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Executive summary

The SWICE consortium aims to identify and quantify the energy saving potential and opportunities for increased quality of life that can emerge from future urban scenarios involving new modalities of living and working, changes in leisure and mobility behaviours. Besides aiming to propose environmental and technological solutions, this research project builds upon the premise that energy demand is, first and foremost, an outcome of social dynamics, involving complex patterns of energy usage and requiring creative approaches in material flows. As a result, it considers the focus on the wellbeing of people, seen both as individuals and as a collectivity, as a crucial component of the energy transition, which, to be successful, must be socially embraced and implemented in the physical spaces we inhabit. Aligned with Switzerland's Energy Strategy 2050 and net-zero targets, SWICE aims therefore to integrate sufficiency, well-being, and low-carbon strategies into renovation practices and neighborhood development, while maintaining a strong focus on social inclusion and resilience.

The consortium brings together a range of different disciplines spanning across Geography, Sociology, Social-Psychology, Transportation, Engineering, Economics and Architecture, allowing to create research synergies on multiple levels and tackle the project's objectives with a holistic approach. Transdisciplinarity is equally central, with more than 20 cooperation partners and more than 30 other local stakeholders actively involved in designing and implementing solutions, ensuring that scientific advances are rooted in real-world applicability.

The SWICE project incorporates six Living Labs across Switzerland accounting for a participative involvement of stakeholders at different levels (residents and employees, property managers, businesses and communes/cities). Living Labs serve as the core observation platforms for research activities as well as for implementation projects where the sufficiency and wellbeing challenges addressed by SWICE are translated into action.

Since its launch, SWICE has advanced theoretical frameworks, practical tools, and real-world applications. Year 3 marked a transition from concept development to implementation and validation. Living Labs in residential and urban environments have started been operationalized to test interventions that combine energy and sufficiency goals with well-being improvements. Behavioral typologies and digital tools have been developed and deployed, including a privacy-preserving mobility tracking application and a human-centered digital twin of the Swiss residential building stock. Environmental modeling and life-cycle assessment methodologies have been applied to understand the impacts of neighborhood-scale interventions.

Zusammenfassung

Das SWICE-Konsortium zielt darauf ab, das Energieeinsparpotenzial sowie die Chancen zur Steigerung der Lebensqualität zu identifizieren und zu quantifizieren, die sich aus zukünftigen urbanen Szenarien ergeben können – darunter neue Wohn- und Arbeitsformen sowie Veränderungen im Freizeit- und Mobilitätsverhalten. Neben der Entwicklung umweltfreundlicher und technologischer Lösungen beruht das Projekt auf der Annahme, dass Energiebedarf in erster Linie das Ergebnis sozialer Dynamiken ist. Diese beinhalten komplexe Nutzungsmuster und erfordern kreative Ansätze im Umgang mit Stoffflüssen. Im Zentrum steht dabei das Wohlbefinden der Menschen – sowohl individuell als auch kollektiv –, das als entscheidender Bestandteil der Energiewende verstanden wird. Eine erfolgreiche Transformation muss gesellschaftlich getragen werden und sich in den physischen Räumen manifestieren, in denen wir leben. Im Einklang mit der Energiestrategie 2050 und den Netto-Null-Zielen der Schweiz will SWICE daher Strategien der Genügsamkeit, des Wohlbefindens und der CO₂-Reduktion in Renovierungspraktiken und Quartiersentwicklungen integrieren – stets mit Fokus auf soziale Inklusion und Resilienz.



Das Projekt Konsortium zahlreiche Disziplinen, darunter Geografie, Soziologie, Sozialpsychologie, Verkehrswesen, Ingenieurwesen, Wirtschaft und Architektur. Dadurch entstehen interdisziplinäre Forschungssynergien, die eine ganzheitliche Herangehensweise an die Projektziele ermöglichen. Transdisziplinarität ist ebenfalls zentral: Über 20 Kooperationspartner und mehr als 30 lokale Akteure sind aktiv an der Entwicklung und Umsetzung von Lösungen beteiligt, um sicherzustellen, dass wissenschaftliche Erkenntnisse praxisnah angewendet werden.

SWICE umfasst sechs Living Labs in der ganzen Schweiz, die eine partizipative Einbindung verschiedenster Interessengruppen (Bewohner*innen, Angestellte, Immobilienverwalter, Unternehmen und Gemeinden/Städte) ermöglichen. Diese Living Labs dienen als zentrale Beobachtungsplattformen für Forschungsaktivitäten und als Räume für konkrete Umsetzungsprojekte, in denen die Herausforderungen von Genügsamkeit und Wohlbefinden praktisch angegangen werden.

Seit dem Projektstart hat SWICE theoretische Rahmenwerke, praxisorientierte Instrumente und reale Anwendungen entwickelt. Im dritten Jahr erfolgte der Übergang von der Konzeptentwicklung zur Implementierung und Validierung. In Wohn- und Stadtumgebungen wurden Living Labs eingerichtet, um Interventionen zu testen, die Energieziele mit Wohlbefinden verknüpfen. Verhaltens-Typologien und digitale Werkzeuge wurden entwickelt, darunter eine datenschutzfreundliche Mobilitäts-Tracking-App und ein menschenzentrierter digitaler Zwilling des Schweizer Wohngebäudebestands. Umweltmodellierung und Lebenszyklusanalyse wurden angewendet, um die Auswirkungen von Maßnahmen auf Quartiersebene zu untersuchen.

Résumé

Le consortium SWICE vise à identifier et quantifier le potentiel d'économie d'énergie et d'amélioration de la qualité de vie qui peuvent émaner de futurs scénarios urbains impliquant de nouvelles modalités de vie et de travail, ainsi que des changements dans les comportements de loisirs et de mobilité. En plus de proposer des solutions environnementales et technologiques, ce projet repose sur le postulat que la demande énergétique est avant tout le résultat de dynamiques sociales, impliquant des schémas complexes d'utilisation de l'énergie et nécessitant des approches créatives dans les flux de matériaux. En conséquence, il considère que le bien-être des personnes, vues à la fois comme individus et comme collectivité, constitue un élément essentiel de la transition énergétique, laquelle, pour réussir, doit être socialement acceptée et mise en œuvre dans les espaces physiques que nous habitons. Aligné avec la Stratégie énergétique 2050 de la Suisse et les objectifs de neutralité carbone, SWICE vise ainsi à intégrer la sobriété, le bien-être et les stratégies bas carbone dans les pratiques de rénovation et le développement des quartiers, tout en maintenant un fort accent sur l'inclusion sociale et la résilience.

Le consortium SWICE réunit un large éventail de disciplines, y compris la géographie, la sociologie, la psychologie sociale, le transport, l'ingénierie, l'économie et l'architecture, permettant de créer des synergies de recherche à plusieurs niveaux et de répondre aux objectifs du projet avec une approche holistique. La transdisciplinarité est également centrale, avec plus de 20 partenaires de coopération et plus de 30 autres parties prenantes locales activement impliquées dans la conception et la mise en œuvre des solutions, garantissant ainsi que les avancées scientifiques soient ancrées dans la réalité.

Le projet SWICE comprend six laboratoires vivants ("Living Labs") répartis en Suisse, assurant la participation active de parties prenantes à différents niveaux (résidents et employés, gestionnaires immobiliers, entreprises et communes/villes). Ces laboratoires vivants servent de plateformes d'observation pour la recherche ainsi que de terrains d'expérimentation pour des projets concrets, où les défis liés à la sobriété et au bien-être sont traduits en actions concrètes.



Depuis son lancement, SWICE a développé des cadres théoriques, des outils pratiques et des applications concrètes. Cette troisième année s'est caractérisée par le passage du développement conceptuel à la mise en œuvre et à la validation. Les laboratoires vivants dans des environnements résidentiels et urbains ont été mis en œuvre pour tester des interventions combinant objectifs énergétiques et de sobriété avec des améliorations du bien-être. Des typologies comportementales et des outils numériques ont été développés et déployés, notamment une application de suivi de la mobilité respectueuse de la vie privée et un jumeau numérique ("digital twin"), focalisé sur l'humain, du parc immobilier résidentiel suisse. Des modélisations environnementales et des méthodologies d'évaluation du cycle de vie ont été appliquées pour comprendre les impacts des interventions à l'échelle des quartiers.

Riassunto

Il consorzio SWICE ha come obiettivo l'identificazione e la quantificazione del potenziale di risparmio energetico e delle opportunità per una migliore qualità della vita che possono emergere da futuri scenari urbani caratterizzati da nuove abitudini legate alla vita privata e professionale, allo svago e alla mobilità e a modelli di business alternativi. Oltre a proporre nuove soluzioni ambientali e tecnologiche, il progetto parte dalla premessa che la domanda di energia è, prima di tutto, un risultato di dinamiche sociali, che coinvolgono complessi modelli di consumo di energia e richiedono approcci creativi in termini di flusso di risorse. Di conseguenza il progetto considera il benessere delle persone, viste nella loro dimensione individuale e collettiva, come una componente cruciale della transizione energetica che, per avere successo, deve essere socialmente accettata e implementata negli spazi fisici che abitiamo. In linea con la Strategia energetica 2050 della Svizzera e gli obiettivi di neutralità climatica, SWICE mira a integrare strategie di sobrietà energetica, benessere e basse emissioni di CO₂ nelle pratiche di riqualificazione e nuovo sviluppo di quartieri, mantenendo un forte focus sull'inclusione sociale e sulla resilienza.

Il consorzio SWICE riunisce un'ampia gamma di discipline – geografia, sociologia, psicologia sociale, trasporti, ingegneria, economia e architettura – creando sinergie di ricerca su più livelli e affrontando gli obiettivi del progetto con un approccio olistico. La transdisciplinarietà è centrale: più di 20 partner di cooperazione e oltre 30 attori locali sono attivamente coinvolti nella progettazione e nell'attuazione delle soluzioni, garantendo che i progressi scientifici siano radicati nella realtà applicativa.

Il progetto SWICE comprende sei Living Lab distribuiti in tutta la Svizzera, che prevedono il coinvolgimento partecipativo di diversi stakeholder (residenti, lavoratori, amministratori immobiliari, imprese e comuni/città). I Living Lab fungono da piattaforme centrali per l'osservazione e la sperimentazione, dove le sfide legate alla sufficienza e al benessere vengono tradotte in azioni concrete.

A partire dal suo avvio, SWICE ha sviluppato quadri teorici, strumenti pratici e applicazioni reali. Il terzo anno ha segnato il passaggio dalla fase concettuale all'implementazione e alla validazione. I Living Lab in contesti residenziali e urbani sono stati attivati per testare interventi che combinano obiettivi energetici e di sufficienza con miglioramenti del benessere. Sono state sviluppate e applicati stil comportamentali e strumenti digitali, tra cui un'app di tracciamento della mobilità rispettosa della privacy e un human-centered digital twin del patrimonio edilizio residenziale svizzero. Sono state inoltre applicate metodologie di modellazione ambientale e analisi del ciclo di vita per comprendere gli impatti degli interventi a scala di quartiere.



1. Work programme overview

The research questions that drive SWICE revolve around how sufficiency practices can be mainstreamed across different domains of everyday life, how behavior change can be effectively promoted to support the energy transition, and how urban spaces and infrastructures can be reimagined to simultaneously enhance energy efficiency and human well-being.

While people and their socio-material dynamics are considered the primary “agents of change” in the energy transition, three main “sectors of change” are identified in terms of their influence on energy demand and supply management: the **built environment**, **open spaces**, and **mobility**.

To address these interdependent pillars, SWICE is structured into eight research work packages (WPs), designed to provide systemic, participative, and evidence-based solutions that respond to the tension between increasing demand for space, comfort, and mobility and the urgent need for decarbonization and circularity—without compromising on well-being.

The **Built Environment** pillar is addressed through **WP3** and **WP4**, which focus on reorienting renovation and planning practices toward sufficiency, low carbon, and quality of life.

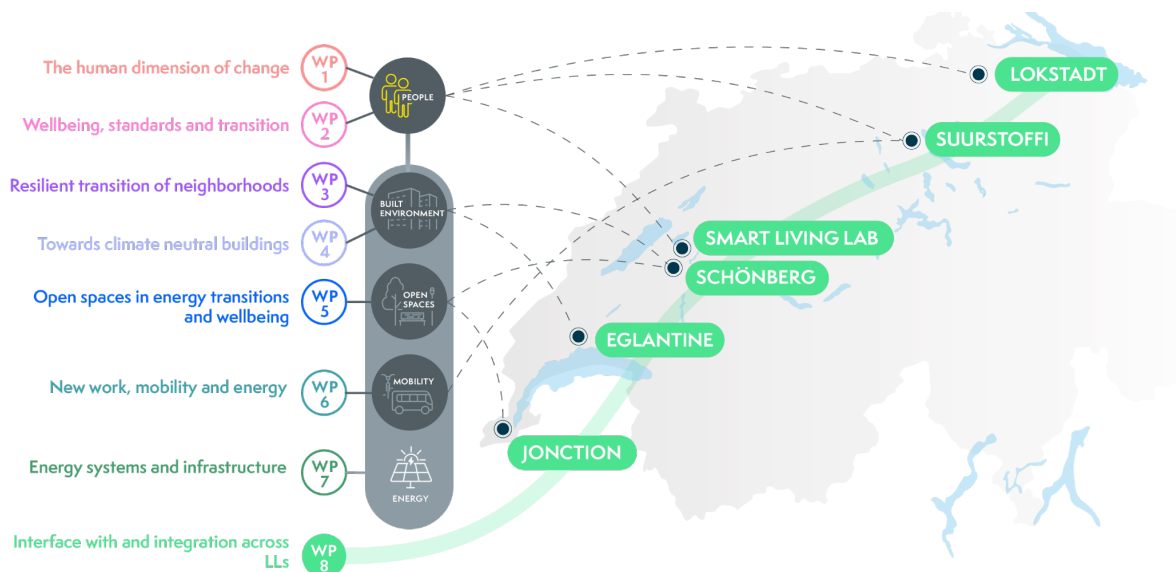
The **Open Spaces** pillar is developed in **WP5**, which investigates how public and semi-public outdoor spaces can support sustainable behaviors and enhance social inclusion.

The **Mobility** pillar is the focus of **WP6**, which explores new models of work and daily travel that reduce emissions while aligning with well-being.

All three pillars are informed by behavioral and societal insights developed in **WP1** and **WP2**, which provide theoretical and normative foundations for sufficiency-oriented lifestyles across all domains.

Transversal integration is supported by **WP7**, which develops a multi-scalar digital twin of the energy system to model the impacts of urban and architectural actions on sustainability and economic performance.

All SWICE research WPs contribute to building robust scientific frameworks, identifying interventions that integrate technical, social, and policy dimensions, and testing these in **real-world Living Labs**. These Living Labs, whose methodological approach is coordinated through **WP8**, are central to the project's **transdisciplinary methodology**, involving residents, municipalities, researchers, and private actors in co-creation processes to ensure relevance, feasibility, and long-term impact.





2. Progress of activities

Since its beginning, SWICE has made steady and substantial progress toward its objectives. Throughout the third reporting period (April 2024–April 2025), activities across the consortium have expanded, matured, and increasingly converged around the central mission of advancing sufficiency and well-being within the energy transition.

At the scientific level, SWICE continued to refine key frameworks that inform intervention design and policy guidance. Building on earlier efforts, the Sustainability Lifestyle Typology developed by WP1 has been successfully applied in several Living Labs to segment populations and tailor interventions accordingly. At the same time, WP2 achieved significant progress in operationalizing sufficiency by quantifying Decent Living Energy needs for Switzerland and modeling interconnected housing and mobility scenarios that account for wellbeing within ecological limits. These advances are crucial in making abstract sufficiency concepts actionable and measurable for policymakers and practitioners.

Eco-Friendly Nikki

Nikki is extremely environmentally friendly. This is reflected in energy-saving behaviour at home and at work, using environmentally friendly means of transport, avoiding food waste and buying seasonal food with sustainability labels. Nikki values privacy and prefers things to be simple but of high quality.

What you can do - Choose suitable tips



- Buy and sell items and clothes at flea markets, second-hand shops or clothing swaps.
- Decide on a day of the week when you will visit the local market or farm shop to buy regional produce.
- Only heat rooms that are in regular use.
- Find out about the next date for switching to a more environmentally friendly electricity product and set it up.
- Advocate for better cycle paths and pedestrian zones.
- Use the night train connections to the cities of Europe.
- Encourage the purchase of organic coffee at work.
- If possible, recycle packaging materials at work, e.g. PE plastic packaging, coffee capsules and milk bottles.

Techie Tony

Tony is socially well-connected, loves trying out new things and has a keen interest in technological innovations. Further, Tony is very involved in society, for example by taking part in activities for the environment. Efforts to save energy or avoid animal products are rather moderate. Tony is a frequent traveller and often uses public transport, but also travels by car or plane.

What you can do - Choose suitable tips



- Discover other cultures through their vegetarian cuisine and invite your friends or family over for a meal.
- Buy second-hand clothes and items online.
- Check your shower temperature and duration with a smart measuring device (e.g. Amphiro shower head).
- Optimise your home with smart devices (e.g. warm water tracking, timers, smart meters, etc.) and buy energy-efficient household appliances.
- Use the night train connections for your trips to European cities.
- Resolve to use your bike for shopping for a month and announce it to your friends and family.
- Use your work laptop for as long as possible before purchasing a new one.
- Go looking for a good veggie lunch at your place of work.

Examples of lifestyle type descriptions and tailored action tips of the WP1 Light Segmentation Tool. The description and tailored tips were presented to participants after filling in a 7-minutes online survey.

In parallel, technical innovations were developed and tested. WP4 constructed a comprehensive database of sufficiency policies supported by AI-powered search functionalities, enabling wider accessibility and application. Field studies and experimental work on indoor environmental quality have yielded a rich dataset linking environmental, physiological, and subjective responses, paving the way for human-centered building design strategies. Additionally, new algorithms for learning human comfort preferences were created, setting the foundation for future intelligent building control systems.

Living Labs have become increasingly central to SWICE activities. In Fribourg (Schönberg Living Lab) and Geneva (Jonction Living Lab), WP5 and its partners organized extensive participatory processes, leading to the co-design of interventions addressing summer comfort and outdoor well-being during heat waves. Interventions planned for summer 2025 include the installation of cooling infrastructures, activation of public spaces, and educational activities. Similarly, in the Lokstadt and Suurstoffi sites, behavioral interventions linked to mobility and coworking practices were advanced through collaboration with residents and local companies.

A notable initiative to enhance stakeholder engagement and co-creation was the establishment of the Mobility Roundtable by WP6. This forum, held biannually, brings together local companies, real estate developers, municipal representatives, and researchers to jointly discuss and shape concrete measures to reduce commuting emissions and promote sustainable work and mobility practices.



Workshop led by HEIA-FR for the reactivation of public open spaces in Schönberg



Mobility Roundtable hosted by HSLU for companies in the Suurstoffi area

In terms of integration, WP8 played a key role in harmonizing methodologies across Living Labs, consolidating a shared monitoring and evaluation framework, and fostering alignment with the SWEET consortium Lantern through joint events and tool sharing. The deployment of the SWICE meta-action tracking tool and the initiation of joint webinars between SWICE and Lantern reflect the growing maturity of cross-consortium collaboration.

Progress was also made in systems modeling and decision support. WP7 advanced the calibration of energy system models using data from Living Labs and external partners, preparing for the future development of an open-source platform that will assist decision-makers in evaluating energy transition pathways. WP3 contributed new theoretical insights by redefining neighborhood structures as "living colonies," providing an innovative and holistic basis for urban diagnostics and transformation strategies.



3. Highlights of outputs

During the third reporting year, SWICE delivered an extensive range of outputs spanning scientific advances, technical tools, fieldwork, and societal engagement, significantly contributing to the energy transition debate in Switzerland and beyond.

Scientific publications and research contributions

Over the past year, SWICE researchers have contributed to advancing knowledge in three interrelated areas that are central to sustainable urban transitions (cf. 14 publications listed under references).

A first body of work focused on **sustainable mobility, teleworking, and energy use in housing and commuting**. Studies by Balthasar et al., Fisch-Romito & Steinberger, and Z'Rotz et al. examined how changes in work-life arrangements, such as the rise of teleworking, affect commuting patterns, CO₂ emissions, and inequalities in energy use. Within this context, SWICE provided baseline data from Swiss Living Labs to measure the CO₂ impacts of teleworking, enabling the long-term monitoring of transformative changes in mobility behavior. The project also explored how housing and commuting energy use is unevenly distributed across social groups, revealing that policies intended to improve work-life balance can have unequal environmental outcomes. By investigating gendered and socio-demographic dimensions of telework, SWICE linked mobility choices to broader goals of well-being and equity in urban sustainability.

Another key theme addressed **urban environmental quality, resilience, and thermal comfort**. Research by Kubilay et al., Lyu et al., and Strebel et al. investigated the influence of urban form, microclimate, and neighborhood typologies on outdoor comfort, particularly under extreme weather conditions. SWICE advanced this field by developing coupled microclimate simulation methods capable of predicting thermal comfort during heat waves in different Swiss neighborhoods, thereby informing climate adaptation strategies. It also produced a multi-domain typology to identify environmentally vulnerable neighborhoods, providing a foundation for targeted mitigation and adaptation measures. Furthermore, SWICE strengthened the bridge between building physics research and sustainable urban planning by refining simulation models for both meso- and micro-scale thermal analysis.

A third area of research addressed **sufficiency, shared spaces, and the energy transition in the built environment**. Works by Nick, Millward-Hopkins et al., Schnidrig et al., and Terrier et al. examined how sufficiency-oriented design, renewable energy communities, and multi-actor collaboration can accelerate the shift towards low-carbon living. Millward-Hopkins et al. quantified the energy requirements for securing well-being in Switzerland, identifying the “space” within which affluence and inequality can exist without breaching environmental limits. Nick contributed systems-level analyses showing how Swiss housing could be transformed by 2040 through measures such as reducing private space in favor of more shared spaces, while preserving quality of life. In addition, SWICE developed and validated decision-support tools for renewable energy communities, integrating mobility–heating synergies and decentralized energy governance models to foster more resilient and participatory energy systems.

Policy impact

During Y3, SWICE has informed sustainability labeling schemes through WP6 by directly engaging with NNBS, Minergie, and SGNi. A dedicated workshop presented research insights, including potential rebound effects and the role of coworking spaces in reducing residential space needs (up to 8%). As a direct outcome, the Minergie guidelines are being revised to better address new mobility and work patterns. Additionally, WP2 fostered dialogue through three high-level stakeholder workshops, online and in-person (Bern, Bulle), bringing together architects, federal housing authorities, and citizens.

Decision-support tools and databases



SWICE placed a strong emphasis on practical innovation, delivering a series of technical outputs:

- **SWICE App:** A **mobile app** to collect people's mobility and sustainability-relevant behavioural data and serving as a point of access to various questionnaires.
- **REHO (Renewable Energy Optimization):** a **decision support platform** to design and optimize renewable energy communities (cf. Lepour et al.).
- **Interactive urban heat mapping:** web-based tools for **Fribourg** and **Geneva** neighborhoods, identifying local heat islands and supporting urban planning decisions.
- **Light Segmentation Tool:** a digital platform allowing rapid lifestyle-based classification of individuals, used for customized sustainability advice.
- **PowerHood Serious Games:** a participatory tool under development to enable stakeholders to understand the complexity of urban transformation and sufficiency strategies.
- **Sufficiency database for building sector (under development):** developed through AI-supported literature reviews, enhancing access to sufficiency-oriented design strategies.

Some of these tools are already being applied in Living Labs and municipal planning contexts.

Living Labs Interventions

Multiple SWICE Living Labs served as testbeds for co-created, user-centered interventions.

For example, in Eglantine (WP3/WP8), the first system energy audit was launched with resident and stakeholder support, leading to a pilot on balancing energy savings and well-being. The second phase will engage the community in co-designing a Sustainability Action Plan.

In Lokstadt, Winterthur, stakeholders co-developed a communication strategy and public event, promoting community engagement through playful activities. Two interventions, mobility visualization and cycling, were co-conceived with residents to foster behavior change and social cohesion.

The Open Spaces Living Labs (Fribourg, Geneva) enabled stakeholders to exchange insights and align on change initiatives targeting summer comfort improvements, scheduled for implementation in summer 2025.

In Suurstoffi, Risch-Rotkreuz, an applied intervention in collaboration with Zug Estates and SPACES tested coworking use among the residents, with surveys measuring behavioral and spatial impacts. Results from a second phase (May–July 2025) will assess long-term potential.

At the Smart Living Lab, Fribourg, a network of 2–3 sensors per office space was installed in the Blueworking space to gather comprehensive occupancy and environmental data and developed a functional monitoring interface for real-time data visualization and analysis. Furthermore, a Sustainable Technologies & Experimentation Pavilion (STEP) was design and constructed, with the support of various companies and technical units, with the aim to showcase experimental façade and roof systems, serving as a testbed for circular construction, prefabrication, and digital twin development.

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