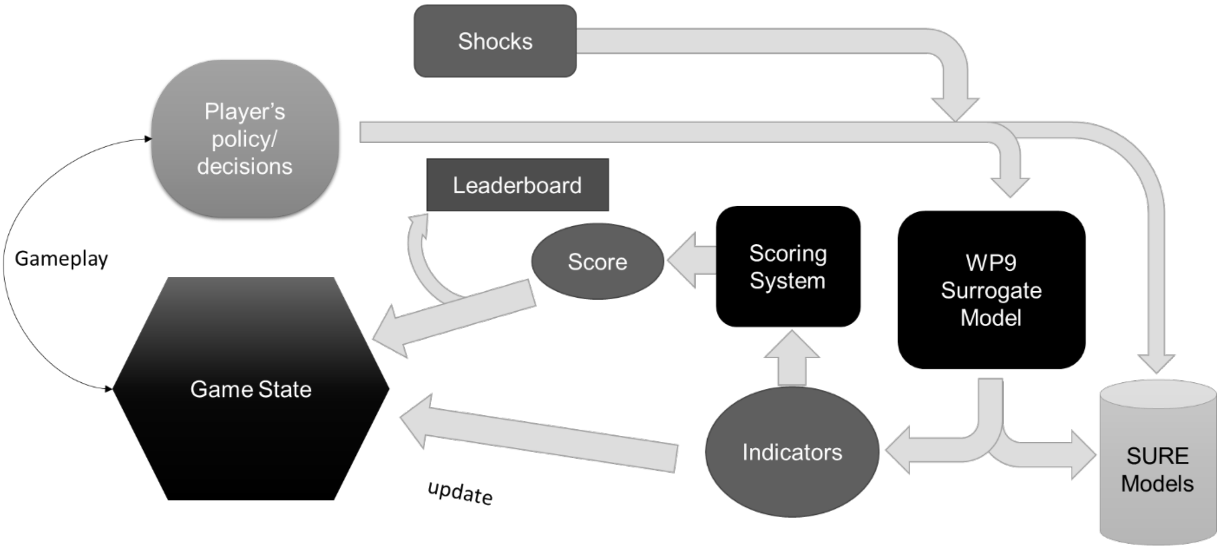



Figure 3: Architecture of gaming environment. The gameplay of the user is to decide on policy and spending of resources. Before simulating shocks are added and a prediction is generated, saved and scored accoring to pathway targets. The leaderbard is updated.

From a top-level perspective the approach chosen by the SURE team will allow the user to experiment with policy combinations and simultaneously allow SURE to adjust the scoring weights transforming the game to a gaming-environment based optimization algorithm for policy decisions. From the players point of view, the goal of the game requires him to find optimal solutions to pathways and responses to the shocks therefore finding an optimal strategy, while SURE can define the optimization's cost function through the scoring to select the pathways steering the optimization to chosen goals.

### 3.4 WP 4 *Energy demand modelling*

| **Title** | Energy demand modelling (buildings and load curves) | | | |
|---|---|---|---|---|
| **Actual start** | *05/2021* | | **End** | *04/2025* |
| **TRL range** | **Starting at** | *6* | **Ending at** | *8* |
| **WP leader** | *Martin Jakob, TEP,* **martin.jakob@tep-energy.ch** | | | |
| **Members and coop. partners** | *Michael Steck, Giacomo Catenazzi, Martin Jakob, TEP* | | | |
| **Objectives** | | | | |

The objective of WP 4 is to improve the spatial building stock model (sBSM) to answer various research questions that are relevant for the SURE project (see project proposal for details). Specifically the sBSM should expand its utility function and other functionalities of the sBSM:

1. The decision function shall include further decision parameters and compliance parameters for existing and future regulations, considering specific relations towards resilience of the system.
2. The utility function shall be expanded to include new and robust demand and RES availability clusters.
3. The utility function shall be expanded to allow for integrating socio-economic groups with different preferences (re technologies and policy instruments) and to allow for uncertainty parameters to be included in terms of RES investment decisions and efficiency measures.
4. The sBSM is enhanced in terms of additional output parameters that are relevant to assess the resilience of the buildings related energy system.
5. The model will be expanded in its functionality to better represent the material flow within the building stock as input to the research question towards circular economy.
6. The model will be expanded in terms of fully integrating load curves from the existing load profile database.

WP 4 is structured into five sub-tasks of which the focus has been put on the first one in year 1:

Task 4.1: Methodology to expand the functionality in the spatial building stock model

In the first project year, activities of WP 4 have been focussing on Task 4.1 which aims at improving and enhancing the methodology of the spatial building stock model (sBSM), particularly to expand several functionalities that are needed to be able to model both scenarios and shocks defined in the SURE project. A substantial part of these activities is described in deliverable D4.1 entitled “Description of methodological improvements of the utility function in the BSM”.

In Task 4.1, a conceptual model development methodology has been pursued. The modelling approach and the functionalities of the existing version(s) of the sBSM were analysed to explore to which extent SURE's research questions could be answered and to which extent model improvements need to be made. Based on this gap analysis and based on new empirical findings from the MISTEE project about the decision behaviour of building owners, a concept to expand the sBSM was drafted. The concept proposes to enhance the utility function of the decision module of the sBSM with the following elements:

1. Interaction between the heating system, the building envelope, and other energy system components such as PV, storage, demand side management (DSM) measures (so fare these decisions are modelled individually in a sequential way).
2. Influence of socio-economic variables (so far, all owners' decisions within each of the main building types SFH, MFH and non-residential buildings are modelled with the same utility function regardless their age, owner type etc.)
3. Impact of spatial constraints: spatial constraints are partly included already in the sBSM, but more emphasis needs to be given to two types of decentralized systems which are very important in the Swiss buildings sector: first, the interaction of geothermal heat pumps across neighbouring buildings and second, aspects of noise of air-water heat pumps, taking into account both noise protection of the own and of the neighbouring buildings.
4. Perceived choice set as compared to the "real" choice set (limited perception, bounded rationality) to be able to incorporate ignorance (also referred to as illiteracy) and high awareness (e.g. achieved by campaigns or due to a changed zeitgeist).
5. Expansion of energy cost calculation to better incorporate energy tariff schemes and regulation such as feed-in tariffs, capacity vs. energy pricing and to take into account the energy performance gap (EPG)

The decision module plays a key role within the sBSM as it simulates the behaviour of the building owners as a function of various exogenous technical, socio-economic, demographic and policy drivers. The decisions of building owners in turn determine the dynamics of the building stock over the next decades.This can be recognized in Figure 4.

Moreover, a conceptual approach is proposed towhich should yield a better fit between modelled and empirical data. This should be achieved by the following steps (see Deliverable report D 4.1 in Appenxix 3 for details):

1. Improving the data base, particularly regarding the feasible choice set of energy options
2. Improve and expand the decision module (see above)
3. Further develop the calibration approach. To this extent a new automated calibration routine needs to be developed (so fare calibration is done manually based on an iterative approach) whith a focus on the lower part of Figure 4, i.e. taking into account decision module, different output dimensions, and respective empirical data.

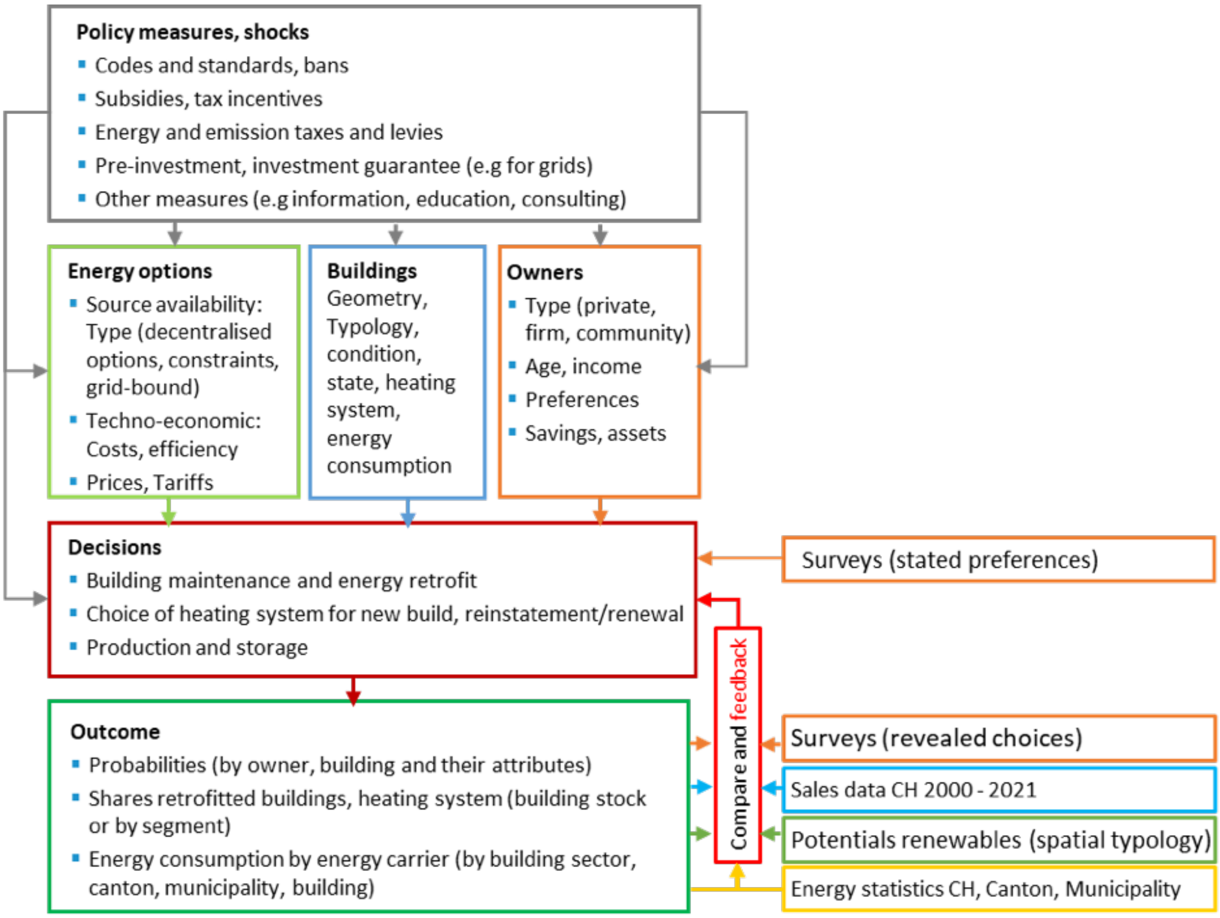



Figure 4: Structure of the sBSM: simplified representation with a focus on the decision module and its calibration.

In addition to the conceptual development described above and in D4.1 preparatory work has been carried out to improve the empirical basis of spatial drivers and constraints. Particularly, a methodology to estimate the potential and restrictions for air-water heat pumps due to noise protection constraints was developed (and partially implemented). To this extent building footprint data and parcel data from the Canton of Zurich were used to determine whether or not enough space is available to respect the distance between a potential heat pump (or its heat exchanger device) and the own and the neighbouring buildings. Said distance depends on the building's energy demand (as a matter of fact its heat power demand), the type of heat pump (there are quite some difference across products and suppliers) and the noise regulation (depending on the type of neighbourhood and partly on the practice of the regulation's implementation). Results achieved from data of the Canton of Zürich are then extrapolated by a discrete choice model which describes the probability whether or not a heatpump is allowed to be installed or not).

The results achieved in WP 4 are relevant for SURE as follows:

- The further conceptual development of the modelling approach allows for modelling the scenarios and shocks that are being defined and discussed within SURE (economic shocks, policy shocks, environmental shocks etc)

- As foreseen the outcome of WP 4 will be the fundamental of many other WP as the results of the sBSM, namely the energy demand of the built environment, will be the input of various other models, both at the Swiss level and for the Canton of TI (WP13).
- The city of Zurich, partner of WP 14, is very much interested to model the probability at which building owners would be willing to install heating systems themselves or accepting offers from thermal grids. These probabilities should be the basis for the energy planning section to implement their decarbonisation policy at a building block, neighbourhood and city scale using the sBSM.

Task 4.2: Integration of newly defined decision parameters in the BSM

Also the work on task 4.2 has started in year one but at lower intensity compared to task 4.1. Task 4.2 is about implementation of the concepts developed in task 4.1. Some preparatory work has been started in year one. In order to advance decision parameters in the BSM, synergies with other on-going project are investigated. For instance, some results of WP 4 regarding the spatial constraints of air-water HP have been used in the SFOE research project LICS. Vice versa results from LICS regarding the techno-economic parameters of heating systems will be used in SURE (as part of the sBSM).

Task 4.3: Definition, implementation and analysis of pathway scenarios

- Not started yet

Task 4.4: Definition, implementation and analysis of shock scenarios

- Not started yet

Task 4.5: Material flow analysis and interface to WP10

- Not started yet

### 3.5 WP *5* Spatial modelling of renewables-based generation

| **Title** | Spatial modelling of renewables-based generation | | | |
|---|---|---|---|---|
| **Actual start** | *05/2021* | | **End** | *12/2025* |
| **TRL range** | **Starting at** | - | **Ending at** | - |
| **WP leader** | *Evelina Trutnevyte, UNIGE, evelina.trutnevyte@unige.ch* | | | |
| **Members and coop. partners** | *Nik Zielonka (UNIGE), Verena Heinisch (UNIGE)* | | | |

**Objectives**

*WP5 brings a spatially-explicit, bottom-up view to the SURE modeling activities with the focus on new renewable generation. Specifically, it aims to achieve these goals:*

- *quantify spatial scenarios of potentially disruptive growth in solar PV and heat pumps on the basis of empirical data from the past and assumptions about future change;*
- *model weather-related shock scenarios with the focus on PV and wind generation and load curves, and exchange with the grid modelling in WP6;*
- *quantify additional social indicators that benefit from the spatial view, such as the indicator of regional equality and the bottom-up assessment of implementation feasibility;*
- *assess the suitability of various locations throughout Switzerland for power-to-x and also quantify the future scenarios of disruptive uptake of power-to-x.*

**Work performed and results**

Task 5.1 Spatial modeling of disruptive growth in solar PV and heat pumps

WP5 work started de facto in February 2022, when the PhD student Nik Zielonka started his appointment at UNIGE. First, a literature review was conducted on various innovative methodologies that could be applied to model future disruptive growth in solar PV and heat pumps in Switzerland at a spatial resolution of over 2'200 municipalities. The literature review identified a potential to apply state-of-the-art methods for generating probabilistic future projections at a high spatial resolution, which would be done for the first time in scientific literature, given the availability of empirical data in Switzerland. The benefit of probabilistic projections is that they enable an empirically grounded analysis of low-probability tails of the distributions which could be considered as disruptive technology uptake. The overall research design for Task 5.1 was then under development with plans to apply various models for generating probabilistic future projections of uptake of solar PV and heat pumps in Switzerland and to test these models retrospectively for their accuracy to choose the most accurate model for future projections.

Second, the existing spatial datasets on the uptake of solar PV and heat pumps in Switzerland were reviewed to develop the dataset for the modeling purpose. Good-quality solar PV data is already available and the latest 2021 data can be readily used in modeling. The data on heat pumps is not directly available and hence work was being done on how multiple datasets (Gebäuderegister, CECB/GAEK etc.) could complement each other to come up with the most reliable and cross-validated dataset at as high resolution as possible. In addition to solar PV and heat pumps, spatial datasets on the uptake of battery electric vehicles were also under investigation, even if this was not foreseen in the proposal. The data-driven methods for empirical projections in principle could be applied to various technologies, and hence the data on battery electric vehicles is also collected for a potential side project.

Third, early modeling activities for solar PV have started. Previous statistical models (Müller & Trutnevyte, 2020) that use socio-demographic and techno-economic variables and empirical PV growth in Switzerland at a level of 143 districts were updated to include data until 2021. Some of the socio-demographic and techno-economic variables were also refined, e.g. adding self-consumption rate for PV electricity. Development of alternative models for probabilistic projections was then in progress, for example, starting with a simple S-shape diffusion curve with Monte Carlo runs.

Task 5.2: Weather-related shocks on the Swiss electricity sector and the resilience indicators

The hands-on modeling work in Task 5.2 is foreseen for later stages of the project. For now, there was work done in collaboration with WP2 on developing narratives of SURE environmental (weather-related) shocks for the integrated analysis and modeling. Two narratives of a cold wave and, after the feedback of the stakeholder workshop, heat wave were developed and they will be translated into modeling parameters in the next project's year.

Task 5.3: Social indicators of regional equality and implementation feasibility

The hands-on modeling work in Task 5.2 is foreseen for later stages of the project. For now, there were only exchanges with WP1 on the choice of the indicators.

Task 5.4: Spatial modeling of disruptive growth in power-to-x

This task has not started.

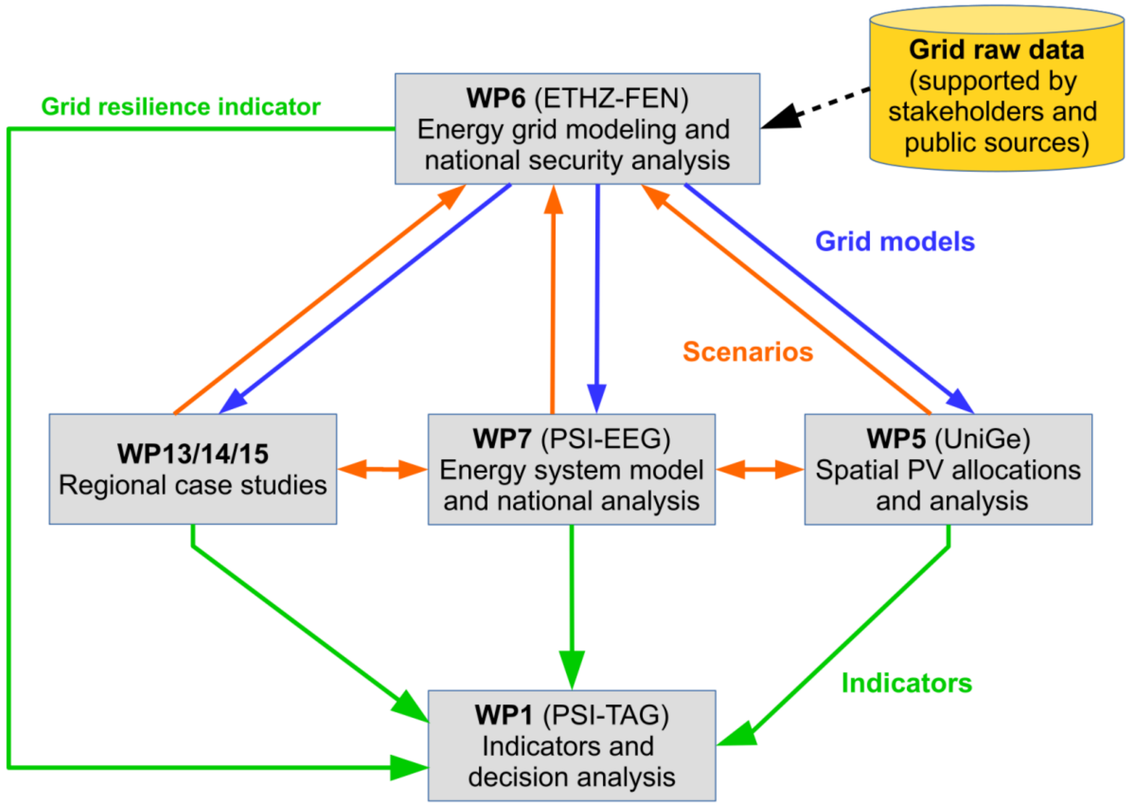
### *3.6* WP *6* Energy grid modeling and security analysis

| **Title** | Energy grid modeling and security analysis | | |
|---|---|---|---|
| **Actual start** | *04/2021* | **End** | *04/2025* |
| **TRL range** | **Starting at** *X* | **Ending at** | *X* |
| **WP leader** | *Alexander Fuchs, ETHZ-FEN, fuchs@fen.ethz.ch* | | |
| **Members and coop. partners** | *Turhan Demiray, ETHZ-FEN* | | |

| **Objectives** |
|---|
| • *Consistent modeling of energy grids suitable for the modeling approaches and the different scenario analysis tools used in other SURE-work packages*<br>• *Security and resiliency analysis for energy grids (electricity, gas and heat) by developing and computing appropriate short- and mid-term grid resiliency indicators* |

**Identification of modeling needs with SURE partners**

Currently, the main efforts within WP6 covering the security and resiliency analysis for energy grids (electricity, gas and heat). Meetings have been carried out with all partners of the SURE consortium linked to the energy grid models, most of which are illustrated in the following figure:



- Meetings with PSI-EEG have been carried out to identify the interface to import scenarios and export relevant indicators and constraints. As a main result, FEN will receive information on electricity demand and production for representative sequences of scenario hours on a Swiss zonal (cantonal) level, as well as for selected neighboring European zones. These scenarios include normal operation as well as stress/shock scenarios. The parameters will be disaggregated to individual nodes of the electricity grid and simulated. Furthermore, constraints will be computed for selected variable parameters, e.g., the zonal production or demand. The aggregated constraints will be used by PSI-EEG in the STEM model on a zonal level to ensure the secure grid operation and mitigate overloadings.
- Similarly, together with PSI-EEG, exchanges have taken place to identify constraints on the gas grid operation. A European gas grid infrastructure model will be adopted to incorporate flow limits of the ENTSO-G network. The model will also assess, how hydrogen can be transported in part of the network during a parallel operation of both energy carriers.
- Meetings with TEP have been carried out, to identify modling needs, in particular to residiential gas grids and heat grids. For the Zurich case study in WP13, part of the future Zurich heat grid will be modelled for the cost and feasibility analysis of replacing part of the gas grid with heat grids.
- Additional dedicated modeling meetings have been carried out with SUPSI and UNIGE. The main focus there is residential and regional electricity grids. The partners have own grid models, and work has not yet started for all related subtasks, but the main focus will be to harmonize the models and scenario parameters used in the assessments.

**Implementation of electricity and gas transmission models**

According to the initial exchanges, in particular with PSI-EEG, modeling work has been carried out on the transmission level of the electricity and gas grid.

For the electricity grid, an open modeling framework, PyPSA, has been combined with European electricity scenarios (TYNDP) to create a fully open and very detailed model of the European transmission grid with ~10’000 lines and nodes. A constraint matrix incorporating all line constraints characterizes the network limits, but is too detailed for incorporation in the STEM model (both for data relevance and complexity reasons). The model has been clustered into regional Swiss zones according to NUTS-2 regions and European zones on a country level.

Current work focuses on two steps. First, the goal is to further reduce the number of linear constraints during normal operation through reduction and approximation techniques. Second, different security indicators are developed, characterizing how far the system is from an insecure operation. These will be based on N-1 security, but also the amount of Swiss generation power for redispatch and capacity reserve. A potential additional security indicator on dynamic resilience is also investigated from a related project on the European level (SCCER-FURIES).

For the gas grid implementation, a public grid model (sci grid) has been adopted and combined with monthly gas exchanges on the borders. Furthermore, gas generator capacities are added to the grid model to characterize potential temporary gas demand peaks. A simple nonlinear gas flow simulation has been implementated, simulating pressure and massflwo for different operational scenarios. The scenarios will focus on Switzerland and have different demand factors on the cantonal level. The

exchange on the European level is aggregated, the appropriate level of granularity is currently investigated. Further investigations concern the development of simplified linearized flow constraints, characterizing the impact of gas flow changes around an average operating point. Preliminary simulations of the Swiss grid revealed low variation of the pressure, but high variability of the mass-flow, partly exceeding the flow limits of the pipes. Current investigations extend the study to neighbouring countries, vary the import directions, investigation the variability introduced by gas power plants and assess the accuracy of linear modeling approaches.
A related project with GAZNAT analyses the different options of a gas storage for the security of gas supply in Switzerland.

Detailed PyPSA electricity grid, forming the basis for the electricity grid model:

Detailed European Gas grid, forming the basis for the gas grid model:

### *3.7 WP 7 Integrated energy systems modelling*

| **Title** | Integrated energy systems modelling | | |
|---|---|---|---|
| **Actual start** | *05/2021* | **End** | *10/2025* |
| **TRL range** | **Starting at** *X* | **Ending a*t*** | *X* |
| **WP leader** | *Evangelos Panos, PSI,* ***evangelos.panos@psi.ch*** | | |
| **Members and coop. partners** | | | |
| **Objectives:** | | | |

- To quantify the response of the whole Swiss energy system for various disruptive events and under different pathways
- To evaluate possible actions to improve the sustainability and resilience of the energy system
- To provide the boundary conditions and the long-term developments in the future Swiss energy system to the regional and topic-specific case studies
- To provide suitable training and validation datasets to the ML algorithm for the uncertainty analysis
- To give basic input to the MCDA and to the creation of roadmaps and strategies

This work package consists of six tasks of which the first three have been started in the first year of the project. The work package focusses on further development of PSI's Swiss TIMES Energy System Model (STEM) and its application jointly with other modelling tools that are part of the project.

**Task 7.1 Implementation of interfaces with other modelling tools**

In order to analyse possible future pathways of the energy sector in greater detail and to facilitate model collaboration on specific topics, STEM has been advanced in various aspects. The process of re-calibration of STEM according to 2019/2020 statistics has been started which is a time-consuming effort given that this is to be preformed for all sectors of the energy system captured by STEM, at a great technological detail and for several end-uses. Moreover, the representation of the industrial sector in STEM has been improved with additional sector disaggregation and advanced technology representation of the pulp and paper sector, as well as food and beverage industry. Particular focus was dedicated to the modelling of production process improvements in addition to energy saving and fuel switch measures, as well as the application of high temperature heat pumps for which advanced modelling of different temperature levels and waste heat recovery options was introduced into STEM. These model improvements specifically address a more realistic representation of climate change mitigation options for the Swiss industry and are expected to contribute to advanced analytics of net zero pathways for Switzerland that are to be evaluated in SURE. These model enhancements translated into one published scientific article (Obrist et al. 2022) and one submission of an additional scientific article (see Obrist et al.).

Major findings from preliminary analyses with the improved representation of Swiss industry indicate:

- Advanced technology deployment and energy savings can be cost-effective even under moderate climate policy conditions, if energy prices increase in future.
- Achieving a net-zero goal in the pulp and paper industry by 2050 requires increased amounts of biomass in the short term and additionally high-temperature heat pumps up to 150-200 °C in the long- term, in case of biomass scarcity or redistribution of bioenergy resources to other sectors.

- Energy related costs for the pulp and paper sector may increase by additional 50% if its full decarbonisation is to be achieved
- The economic potential of high temperature heat pumps in the food & beverage industry exceeds by far the one of pulp and paper industry, constituting them an important option for decarbonising the industrial sector.

Beyond these model developments and related to the goals of task 7.1, several bilateral meetings have been conducted with modelling partners in order to specify interfaces of STEM with other models. Specifically, an update of the methodology and data for the link to the energy grid models of ETH Zürich FEN was discussed and is at the first design stages. A first discussion with linking STEM and the GEM-E3 model from E3M has also taken place, and a first design of the coupling interface has been sketched.

**Task 7.2 Implementation of sustainability and resilience indicators**

The aim of this task is to identify sustainability and resilience indicators developed in WP1 which can be incorporated into the STEM modelling framework. Ultimately, the relevant indicators are to be implemented in the model that they are directly retrieved from the quantitative analysis of STEM. While a long list of more than 100 indicators has been collected in WP1, the consolidation process and the evaluation of the most relevant indicators is still in progress and subject to the feedback from the SURE stakeholders. Nevertheless, the STEM modelling team was engaged in the discussions on resilience and sustainability indicators and has contributed with input on possible indicators that can be retrieved from STEM. This is based on previous projects and the comprehensive model results processing procedures that are in-place. It is expected that in the course of the exchange on the indicators, STEM needs to undergo further developments to be able to compute an extended set of sustainability and resilience indicators.

**Task 7.3 Integration of actors' behaviour and legal aspects**

This task deals with an improved representation of actors' behaviour in STEM. With the aim being able to quantify energy transformation pathways in view of technical, economic, environmental and social aspects, a first action in this task concerns the advancement of STEM by incorporating a more realistic response of consumers on changes of the energy system configuration and related changes in energy costs. Therefore, we employ a complementary agent-based model which is linked to STEM. In this regard, the energy transition pathways assessed and suggested by STEM will entail a high degree of both technical and societal feasibility.The model advancement is preceded by a comprehensive literature review (see Stermieri et al. 2022) and intends to enable the analysis of societal practices combined with energy systems modelling. Key features of the advanced modelling comprise:

- Improved decision mechanism for the actors that considers costs, preferences for technologies and societal practices, as well as infrastructure anxiety
- Representation of 500 households as agents, which ensemble the real population
- Representation of both physical and virtual social networks between the agents and social dynamics in the preference evolution of the households over time
- Time-dynamic modelling of the evolution of the agents, technology costs and demands, as well as their preferences for technologies and societal practices
- Distinction between several "traditional" societal practices (e.g. commuting to work) and new "digital" social practices (e.g. teleworking).

- Detailed representation of socio-economic structures, energy systems and infrastructures of four key Swiss regions (it can be expanded, if needed).
- Flexibility in integrating field studies, societal and technology databases, e.g. SHEDS, Mircocensus, SINUS-Millieus and Time-Use Surveys.
- Establishment of bi-directional collaboration links with living labs and field studies.
- Customisable interface for different stakeholder groups, to analyse the role of active participation of relevant stakeholders in energy transition.

The new modelling framework could be successfully demonstrated using real-world data sets. Main focus was dedicated to residential consumers and behavioural impacts related to remote work and further e-services. A corresponding publication is currently in preparation but has not been submitted yet.

The newly developed agent-based model will be also extended to include notions of legal aspects also in the decisions of the agents.

**Tasks 7.4 to 7.6 have not started yet.**

### *3.8 WP 8 Macro-economic modelling*

| **Title** | Macro-economic modelling | | | |
|---|---|---|---|---|
| **Actual start** | *04/2022* | | **End** | *03/2025* |
| **TRL range** | **Starting at** | *X* | **Ending at** | *X* |
| **WP leader** | *Leonidas Paroussos,* ***paroussos@e3modelling.com*** | | | |
| **Members and coop. partners** | | | | |
| **Objectives:** | | | | |

- Examine in a unified and consistent methodological framework the Swiss socio- economic implications of alternative future plausible transition pathways and disruptive events.
- Develop an economic outlook for Switzerland (both at national and regional level) that will serve as the basis (sectoral production, household income etc.) for the energy system modelling.
- Quantify the effects on the economic and social systems of different transition pathways and disruptive events
- Evaluate the performance of alternative scenarios across a series of sustainability and resilience indicators
- Provide the output to be used by the machine learning task

There are three tasks currently in progress: i) Data Collection, Harmonisation and Reconciliation and ii) Model development, iii) Reference projection of Swiss economy.

i. Data Collection

Data to calibrate the GEM-E3-CH model are collected from the Swiss National Statical office, EUROSTAT and other dedicated datasets including IEA, ILO and others. The most recent symmetrical Input Output table available at the national statistical office of Switzerland is for the year 2017 (published but not yet finalised until today). This table is available for 50 economic activities (CPA 2 digit classification) and needs to be further extended so as to be compatible with the GEM-E3-CH sectoral coverage where power generation technologies and clean energy sectors (e.g., PV, Wind turbine manufacturers, batteries etc) are discretely identified. Extending the IO table is a process that reconciles data from the SIOT, energy balances and engineering studies. The data are then harmonised to a closed accounting system using a cross method that ensures that the least possible distortions to the original matrix / dataset takes place. Particular focus is given on the consistency between the energy balance statistics and associated energy transactions in the SIO table. This consistency is essential both for the accurate accounting of energy efficiency and emissions but also for allowing the soft-link with the Swiss energy system model. To this end a set of data needs to be harmonized between the two models (including power mix, fuel consumption by economic agent, LCOEs and technology capital costs). In parallel with the extension of the IO table a critical task is the harmonization of bilateral trade flows as found in GTAP and COMEXT with the trade statistics found in the nationals accounts. Additional statistics regarding the flow of funds matrix and the current account are collected so as to derive the Swiss financial SAM. Finally, the national IO table is split to regional IO tables. As no full IO datasets are available on the regional level the tables are derived assuming uniform production structures inherited from the national IO table. Regional specific data are used as anchor points around which the remaining IO table is populated using indirect methods.

ii) Model Development

The GEM-E3-CH model is being updated and recalibrated to focus on Switzerland and key trading partners. The model is expected to be calibrated on the 2017 SAM and feature state of the art mechanisms such as: i) Discrete representation of power generation technologies, ii) Semi endogenous technical progress based on two factor learning curves, iii) Explicit representation of the financial sector allowing for the design of alternative financing schemes, iv) involuntary unemployment, v) multiple households, vi) regional modelling.

iii) Reference projection of the Swiss economy

The GEM-E3-CH model is calibrated to a reference projection that has been initially conceived using the latest information and long-term trends regarding: energy & climate policies, technical progress, fossil fuel prices, technology costs and population growth. The model ensures that aggregate GDP growth rate provided exogenously by third parties (National office of Finance, Swiss National Bank, IMF) is consistently detailed by component and sector. The default assumption for sectoral economic growth is to follow a sustainable growth pathway where excess deficits or surpluses are balanced over time. The Reference projection will have to take into account effects triggered by COVID -19 and the war in Ukraine.

The calibrated version of the GEM-E3-CH model will be used in conjunction with the sectoral models participating to this study to assess the socio-economic and distributional effects that different transformation pathways and disruptive events (e.g., related to climate, energy and finance) have onto the economic system of Switzerland.

A product of this WP (beyond the promised deliverables) will be a scientific publication focusing on Socio-economic implications of alternative transformative pathways of the Swiss energy and economic systems: A model-based analysis".

### 3.9 WP *9* Reconciled model-based uncertainty analysis

| **Title** | Reconciled model-based uncertainty analysis | | | |
|---|---|---|---|---|
| **Actual start** | *11/2021* | | **End** | *12/2025* |
| **TRL range** | **Starting at** | *X* | **Ending at** | *X* |
| **WP leader** | *Micheal Multerer, USI Euler, USI*<br>*Rolf Krause USI Euler, USI* | | | |
| **Members and coop. partners** | Davide Baroli, USI Euler, USI | | | |

**Objectives**

*Text or bulleted sentences.*

- Investigate a probabilistic kernel-based surrogate model for each module of SURE model.
- Interlace the surrogate model within modular coupling of SURE framework
- Investigate fast multi-fidelity kernel-based surrogate model which approximate the modular design of SURE model framework
- Assess uncertainty of resilient indicators respect to shocks represented as variation in input-parameter space by Kernel-ANOVA analysis

**Work performed and results**

WP9 work started de facto in November 2021, when the PostDoc Davide Baroli started his appointment at USI.

The work performed on uncertainty quantification methods is primarily addressing the definition of a probabilistic surrogate model, which can be used within the SURE framework in a modular way. The probabilistic model consists of “kernel-based” perception methods coupled with novel multiresolution techniques developed. This approach allows to achieve competitive scalability of the surrogate model and in the performance of optimization of its hyper parametrization. Additionally, by construction the kernel-based models under development can evaluate the following scenarios: high oscillatory outputs, high-dimensional and explored sampling of design space (inputs parameters). With regard to the envisaged sensitivity analysis, kernel ANOVA representations will be studied.

The deliverables and milestones achieved will be achieved as intended. A 1$^{st}$ manuscript on multiresolution methods for scattered data approximation is currently under review and further publications of the planned probabilistic model should be reached. A joint peer review paper on the application of the probabilistic modelling for month 18 should be reached using the dataset from the TIMES and EXPANSE models.

The current investigation is addressing the implementation of developed frameworks and its validation with datasets provided by PSI TIMES (WP1) partner and UNIGE EXPANSE. Based on iterations of dataset provided, the surrogate model will be trained on variations of the input parameters (demography, technology changes, industrial demanding and services and macro-economic factors) to assess the uncertainty of indicators among different pathways that are investigated by the project partners.

The further development described here below about the surrogate modelling and its interlacing within SURE framework was analysed and is based on the model reference cards developed by consortium partner after the general assembly and scientific exchange in meetings with the coordinator PSI.

Based on activities on construction of surrogate methods and its current validation and improvement on datasets provided by the partners of SURE, the investigation of surrogate modelling will involve two fundamental features:

- Bayesian Optimization or active learning that allows to explore and detect the most informative input dataset for increasing the accuracy of the surrogate model.
- Multi-Fidelity approaches that allow fusing different levels of fidelity in input-output relation. For example, a low fidelity dataset can be associated with current assumption of one model of SURE and a high-fidelity dataset is generated by its advanced construction. An alternative scenario is considered as low-fidelity the dataset generated by one model and as high-fidelity the dataset generated by the coupling with another model. Due to multifidelity and its analysis with ANOVA it is possible to identify which parameters influence the variation of the output (indicators) mest and the quantity of information obtained by coupling of the models.

The multifidelity approach allows to provide a probabilistic modeling for coupling model of WP2.

The overall beneficial of surrogate modeling in SURE framework allows to reach the scalability without losing accuracy up to a sufficiently rich dataset provided and embedding of active learning functionality of the probabilistic model.

The interactions with partners of the consortia are performed by joined meetings on discussing the design of variation of input parameters, the interaction of surrogate models in their framework, potential of uncertainty quantification and interaction on dataset from their current and previous studies with the EXPANSE and TIMES platforms.

Due to the modularity and the hierarchical construction of the surrogate modeling, it allows a potential validation also in other SWEET consortia (for instance EDGE) which have model frameworks characterised by interlaced modularity and assessing uncertainty variation of their objectives with respect to different pathways investigated.

### 3.10 WP 10: Life Cycle Analysis and Circular Economy

| Title | Life Cycle Analysis and Circular Economy | | | |
|---|---|---|---|---|
| **Actual start** | *06/2021* | | **End** | *12/2025* |
| **TRL range** | **Starting at** | *n.a.* | **Ending at** | *n.a.* |
| **WP leader** | *Christopher Mutel, PSI LEA-TA, christopher.mutel@psi.ch* | | | |
| **Members and coop. partners** | *Aristide Athanassiadis, HERUS - EPFL, Claudia Binder, HERUS - EPFL,* | | | |
| **Objectives** | | | | |
| • *Creation of hybrid LCA database* | | | | |

**Work performed and results**

*New context:*

The war in Ukraine has reinforced the need for tools to adjust existing life cycle assessment databases which model global supply chains. While we have made substantial progress on integrating future scenarios, we also need to develop and test similar techniques for adapting to current conditions, and especially for the use of online data sources such as the ENTSO-E or UN COMTRADE APIs. We have prepared an online example of such usage at https://try.brightway.dev/.

The war in the Ukraine is also heavily influencing both our future background scenarios (evolution of the European and global energy system), and the Swiss shock scenarios being developed in other work packages. Some deliverables might need to be revisited to take into account the continuously changing circumstances.

*M10.1 Creation of hybrid LCA database*

We have constructed a prototype hybrid database, and are using this in our current research. The hybridization procedure follows the work of Arthur Jakobs (**https://www.frontiersin.org/articles/10.3389/frsus.2021.666209/**), and is based on using heuristics to decide when to supplement the bottom-up inventories with top-down data to provide a more complete picture of the economy while avoiding double-counting. However, the prototype is based off of academic code, and this software needs to be substantially improved to have confidence in its correctness and reproducibility. To this end, we have hired Arthur for a one year postdoc starting in November 2022.

In combination with other data-gathering projects, we will extend the prototype database to include additional data sources, both as supplements for sectors not well covered in our current foundation, and as validation checks or constraints during the hybridization algorithm. In other words, our ambition for this deliverable has increased, as has our expectations for our eventual data quality.

*D10.2 Report or publication on global sensitivity analysis of hybrid database*

This manuscript is in preparation (Kim et al. 2022), with expected submission in June. The foundation for this work has already been published (**https://pubs.acs.org/doi/10.1021/acs.est.1c07438**), and our current work is focused on the inclusion of correlated uncertainties in uncertainty analysis and global sensitivity assessment (GSA). The inclusion of such correlations not only increases the realism of our product systems and the data quality of uncertainty results, but also allows our GSA techniques to identify more relevant factors for future data quality increases or new modelling approaches (as opposed to the status quo, where we mostly find artifacts of strange modelling choices or compromises due to inadequate data formats for more realistic modelling).

Our manuscript in publication is a big step forward for the life cycle assessment community as a whole, as it presents substantially better modelling principles that can be used directly on existing databases and is accompanied by robust free and open source software.

*M10.2 Selection of global scenarios for prospective life cycle assessment*

This milestone is progressing well; while the selection of shock scenarios has taken a bit more time, we have been developing software tools to be able to consume scenarios produced by many different integrated assessment models (we previously worked only with REMIND) based on the new AR6 reporting format. We have also been putting together a series of analysis workbooks that allow us to get a quick, graphical overview of key trends and drivers within each scenario, which will allow us to better ensure consistency between the shock scenarios and the global IAM scenarios.

### 3.11 WP *11 Political environment and regulatory aspects*

| | | | | |
|---|---|---|---|---|
| **Title** | **Political environment and regulatory aspects** | | | |
| **Actual start** | 11/2022 (M19) | | **End** | 10/2026 (M66) |
| **TRL range** | **Starting at** | n.a. | **Ending a***t* | *n.a.* |
| **WP leader** | *Isabelle Stadelmann-Steffen, UniBE,* isabelle.stadelmann@ipw.unibe.ch | | | |
| **Members and coop. partners** | *A. Abegg / G. Seferovic / R. Müller, ZHAW*<br>*Gracia Brückmann, UniBE* | | | |
| **Objectives** | | | | |
| The main goal of this work package is to bring in the political and legal perspectives into the definition and evaluation of newly proposed scenarios (by other work packages). More specifically, its objectives are fourfold:<br><br>1) Understand the newly proposed scenarios by other WPs and analyze the legal and political consequences they may pose<br><br>2) Identify relevant political stakeholders (depending on the different scenarios) and analyze more precisely the position of political stakeholders, namely whether and where political stakeholders exhibit divergent preferences or priorities compared to other stakeholders, and how this could affect the implementation chances of the scenarios.<br><br>2) Identify and assess different solutions and measures to reduce legal and political barriers for a timely implementation of the proposed scenarios.<br><br>3) Propose recommendations on how from a legal and political points of view the likelihood for successful implementation of the proposed scenarios can be increased. | | | | |

This work package has not started yet. First progress reporting foreseen in the following reporting period.

### 3.12 WP 12 *Formulation of strategies and roadmaps for implementation*

| | | | | |
|---|---|---|---|---|
| **Title** | **Formulation of strategies and roadmaps for implementation** | | | |
| **Actual start** | 08/2026 (M64) | | **End** | 04/2027 (M72) |
| **TRL range** | **Starting at** | n.a. | **Ending at** | *n.a.* |
| **WP leader** | *Tom Kober, Peter Burgherr, PSI-LEA,* ***tom.kober@psi.ch****,* ***peter.burgherr@psi.ch*** | | | |
| **Members and coop. partners** | *E. Panos / C. Mutel / L. Siskos (PSI)*<br>*T. Demiray / A. Fuchs (ETHZ)*<br>*C. Binder / A. Athanassidis (EPFL)*<br>*R. Krause / M. Multerer (USI)*<br>*M. Jakob / M. Steck (TEP)*<br>*R. Rudel / F. Cellina (SUPSI)*<br>*I. Stadelmann (UniBe)*<br>*E. Trutnevyte (UniGe)*<br>*A. Abegg / G. Seferovic / R. Müller (ZHAW)*<br>*L. Paroussos (E3M)* | | | |
| **Objectives** | | | | |
| This work package consolidates the output from the stakeholder-based integrated assessment and evaluation of pathways and policies to implement them, in order to recommend strategies, roadmaps of implementations, as well as policies that address shortcomings of available instruments and propose new approaches. WP12 bridges the quantitative analyses performed in SURE with the recommendations for policy measures and regulations that could lead to the implementation of energy transitions pathways for Switzerland that are sustainable and resilient with broad acceptance from stakeholders | | | | |

This work package has not started yet.

### 3.13 **WP 13** *Case study on cantonal level - Ticino: Modelling socio-technical energy transition*

| **Title** | ***Case study on cantonal level - Ticino: Modelling socio-technical energy transition*** | | | |
|---|---|---|---|---|
| **Actual start** | *05/2022 (M01)* | | **End** | *04/2027 (M72)* |
| **TRL range** | **Starting at** | n.a. | **Ending at** | *n.a.* |
| **WP leader** | *Francesca Cellina, SUPSI,* **francesca.cellina@supsi.ch** | | | |
| **Members and coop. partners** | *Fabrizio Noembrini, Ticinoenergia*<br>*Giovanni Bernasconi, Cantonal office for climate, air and renewable energies*<br>*Sandro Pitozzi, Cantonal office for energy*<br>*Roberto Pronini, AET*<br>*Marco Bigatto, EnerTI*<br>*Fabio Battaglioni, Parliamentary commission on energy*<br>Martin Jakob, Giacomo Catenazzi, TEP | | | |
| **Objectives** | | | | |
| *In line with the goal of the SURE consortium to assess pathways that balance the sustainability and the resiliency of the Swiss energy system, this WP adopts the methods and tools developed by the consortium and applies them in a regional context. The participatory development of a System Dynamics model of the Ticino energy system, reflecting the Ticino landscape and integrating local stakeholder perspectives, aims at providing a form of Socio-Technical Energy Transition (STET) simulation tool that will be used to dive into a Cantonal case-study to:*<br>• *gauge the resiliency of a sustainable energy system at a regional level;*<br>• *reflect and validate the cohesion between federal and regional pathways, as different regions might have different technical boundaries and social narratives;*<br>• *provide guidelines that support the formulation of a Cantonal Energy Plan.* | | | | |

The overall goal of WP13 is to evaluate the response of the regional energy system to public and private actions aimed at achieving a sustainable energy system, and assess its resiliency to shocks that might undermine the achievement of that goal. WP13 implements the general SURE approaches and methodologies (pathways, shocks, indicators and participatory multi-criteria decision making), by customising them on a regional level, in order to reflect the specific conditions, narratives, goals and needs by local stakeholders. For this purpose, WP13 specifically co-creates a regional energy system model together with the relevant stakeholders, by involving them in participatory modelling activities from the very beginning of the modelling process. Early engagement of local stakeholders and their active contribution to the identification of the key model variables, their interconnections as well as the magnitude of the influence of their relationships, and ultimately the assumptions behind them, lays the grounds for a later trust in the model outcomes and results, which is in turn fundamental for prompt, less conflictual and effective decision-making and deliberation aimed at steering the system towards the desired direction, and the later implementation of the decisions made (Voinov and Bousquet, 2010). By activating a collective learning process, helping to get a shared understanding of the complexity of the regional energy system, allowing possible conflicts to arise (and therefore to be properly managed), modelling with stakeholders favours social acceptance of the transition pathway and therefore it is expected to provide tangible and valuable support to the implementation of the Swiss Energy Strategy 2050.

In order to support such a modelling with stakeholder process, we opted for the system dynamics modelling approach (Sterman, 2001), which allows to represent the system bv a collection of stocks (the variables) connected by flows of materials or energy: the latter either get accumulated in stocks or move between them. Such a representation is easy and intuitive and favours the involvement of both experts and non-experts in the development of the model components, through the identification of the causal loops between the energy system elements. Furthermore, system dynamic approaches were identified as potential tools to enrich quantitative energy models with socio-technical facets related to learning processes, policy, and behavioural changes (Bolwig et al. 2019), and therefore aligned with SURE's aim to account for society- and economy-wide implications of given pathways and shocks. An initial literature review we performed for WP13 has in fact shown that system dynamics approaches have already been explored in the Swiss modelling landscape to evaluate national pathways for de-nuclearization and capacity expansion (Ochoa 2007; Osorio and van Ackere 2016; Osorio, van Ackere, and Larsen, 2017) and for the evaluation of the roll-out of entrant technologies and/or concepts (Dehdarian 2018; Kubli 2016; Zapata Riveros, Kubli, and Ulli-Beer 2019). Instead, its potential as a methodology supporting participative modelling processes has only been explored to a limited extent (for instance, in Switzerland by Ulli-Beer et al. 2017), and SURE therefore provides the opportunity to explore its effectiveness via applied research.

The regional case study of WP13 focuses on the Canton Ticino regional energy system, which appeared to be well-suited for these activities, since early system dynamics modelling attempts have already been performed by SUPSI in a project supported by the Canton and in collaboration with a local DSO. The project aimed at evaluating the diffusion of key technologies that could provide electric flexibility to the grid (heat-pumps, electric vehicles, photovoltaics), considering the economic, environmental, social, and technical factors that could influence the adoption of these technologies by different types of households and the willingness to participate in an electric flexibility program. The model also included Marco-trends such as tightening standards of efficiency of appliances and the thermal envelope of the building and policies seeking to encourage low-carbon emitting technologies. This model was judged to have a complementary value to techno-economic and deterministic scenario modelling approaches by local stakeholders that highlighted the need for an interactive and dynamic tool to support the ongoing decision-making process for the revision of the cantonal energy plan (Piano Energetico Cantonale, PEC). Key stakeholders actively engaged in the revisions process of the cantonal energy plan have in fact joined WP13 as cooperation partners. Further stakeholders will be engaged in later stages, when the modelling tool will have been developed and will be available for interactive exploration and assessment of pathways, shocks, and their effects.

During SURE's first year, WP13 focused on Task 13.1 and Task 13.2, which are respectively aimed at identifying and mobilizing local stakeholders and at creating a dynamic hypothesis and mapping of the system. Here we summarize the methodology we designed and adopted for these two tasks overall and present the preliminary insights we collected so far.

**Methodology**

Since active engagement in participatory modelling activities is an intellectual and practical effort, requiring an in-depth knowledge of the system being modelled and also time to focus on its various components, the workshops and individual reflections extends over respectable timeframe. We opted for performing co-creative system mapping activities with the group of cooperation partners who had already committed to support WP13 activities. These had accepted to guarantee the needed level of personal and institutional engagement, as well as to devote time to provide their expert insights for the co-creation activities, and therefore we refer to them as our "core" stakeholders. Additional regional stakeholders will be involved in later stage of the modelling process, in order to explore pathways and shocks and collectively assess their effects on the system as a whole and on specific fields of interest. The involved core stakeholders are summarised in Table 1

Table 1: Core stakeholders engaged in co-creation activities in WP13.

| Core stakeholder institution | Role of involved person(s) |
|---|---|
| Cantonal office for energy | Head |
| Cantonal office for climate, air and renewable energies | Head |
| TicinoEnergia | Director |
| AET (cantonal utility company) | Director; Grid asset manager |
| EnerTI | President |
| Parliamentary commission on Energy – Canton Ticino | President |

In order to co-develop the participatory system dynamics model with the core stakeholders, we arranged a four-stage process, in which each stage is supported by a workshop aimed at collecting information on the knowledge, needs and expectations by the core group. The goal of each stage can be summarised as follows:

- *Stage one*: perform an overall representation of the regional energy system's components and identify elements that could play a role in the system transition processes with a long-term perspective;
- *Stage two*: identify which components, either internal to the regional energy system or external to it, are relevant for the core group in order to be dynamically manipulated by the stakeholders to explore their impact on the system;
- *Stage three*: identify the assumptions behind pathways and shocks that are relevant at the regional level, as well as the indicators that are needed to assess the system performances at a given time;
- *Stage four*: for each of the system components, identify the factors influencing its evolution and the factors that are influenced by it.

The workshop supporting each stage are planned to occur quarterly, over about one full year of activities. If needed, workshops might be split in more than one session, until all the information needed by SURE's modellers is collected and there is agreement within the core group. Once all the related inputs will have been collected, an "alpha version" of the model is developed (Task 13.3), which is then refined and improved, again via the interactions with the core stakeholders.

Activities at *Stage one* are inspired by the work of Ulli-Beer et al. (2017), who use system dynamics to model energy system transition pathways and adopt the Multi-Level Perspective (MLP) on socio-technical transitions by Geels (2007) as an overarching theoretical framework. The MLP is in fact particularly suitable to activate a discussion and favour achievement of a shared understanding of the dynamics underlying a system's components and their role within a transition process, as it conceptualises the system itself as the result of continuous interaction between i) innovation processes occurring in protected *niches*, ii) *regime* elements that keep perpetuating themselves under reinforcing conditions, and iii) *landscape* factors that bring exogenous pressure on regime and niches[1].

1 According to the MLP, socio-technical transformations can occur when three mutually reinforcing processes occur: the emergence of innovations in protected niche spaces, the weakening of existing dominant configurations in regime conditions, and the emergence of exogenous pressures among the landscape factors. When all niches, regimes and landscapes align towards novel directions, they can create windows of opportunities for socio-technical transitions to emerge and settle, thus replacing previous system configurations. This process of learning, co-evolution and adaptation at multiple levels results in multiple innovations, such as ``investment in new infrastructures, establishment of new markets, development of social preferences, and adjustment of user practices'' (Geels et al., 2017, page 1242).

Activities at *Stage two* are instead informed by the system dynamic-based "En-ROADS" climate simulator (Sterman et al., 2013; Siegel, 2018; Rooney-Varga et al., 2020, available online at **https://www.climateinteractive.org/en-roads/**), which simulates the impact of energy, economy and societal scenarios on global carbon emissions and is used within awareness-raising role-playing activities. En-ROADS is equipped with an interactive dashboard that represents all the key system elements that its users can act on, by simply moving dynamic sliders (see an example in Figure 5). Setting a slider value for each element of interest means setting the model assumptions for a simulation: as the user changes the assumptions on the different elements, a simulation is automatically launched and its effects shown via charts and selected indicators. While the users "act on the sliders" and explore the outcome of different modelling assumptions, they learn how the system responds and, ultimately, get an understanding of the complex, non-linear, and occasional unexpected effects of such variations.


Figure 5: The interactive dashboard of the online En-ROADS climate simulator developed by Climate Interactive/MIT Management Sustainability Initiative. The system elements that users can act upon to set simulation assumptions are represented through sliders.

The system dynamics tool we will develop in WP13 aims at delivering a similar user experience as the En-ROADS tool – though adapted to the Canton Ticino context and likely to have a different graphical interface. To guarantee that the whole tool is really informative to the user, it is however important that the tool provides its users with the right variables to act on – namely, the endogenous or exogenous elements that they believe are relevant to the future energy system and could have an influence on it, within the simulation time horizon. For this reason, we believe the selection of the system elements to act upon (the "sliders") has to be performed together with the potential users of the model, and this is why workshops at *Stage two* focus on the identification of the components to include among the sliders. The system components that are not selected among the sliders, which however have been identified in *Stage one*, can be included in the model, however they will not be available for direct manipulation by the user.

Activities in *Stage three* are performed according to the methodologies for co-creation of pathways, shocks and indicators respectively developed in SURE's WP2 and WP1. While the development of the system dynamics model of the Canton Ticino energy system is specific to WP13, the activities aimed at the identification of relevant pathways and shocks affecting the cantonal energy system are instead shared with the broader SURE framework. In this case, in fact, WP13 acts as a testbed, offering an additional venue to implement SURE's methodology besides the national level. Discussion with the Ticino core stakeholder on pathways, shocks, and indicators is therefore performed after the stakeholder meetings on the related topics have been performed and is also informed by the discussions that emerge at the national level. Outcomes of the following discussion with Ticino stakeholders are essential as they provide feedback from a Cantonal perspective to the national stakeholder forum before a final decision is made on which specific pathways and shocks to simulate and on which specific indicators to consider in order to assess their outcome.

Finally, activities in *Stage four* adopt the system dynamics modelling approach. Based on the inputs collected on the previous workshops, SURE modellers develop a preliminary map of the whole energy system, by setting the system boundaries, drawing the connections between the system elements, identifying the causal loops between them, and making hypotheses on the strengths and directions of such relations. Such a preliminary map is then discussed in detail with the core stakeholders, as one of the principal methods to validate a system dynamics model is to confront the assumptions and system responses with field experts, identify missing connections and removing irrelevant ones, and agree on the weight of these connections. This activity is performed as the very last stage, since, though the model is modular and new elements/connections could potentially be included, its complexity is definitely higher than the participatory activities at the previous stages. We opted therefore to perform it only after the core stakeholders had gained some familiarity with the whole SURE process and the modelling approach in WP13.

**Preliminary results**

For each stage, a co-creation workshop is planned, to be performed in one or more sessions, depending on the progress achieved during each meeting. Workshops are tentatively scheduled on a quarterly basis, in order to provide SURE's team with sufficient time to elaborate the feedback received at each stage and inform next stage. At the time of writing (end of May 2022), workshops for Stage one and Stage two have been performed (the former via a Teams meeting on January, 19 2022 exploiting Google Jamboard interaction features; the latter with an in-person meeting on May, 17 2022). A video recording of the first workshop and detailed minutes of the second one are available upon request. Next workshops are planned after the Summer break and at the end of Autumn/early Winter 2022/2023.

Since the Stage two meeting has just been performed, here we can only report on the outcome of the Stage one workshop, whose goal was to identify the regime elements, the innovation processes occurring in niches, and the external landscape factors that specifically characterise the Ticino regional energy system and are relevant to its core stakeholders. The overall outcome of the workshop, in terms of the regime elements, the innovation niches and the landscape factors that were identified, is summarised in Figure Figure 6.

The identified elements have been used to populate a preliminary proposal about the slider elements to act upon via the modelling tool interface, which was discussed during the second workshop and is currently being reworked and improved based on the received feedback.

To conclude in the current reporting period, no WP13 milestones or deliverables are planned: the first WP13 milestones and deliverables are respectively M13.1 “Stakeholder analysis and mapping” and D13.1 “Report on local stakeholder analysis”, both due at month 18. Activities are however currently on track and there are no critical situations to notify.

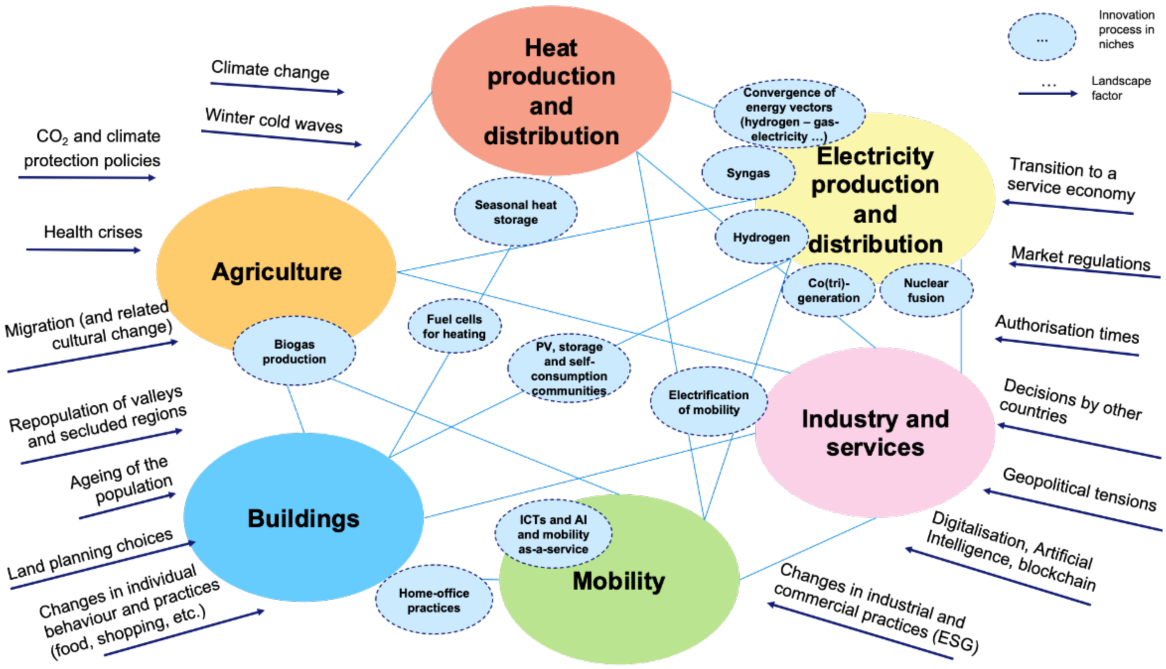



Figure 6: The regime components (large coloured bubbles) currently into dynamic equilibrium into the energy system, the innovation processes emerging in niches (small, light blue dotted bubbles), and the landscape factors (arrows) affecting both regime component

### *3.14 WP 14 Case study on city level*

| Title | **Case study on city level** | | | |
|---|---|---|---|---|
| **Actual start** | 05/2022 (M1) | | **End** | 10/2025 (M54) |
| **TRL range** | **Starting at** | n.a. | **Ending at** | *n.a.* |
| **WP leader** | Martin Jakob, TEP, **martin.jakob@tep-energy.ch** | | | |
| **Members and coop. partners** | *M. Steck (TEP)*<br>*E. Panos (PSI)*<br>*T. Demiray / A. Fuchs (ETHZ)*<br>*A. Abegg / G. Seferovic / R. Müller (ZHAW)* | | | |
| **Objectives** | | | | |
| WP 14 aims to implement the objectives, concepts and approaches of SURE to the urban and sub-urban context and to highlight to which extent sustainability and resilience criteria are different between a international/national and urban energy systems. The goal is to explore how a resilience concept for urban energy systems could be defined and operationalized for the Swiss urban context and how an urban energy system can be (re)designed to become sustainable and resilient according to such a concept. | | | | |

To achieve the aforementioned objective, the work is structured into five tasks (Task 14.0 to 14.4):

- **Task 14.0: Develop a resilience and sustainability concept for the urban context in Switzerland**
  In WP 14.0: referring to the literature, the resilience and sustainability concept for the urban context in Switzerland is transferred from other SURE WPs).
- **Task 14.1: Integrated modelling of demand and supply for the transition phase**
  In WP 14.1 resilience is assessed for the transition phase adopting an integrated approach to modelling demand and supply in different scenarios up to 2050.
- **Task 14.2: Grid and infrastructure security**
  WP 14.2 analyses the network security for the target stage of the energy system (in 2050), with a focus on the electricity system.
- **Task 14.3: Legal embeddedness of sustainability and resilience**
  In WP 14.3 sustainability and resilience is assessed from a policy and legal perspective, e.g. by embedding potential policy instruments in the current legal context and to anticipate necessary changes.
- **Task 14.4: Interactive visualization of results and transfer of outcome to other urban spaces**
  Finally in WP 14.4 results are visualised, processed and synthesized and generalized in a form to enable stakeholders of other urban spaces to directly adopt the outcome to their situation.

As part of Task 14.0, first steps of a comprehensive literature review have been undertaken. About 50 papers and reports that deal with resilience of energy systems and/or urban/city contexts have been identified so far. A first screening-type review revealed some preliminary evidence: resilience is mainly discussed either related to electricity grids, (small) smart grids on the one hand side or related to urban planning issues on the other hand side. Often, resilience is discussed with regard to natural hazards (such as cold waves, storms, droughts etc.) which are mainly relevant for large-scale (regional or national) energy systems that include also rural dimensions. Only few studies combine both aspects and deal with the specific challenges of delivering a decarbonized energy system, which would include thermal grids or an integrated view of sustainable or green urban energy planning where both dezentral and grid-bound energy supply is assessed. Some papers propose a resilience aseessment framework or a resilience metric. In a next step it will be assessed which of these metrics could be used in the context of SURE's case study 14. In a next step, the content and the methodologies of the screened papers will be analysed and it will be explored to which extent a further methodological development is needed to implement the City of Zurich case study. Also, additional literature needs to be searched to cover further topics, specifically those related to the shocks that are being discussed as part of the respective WP of SURE.

Task 14.1: In an urban or sub-urban context, the transition from a fossil-based energy system to an integrated sustainable and decarbonized demand and supply energy system poses one major specific challenge: how to provide all buildings with renewable thermal energy to heat and cool buildings. Although there are various options are available, each of them is associated with specific challenges. For instance, grid-bound energy carriers either are lacking of cost-effective renewable energy sources (e.g. renewable gas) and/or are not built yet (e.g. thermal grids) and/or entail high specific distribution costs (e.g. due to low linear energy density or low grid connection rates). Thus, decentral energy systems such as air-water heat pumps represent an option to be reckoned with, all the more such systems have the advantage of comparatively lower up-front investment costs. Yet, in the urban context, also air-water heat pumps are faced with specific challenges. Specifically they need space, either within the building and/or outdoor. Outdoor spaces are particularly relevant for larger residential or non-residential buildings. Yet, this segment is faced with another specific challenge which is related to noise emissions and noise protection regulation. To cope with such regulation, heat pumps either need to become less noisy, specific noise protection measures need to be implemented, or minimal distances to the neigbouring buildings (and to the own) need to respected. To assess the potential restrictions of air-water heat pumps deployment, a spatial analysis adopting geographical information system (GIS ) methods was performed. This analysis was built on approaches jointly developed in a previous project called low-invest cost solutions (LICS) and has been refined as part of SURE's WP14. Particularly the special requirements proposed by the City of Zurich which entail additional distances between heat pump and building, have been incorporated in this analysis. In a next step additional installation sites, particularly the flat roof of buildings, will be included in the analysis in order to increase the potential of such heat pumps. Also, the potential of geothermal heat pumps in urban contexts will be assessed more in-depth. Specific challenges are limited geothermal potentials as compared to the thermal demand of buildings, which might be be overcome by spatial management approaches or partly be compensated by opportunities such as combined heating and cooling.

Task 14.2. assesses the grid and infrastructure security at the regional and local scale.

The grid security assessment at the international and national scale has been started in WP6, applying the results from the national SURE case study to the Swiss electricity and gas transmission systems. For the **regional and local grid security assessment**, the following steps have been performed:

- **Disaggregation logic to parameterize regional electricity grid**: Based on aggregated national demand profiles from STEM, the disaggregation logic first distributes the profiles among the high-voltage grid, performed in WP6 for the national grid security analyses. In this Task, the electricity demand-profile is further disaggregated to the medium-voltage and low-voltage level of the selected area. The procedure combines population statistics (e.g. number of households per area), behavioral statistics (e.g. distance traveled with electric vehicles per day, number of occupants per vehicle), technical statistics (e.g. solar and heat-pump profiles) to derive a parameterized regional electricity grid model corresponding to the higher level national scenario. The procedure has been applied to example grid from Swiss DSOs and is illustrated in the figure.

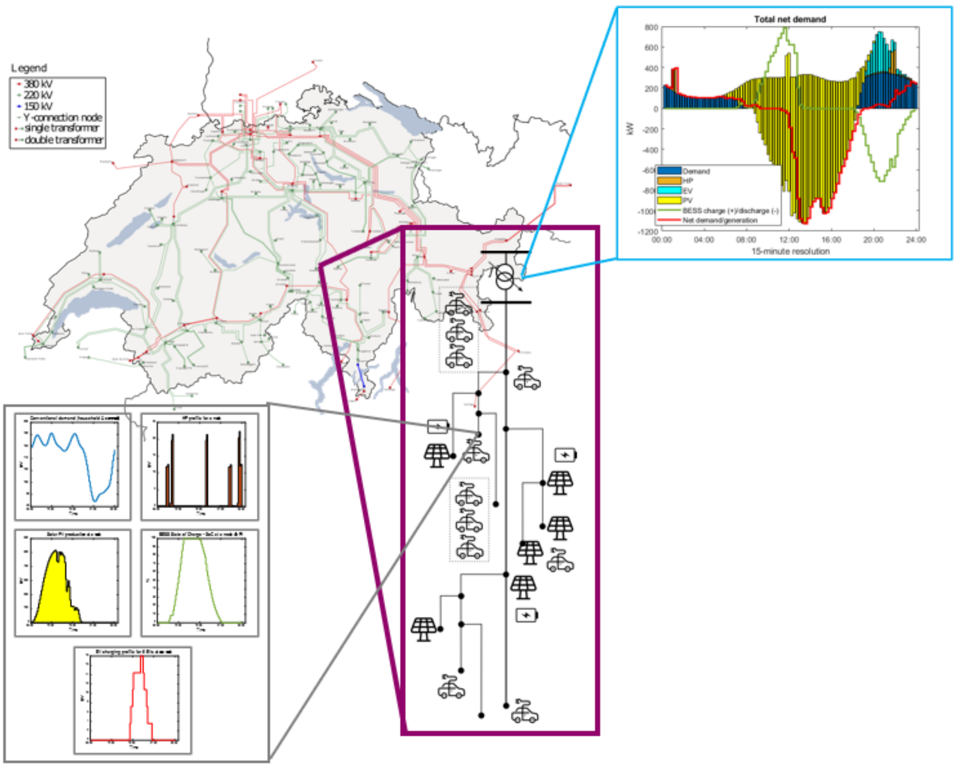



**Figure:** Illustration of the disaggregation procedure from the national (STEM) to the regional and local scale (case study Zurich in WP14)

The following next steps are currently investigated:

- application to the selected Zurich area (requires a network input from ewz).
- The outlined top-down procedure will be checked against the bottom-up building stock model of TEP, identifying complementing and contradictory aspects and synthesizing a joint final network profile for the selected Zurich area.

- **Simulation and congestion analysis** of the parameterized regional/local grid model. It allows to identify congestions and the need for future network expansion. Alternatively the tool uses **the inherent flexibilities in the system to mitigate congestions**. A tool for the application of a simple rule-based flexibility operation has been developed. It assumes no centralized optimization but a local operation on the customer side, for example to optimize the self-consumption. The tool showed for example networks, the distribution grid congestions (line loading, trafo loading and voltage) can be mitigated by local customer optimization and partially mitigate the need for future network upgrades. Again, the next step is the application to the selected Zurich area.

- A first exchange between TEP and FEN has been performed on the **thermal grid modeling** needs and the planning of future heat grids. Besides nominal technical security, the planning will include the security requirements for long-term secure operation. The next steps include an exchange with the security and resilience experts from ewz and the City of Zurich.

- In electricity grids, security and resilience relies to a big part on the **protections system**, clearing faults and reconnecting after a fault. Since a lot of converter-interfaced units will participate in the local electricity grid, the protection behaviors and setting will potentially change. A systematic review of the protection aspects has been started. As next steps, an application of the findings to an example grid of ewz is planned.

Task 14.3 and Task 14.4 have not been started yet.

### *3.15* WP *15* Thematic case studies on sustainability and resilience in industry and transport

| **Title** | Thematic case studies on sustainability and resilience in industry and transport | | |
|---|---|---|---|
| **Actual start** | *04/2021* | **End** | *10/2025* |
| **TRL range** | **Starting at** *X* | **Ending a*t*** | *X* |
| **WP leader** | *Martin Jakob, TEP, martin.jakob@tep-energy.ch (Industry)*<br>*Alexander Fuchs, ETHZ-FEN, fuchs@fen.ethz.ch* | | |
| **Members and coop. partners** | *Martin Jakob, Joachim Bagemihl, Marc Melliger TEP,*<br>*Ulrich Reiter, IWB,*<br>*Turhan Demiray, ETHZ-FEN,*<br>*Robert Strietzel, SBB* | | |

**Objectives**

- *Due to several reasons the decarbonization of the industrial process heat sector is a particular challenge: Specific needs arising from industrial processes, particularly temperature levels, limit the technological options, that are explored in the SURE context within this Workpackage*
- *The case study investigates the interdependencies of SBB and the Swiss energy system within the SURE context, with a particular focus on resilience and sustainability. Providing reliable transport services is a major objective of SBB which needs to be considered under a changing socio-economic environment and energy landscape in future.*

Activities within the **industry / process heat** sector have started with some delay due to personnel changes. So far, activities have been focussing on Task 15.1 about the techno-economic cost-effectiveness analysis of the main process heat decarbonization options. A special focus has been given on new technological approaches. Based on a combined literature review and exploring desktop research methodology. The following preliminary findings are stated:

- Special attention is being attributed to the technology of industrial size heat pumps. This technology is becoming pivotal in the decarbonisation process with its unparalleled energy efficiency. Until today it is still considered a niche product in industry with a very large future dissemination potential in the low to mid heat temperature range.
- The technology, even though widely spread for decades in small scale lower temperature applications, still offers technological development potential which allows accession of application with higher temperature heat sinks in industry.
- The recent dramatic changes in final energy market prices and emission costs improve economic competitiveness of HPs significantly.
- First discussions with Heat Pump Original Equipment Manufacturers (HP OEMs) reveal that recently the market demand increased notably also beyond industry segments which were susceptible to this technology for mainly environmental reasons.
- Heat decarbonisation through hydrogen is gaining momentum as well due to the political will to promote hydrogen while financing hydrogen research and demonstration projects at large scale.
- Continuous cost degression in renewable energy production locally as well as the emergence of large-scale hydrogen production facilities in middle east OPEC countries preparing to diversification are ongoing.

- Technology cost (electrolysis, fuel cells, transport and distribution infrastructure) offer enormous economies of scale. Contact with commercial project developer have been established.

On the **transport-sector side**, an initial bilateral exchange with SBB and further discussions at the 1st stakeholder workshop have identified resilience aspects of the energy sector relevant for SBB.

A key topic is the question of fully covering the SBB energy portfolio throughout the full year and in particular during winter, when SBB's own hydro power plants have low reservoir levels. The topic of "Winter-Reserve" fits nicely into the SURE framework:

- The same question arises in the "conventional" Swiss energy system, allowing a transfer of methods and tools.
- The SBB and Swissgrid electricity grid are coupled, allowing a further exploration of a joint reserve system to enhance resiliience.

Further resilience-related aspects that have been identified and will be explored are:

- the use of hydrogen as intermediate energy storage
- impact of a transformation of the Swiss energy sector on the SBB operation

impact of alternative SBB energy supply portfolios on the Swiss energy sector as represented in SURE

### 3.16 Knowledge and technology transfer (incl. Stakeholder Forum)

| | |
|---|---|
| **WP leader** | *Evgenia Tsianou, PSI, **Evgenia.tsianou@psi.ch*** |
| **Members and coop. partners** | *T. Kober, P. Burgherr (PSI)*<br>*A. Fuchs (ETHZ)*<br>*A. Athanassidis (EPFL)*<br>*R. Krause / M. Multerer (USI)*<br>*M. Jakob / M. Steck (TEP)*<br>*F. Cellina (SUPSI)*<br>*I. Stadelmann (UniBe)*<br>*E. Trutnevyte (UniGe)*<br>*A. Abegg / G. Seferovic / R. Müller (ZHAW)*<br>*L. Paroussos (E3M)*<br><br>*N.Brauchli , Verband Schweizerischer Elektrizitätsunternehmen*<br>*D. Decurtins, Verband der Schweizerischen Gasindustrie*<br>*D.Hofer & Dr. R. Bilang, Avenergy Suisse,*<br>*R. Bautz & G. Verdan, GAZNAT SA*<br>*D. Hofer, World Energy Council Switzerland*<br>*C.Zeyer, Swisscleantech*<br>*D. Magallon, Basel Agency for Sustainable Energy*<br>*G. Bernasconi ,Ticino Cantonal office of air, climate and renewable energies*<br>*S. Pitozzi, Ticino Cantonal office of energy*<br>*F. Scerpella, Azienda Elettrica Ticinese*<br>*M. Mazza, ENERTI SA*<br>*F. Noembrini, Associazione Ticino Energia*<br>*H. Bang, Parliamentary commission on Environment, Land planning and Energy*<br>*R. Strietzel, SBB AG*<br>*M. Balmer, Industrielle Werke Basel*<br>*S. B. Frost, City of Zurich, Departement der Industriellen Betriebe (Energiebeauftragte)* |

**Work performed and results**

In the first year, the SURE project got its visual identity as well as the D&C plan was delivered together with the website launch. On top, the project attracted media attention and other communication and dissemination actions have already taken place. The D&C plan together with the exploitation activities is the backbone of the communication of the project. In detail, it describes which stakeholders within which channels will be engaged in SURE.

The KTT actions include three pillars; A.Communicate, B. Engage, C. Transfer.

The first pillar, to communicate, includes actions promoting SURE as a project, its objectives and to disseminate various results depending on the stakeholder group. The second pillar is about engagement of SURE's stakeholders with the mail tool, the Stakeholder Forum. This pillar invites stakeholders for co-creation activities related to important research elements of SURE. Beyond this, we intend to involve the stakeholders in communication actions and create so called "SURE ambassadors". The last pillar regards knowledge transfer and expoitation of results. Related tools are, for instance, short videos, website features, webinars and link to exploitable deliverables.


Figure 7: Summary of the KTT main activities, with orange mark, the ones which are already on-going

## A.) Communicate

### *General audience*

- The **flyer** in different languages aims to communicate the importance of SURE's model and relate them to the necessity of the energy transition. The first draft includes the "The alphabet to the energy transition" from A to Z. We aim to familiarize the general audience with the terminology of the energy transition such as for N - Net zero GHG emissions, C - CO2-neutral, R – Resilience, S - Sustainability, Z - zero emission technologies.
- **Event**: We are preparting SURE's participation in the PSI open day in Autumn 2022 which takes every few years to bring general audience closer to research.

### *Industry & academia*

Communication to this target group is being performed through scientific publications, presentations on conferences (See Section 4.Outreach & outputs), as wel as on social media. A social media plan for Linkedin is drafted and available for internal review.

**Communication channels**

- Events
    - At SFOE's IEA-TCP networking event, the SURE project was provided a application example of the IEA-TCP ETSAP activities. Therefore, the logo of SURE was included in the distributed ETSAP flyer on the event (see picture below).

- Communication of the approach on stakeholder engagement in a talk on “Participatory processes in the development and dissemination of long-term energy scenarios.” By E. Panos at the IRENA event on the 40th International Energy Workshop, 25-27 May 2022, Freiburg, Germany

- Presentation«Energieversorgungssicherheit im «Netto-Null-Kontext»» in a VSG webtalk by Tom Kober on 16. März 2022

- ARAMIS: brochure and video (https://www.bfe.admin.ch/bfe/en/home/research-and-cleantech/funding-program-sweet/calls-for-proposals-overview/sweet-integration-of-renewables.html)

- Press release & Newspaper:

  - SURE got its first interviews in a widely public newspaper. The game (to be developed in WP3) was subject of a newspaper article in 20 Minuten titled Zockend in die Zukunft – Gamer sollen der Schweiz zu einem stabilen Energiesystem verhelfen (https://www.20min.ch/story/gamer-sollen-der-schweiz-zu-einem-stabilen-energiesystem-verhelfen-474577800820). From this interview, gamers already contacted to be the game testers of SURE’s WP3 (01 February 2022)

  - Interview PSI Improving the resilience of Switzerland’s energy supply | Our Research | Paul Scherrer Institut (PSI) (https://www.psi.ch/en/media/our-research/improving-the-resilience-of-switzerland-s-energy-supply) (04 May 2021)


Figure 8 Screenshots with the newspaper articile in 20 Minuten (left) and flyer with ETSAP (right)

**B.) Engage**

Our main tool is the Stakeholder Forum, there we pursue thematic co-creation activities related to SURE research foci. Besides the direct ivolvement of stakeholders on the workshops, we follow-up with stakeholders concerning the outcomes and how we integrated them in SURE’s research. We have planned one stakeholder workshop per year, of which the first workshop took place in April 2022. We are currently planning the engagement of our key stakeholders in the communication activities, for example with blog stories and/or ambassadors of the project e.g. with banners badges in the social media.

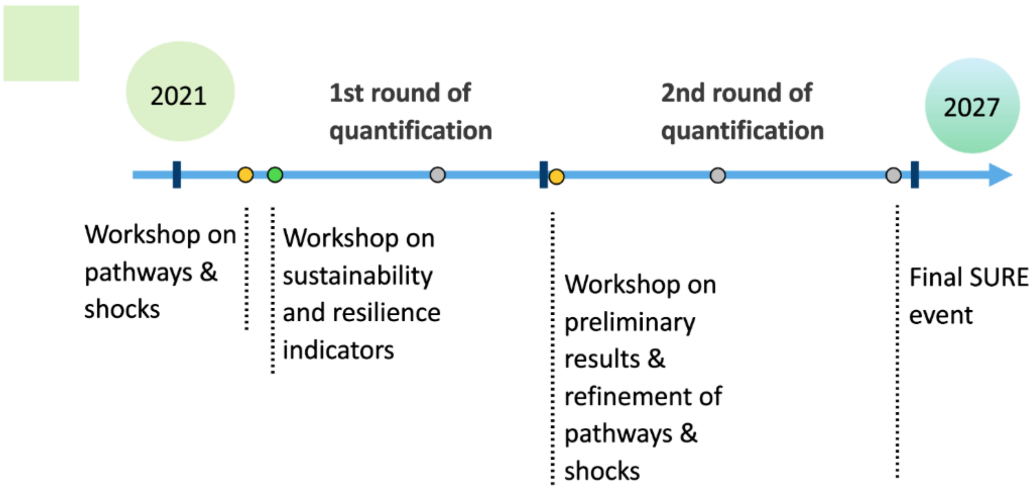



Figure 9: Stakeholder Forum - workshops

**1st SURE stakeholder workshop held on 7 April 2022**

The stakeholder workshop has been used to discuss the long-term pathway scenarios and the shock scenarios. Further details on the workshop are provided in section 3.2.


Photos from the 1st SURE Stakeholder workshop

## A. Transfer

### *Website*

The website is published on the domain www.sweet-sure.ch based on five pages in the menu bar: Home, News, About, Data Portal and Output. A contact form is on the bottom page and the links to social media. We track the analytics on the website with info about number of visitors, geography and other information.

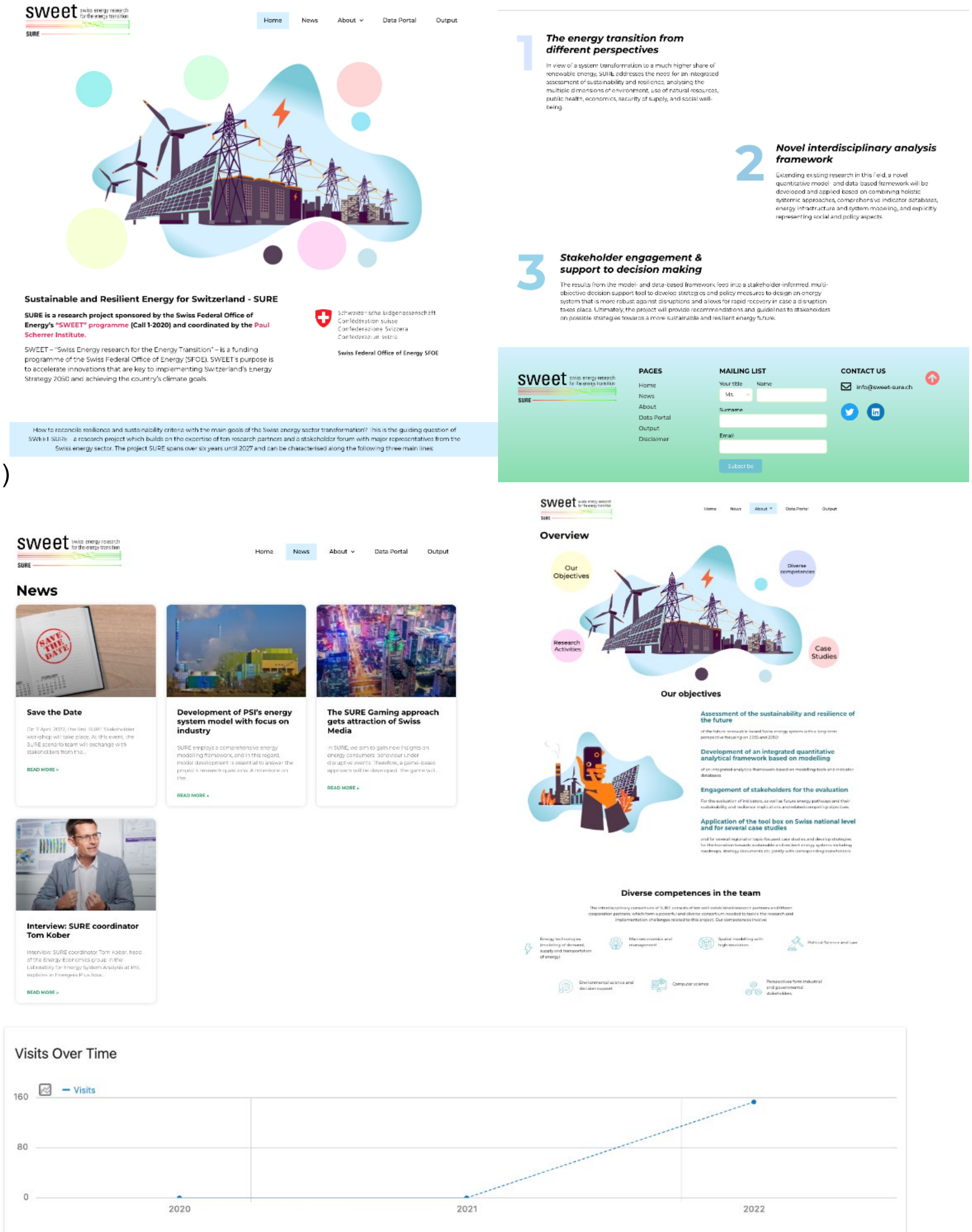



Figure 10 Screenshots of the website and website's statistics

The website serves as a platform to provide access project related information for academia, industry and the interested public. Specifically for those interested in comprehensive and detailed data of our analytical framework, we set-up the so-called “Data portal” webpage which will be updated as new numerical information is available.

**Data sets for download**

| NR. | DESCRIPTION & CITATION | LINK | CONTACT PERSON |
|---|---|---|---|
| 1 | **As starting point for the exploration of future pathways for the energy transition we use the scenarios developed in the Joint Activity “Scenarios and Modelling” of the Swiss Competence Centers for Energy Research:**<br><br>Panos E., T. Kober, R. Kannan and S. Hirschberg (2021). *Long-term energy transformation pathways – Integrated scenario analysis with the Swiss TIMES energy systems model. JASM final report.* DOI: https://doi.org/10.3929/ethz-b-000509023 | **Link** | Evangelos Panos |

Figure 11 Webpage Data portal

### Videos

**http://www.sweet-sure/**The first youtube video out of the three was delivered. The project coordinator in short and concrete describes the project for wide communication (7 December 2021, **https://energeiaplus.com/2021/12/07/sicher-in-die-energiezukunft-sure-rueckt-versorgungssicherheit-ins-zentrum/**)

### Open source tools

Besides reports produced to document our research, selected deliverables will be accompanied by an open-source model data, such as the zonal model of the electricity and gas-grid of WP6, which is expected to enhance the overall visibility, transparency and reproducibility of the SURE project.

Related to LCA (WP10), there are two major components of our KTT activities. The first is PSI’s leadership of the prospective LCA working group (https://github.com/polca), which has members in eight European countries. In this working group, PSI is developing, documenting, and testing methods for the integration of external scenarios into LCA databases. These scenarios can be global and broad based (e.g. from Integrated Assessment Models), or narrow and subject area-focused (e.g. specifics on cobalt use, recycling, and value chains). Research from SURE is expected to contribute to this repository. Our premise software (https://github.com/polca/premise) integrates with our Brightway life cycle assessment ecosystem (https://github.com/brightway-lca/) to allow for flexible and open source integration. Polca has biweekly meetings and regular group coding sessions. One particular element of current work is the development of scenario definition files which will allow for the reproducible, simple, and consistent use of many different kinds of scenarios in the premise/brightway framework.

The second component is the organization of an international conference on open source sustainability assessment data and software. Brightcon 2022 (https://2022.brightcon.link/) will be held from Sept. 26-30 in Luxembourg, with sessions on all topics related to our SURE work. Based on previous years, we expect between 75-100 people to attend. With a budget of over €20.000, this years conference will be a significant advance compared to the previous two conferences, which were primarily online.

**https://github.com/polcahttps://github.com/polca/premisehttps://github.com/brightway-lca/https://2022.brightcon.link/**

## 4 Outreach & outputs during the reporting period

Peer-reviewed publications

| **Members and coop. partners** | **Description :** author(s), title, journal or type of publication, year of publication | **doi** |
|---|---|---|
| PSI | Obrist MD, Kannan R, Schmidt TJ, Kober T. Long-term energy efficiency and decarbonization trajectories for the Swiss pulp and paper industry. Sustainable Energy Technologies and Assessments. 2022; 52: 101937 (14 pp.) | https://doi.org/10.1016/j.seta.2021.101937 |
| USI | H. Harbrecht, M. Multerer, Samplets: Construction and scattered data compression | https://doi.org/10.1016/j.jcp.2022.111616 |
| PSI | Michel D. Obrist, Ramachandran Kannan, Thomas J. Schmidt, Russell McKenna, Tom Kober. High-temperature heat pumps in climate pathways for selected industry sectors in Switzerland (under review) | Submitted manuscript |
| PSI | Kim et al. Global sensitivity analysis of correlated uncertainties in life cycle assessment (under review) | Submitted manuscript |
| PSI | Stermieri L., Kober T., Schmidt T.J., McKenna R., Panos E.. Quantifying changes in user behavior induced by ICTs and related energy and environmental implications: a systematic review of methodological approaches (under review) | Submitted manuscript |

Policy briefs, white papers

| **Members and coop. partners** | **Description :** author(s), title, channel or type of publication, year of publication |
|---|---|
| | |
| | |

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

| **Members and coop. partners** | **Description :** author(s), title, channel or type of publication, year of publication |
|---|---|
| PSI | *Press release: Improving the resilience of Switzerland's energy supply, 14 May 2022* |

| | |
|---|---|
| USI/PSI | *Jan Graber, ZOCKEND IN DIE ZUKUNFT: Gamer sollen der Schweiz zu einem stabilen Energiesystem verhelfen, 20Minuten, 1 February 2022.* |

Public oral and visual presentations (scientific or broad audience)

| **Members and coop. partners** | **Description :** author(s), title, name of the event and location, year of presentation |
|---|---|
| PSI | Kober, T.: Energieversorgungssicherheit im «Netto-Null-Kontext» VSG webtalk, 13 March 2022 |
| PSI | Panos E., Participatory processes in the development and dissemination of long-term energy scenarios. IRENA event on the 40th International Energy Workshop, 25-27 May 2022, Freiburg Germany |

Completed theses

| **Members and coop. partners** | **Description :** author(s), title, type (master, PhD), year |
|---|---|
| *Short names* | |
| | *Add as needed* |

Patent applications and awarded patents

| **Members and coop. partners** | **Description:** inventor(s), title, priority date, patent exploited, status, validity, brief description |
|---|---|
| *Short names* | |
| | *Add as needed* |

Licences

| **Members and coop. partners** | **Description :** subject, grantor of license, license holder, year, contract period, brief description |
|---|---|
| *Short names* | |
| | *Add as needed* |

Spin-offs

| Members and coop. partners | **Description :** name of spin-off company, founder, year of incorporation, town, brief description of the business idea |
|---|---|
| *Short names* | |
| | *Add as needed* |

Other outputs

| Members and coop. partners | **Description**: brief description of the outputs. |
|---|---|
| *Short names* | |
| | *Add as needed* |

Final reports

| WP n° | Members and coop. partners | ARAMIS link |
|---|---|---|
| | *Short names* | |
| | | *Add as needed* |

## 5 Updated list of consortium members and cooperation partners

Table 2: List of consortium members (Any modification is subject to prior approval by the SWEET Office)

| **Additional members** | | | | | *Number of the new member in the list below* | | |
|---|---|---|---|---|---|---|---|
| **Previous members** (no longer part of the consortium) | | | | | *Short name of the organisation and group/laboratory* | | |
| **N°** | **Members**<br>• Legal organisation's name<br>• Group/laboratory<br>• Name of the representative | **Short name** | **Type of organisation** | **Canton or country** | **Language region of CH** | **Expertise and contribution**<br>*Using keywords or brief sentences describe the expertise and the contribution to the work programme, and state the WP number(s)* | **Member in other SWEET consortia** |
| 1 | *Paul Scherrer Institut*<br>*Laboratory for Energy Systems Analysis*<br>*Tom Kober* | PSI | Institute of the ETH domain | AG | German | Expertise:<br>Integrated energy technology assessment and systems modelling<br>Contribution:<br>Life Cycle Analysis, Multi-Criteria-Decision-Analysis, Energy Scenario Modelling, KTT | *n.a.* |
| 2 | *ETH Zürich*<br>*Research Center for Energy Networks*<br>*Turhan Demiray* | ETHZ | ETH Domain | ZH | German | Expertise:<br>Energy grid modelling and analyses<br>Contribution:<br>Modelling of gas and electricity networks<br>Case study on sustainable transport | PATHFNDR |
| 3 | *Ecole Polytechnique Fédérale de Lausanne*<br>*Laboratory on Human-Environment Relations in Urban Systems*<br>*Claudia Binder* | EPFL | Institute of the ETH domain | VD | French | Expertise:<br>Environmental Assessment of Territories ; Transition pathways of urban systems<br><br>Contribution:<br>Circular Economy, Material Flow Analysis | EDGE |
| 4 | *Università della Svizzera Italiana*<br>*Istituto Eulero*<br><br>*Rolf Krause* | USI | University | TI | Italian | Expertise:<br>Uncertainty quantification, Surrogate modeling, Artificial Intelligence, High Performance Computing,Digital Twin, Optimization SolverContribution: | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Surrogate modelling & Game Development. | |
| 5 | *TEP Energy GmbH*<br>*Martin Jakob* | TEP | Small and medium enterprise (SME) | ZH | German | Expertise:<br>Energy demand and building stock modelling, techno-economic analysis, conometrics, edecision modelling, spatial analysis, interdisciplinary approaches, policy analysis, empirical methods.<br><br>Contribution:<br>Energy demand modelling at the national scale (WP4) and at the city scale (WP14) and at the Cantonal scale (support WP13). Empirical research about decarbonizing the industry sector (WP15). | None |
| *6* | *University of Applied Sciences and Arts of Southern Switzerland*<br>*Institute for Applied Sustainability to the Built Environment*<br>*Francesca Cellina* | SUPSI | University of Applied Sciences | TI | Italian | Expertise:<br>System Dynamics modelling, Multi-criteria decision making, Participatory modelling<br>Contribution:<br>Energy system modelling for Canton Ticino and participatory exploration of pathways, shocks and their effects | LANTERN |
| 7 | *University of Bern*<br>*Institute of Political Science*<br>*Isabelle Stadelmann-Steffen* | UNIBE | University | BE | German | Expertise:<br>Political Science, individual attitudes and behavior, Survey research (including conjoint analysis and other experimental approaches)<br><br>Contribution:<br>Political acceptance analysis, evaluating future energy systems and paths from a political perspective, integrating a social science perspective to MCDA | EDGE |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | *Univeristy of Geneva*<br>*Renewable Energy Systems gorup, Section of Earth and Environmental Sciences, Institute for Environemntal Sciences*<br><br>*Evelina Trutnevyte* | UNIGE | University | GE | French | Expertise: renewable energy, energy systems modeling, socio-technical transitions, integrated assessment, uncertainty analysis<br><br>Contributions: renewable energy modeling, modeling weather impacts, power-to-x, regional equity | EDGE, PATHFNDR |
| 9 | *Zurich University of Applied Sciences*<br>*School of Management and Law*<br>*Andreas Abegg* | ZHAW | Institute of higher education | ZH | German | Expertise: Regulatory approaches and instruments on the energy transition.<br>Contributions:<br>WP 1, WP 2, WP 11, WP 12, WP 14, WP 15, WP 16, WP 17<br>Will actively participate in the project and analyses the legal framework and provide legal expertise on regulatory approaches and instruments on the energy transition. | *Call1-2020 DeCarbCH*<br>*Call1-2021 LANTERN* |
| 10 | *E3-Modelling, Economics, Leonidas Paroussos* | E3M | Small and medium enterprise (SME) | EL | Greek | Expertise: Large Scale applied economic and energysystem modelling, decarbonization pathways<br><br>Contribution:<br>Design and Quantification of pathways, quantification of Socio-Economic Reference Outlook, Assessment of soico-economic and distributional implications, support on the calibration of machine learning | |

**Table 5-2: List of cooperation partners**

| **Additional cooperation partners** | | | | *16* | | |
|---|---|---|---|---|---|---|
| **Previous cooperation partners** (no longer cooperating) | | | | *n.a.* | | |
| **N°** | **Cooperation partner**<br>• Legal organisation's name<br>• Group/laboratory<br>• Name of the representative | **Short name** | **Type of organisation** | **Canton or country** | **Language region of CH** | **Expertise and contribution**<br>*Using keywords or brief sentences describe the expertise and the contribution to the work programme, and state the WP number(s)* |
| 1 | *N.Brauchli*<br>*Verband Schweizerischer Elektrizitätsunternehmen* | VSE | Association/ private sector | Aargau | German | Expertise:<br>Electricity system/market<br>Contribution:<br>Participation in stakeholder workshops |
| 2 | *D.Decurtins*<br>*Verband der Schweizerischen Gasindustrie* | VSG | Association / private sector | Zürich | German | Expertise:<br>gas system/market<br>Contribution:<br>Participation in stakeholder workshops |
| 3 | *D.Hofer & R. Bilang*<br>*Avenergy Suisse* | AVENER | Association / private sector | Zürich | German | Expertise:<br>liquid fuel markets<br>Contribution:<br>Participation in stakeholder workshops |
| 4 | *R. Bautz & G. Verdan*<br>*GAZNAT SA* | GAZNAT | Private sector | Vaud | French | Expertise:<br>gas system/market<br>Contribution:<br>Participation in stakeholder workshops and support of gas storage case study |
| 5 | *D.Hofer*<br>*World Energy Council Switzerland* | WEC-CH | Association / private sector | Zürich | German/ French | Expertise:<br>Swiss energy system/market<br>Contribution:<br>Participation in stakeholder workshops |
| 6 | *C.Zeye*<br>*swisscleantech* | SCT | Association / private sector | Zürich | German | Expertise:<br>Swiss energy system & technology<br>Contribution:<br>Participation in stakeholder workshops |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | *D.Magallon*<br>*Basel Agency for Sustainable Energy* | BASE | Private Sector | Basel Stadt | German | Expertise:<br>Low carbon energy technology<br>Contribution:<br>Participation in stakeholder workshops |
| 8 | *G. Bernasconi*<br>*Ticino Cantonal office of air, climate and renewable energies* | TCOACR | Canton | Ticino | Italian | Expertise:<br>Incentives and regulations for the diffusion of renewables and energy efifciency in buildings, cantonal energy planning<br>Contribution:<br>Participation in stakeholder workshops |
| 9 | *S. Pitozzi*<br>*Ticino Cantonal office of energy* | TCOE | Canton | Ticino | Italian | Expertise:<br>Civil servant responsible for the authorisation of new energy plants, cantonal energy planning<br>Contribution:<br>Participation in stakeholder workshops |
| 10 | *F. Scerpella*<br>*Azienda Elettrica Ticinese* | AET | Canton/Public company | Ticino | Italian | Expertise:<br>Cantonal electricity provider<br>Contribution:<br>Participation in stakeholder workshops |
| 11 | *M. Mazza*<br>*Enerti SA* | ENERTI | Public company | Ticino | Italian | Expertise:<br>Electric grid management, technology development<br>Contribution:<br>Participation in stakeholder workshops |
| 12 | *F. Noembrini*<br>*Association Ticino Energia* | ASTE | NGO | Ticino | Italian | Expertise:<br>Energy consultancy, awareness-raising<br>Contribution:<br>Participation in stakeholder workshops |
| 13 | *H. Bang*<br>*Parliamentary commission on Environment, Land planning and Energy* | PACELE | Political body | Ticino | Italian | Expertise:<br><br>Political decision-making |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | Contribution:<br><br>Participation in stakeholder workshops |
| 14 | *R. Strietzel*<br>*Schweizerische Bundesbahnen* | SBB | enterprise affiliated with the Swiss Confederation | Bern | German | Expertise:<br>Swiss energy system & technology<br>Contribution:<br>Participation in stakeholder workshops and support to WP 15 |
| 15 | *M. Balmer*<br>*Industrielle Werke Basel* | IWB | Public company | Basel | German | Expertise:<br>Swiss energy system & technology<br>Contribution:<br>Participation in stakeholder workshops and support to WP 15 |
| 16 | *S. B. Frost*<br>*City of Zurich, Departement der Industriellen Betriebe (Energiebeauftragte)* | ZH-DIB | Public body | Zürich | German | Expertise:<br>Swiss and urban energy system & technology, economics and policy.<br>Contribution:<br>Participation in stakeholder workshops and support to WP 14.<br>Provide detailed data.<br>Door opener.<br>Provide matching fund. |

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# 7 Appendix 1: Deliverables defined as reports

## 7.1 Deliverable report D 4.1

| | |
|---|---|
| **Deliverable n°** | D4.1 |
| **Deliverable name** | Description of methodological improvements of the utility function in the BSM |
| **Authors**<br>The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom. | Martin Jakob, TEP, **martin.jakob@tep-energy.ch** |
| **Delivery date** | April 2022 |

Document provided as separate file: Appendix-1_DeliverableReport-D4-1_BuildingStockModel.pdf