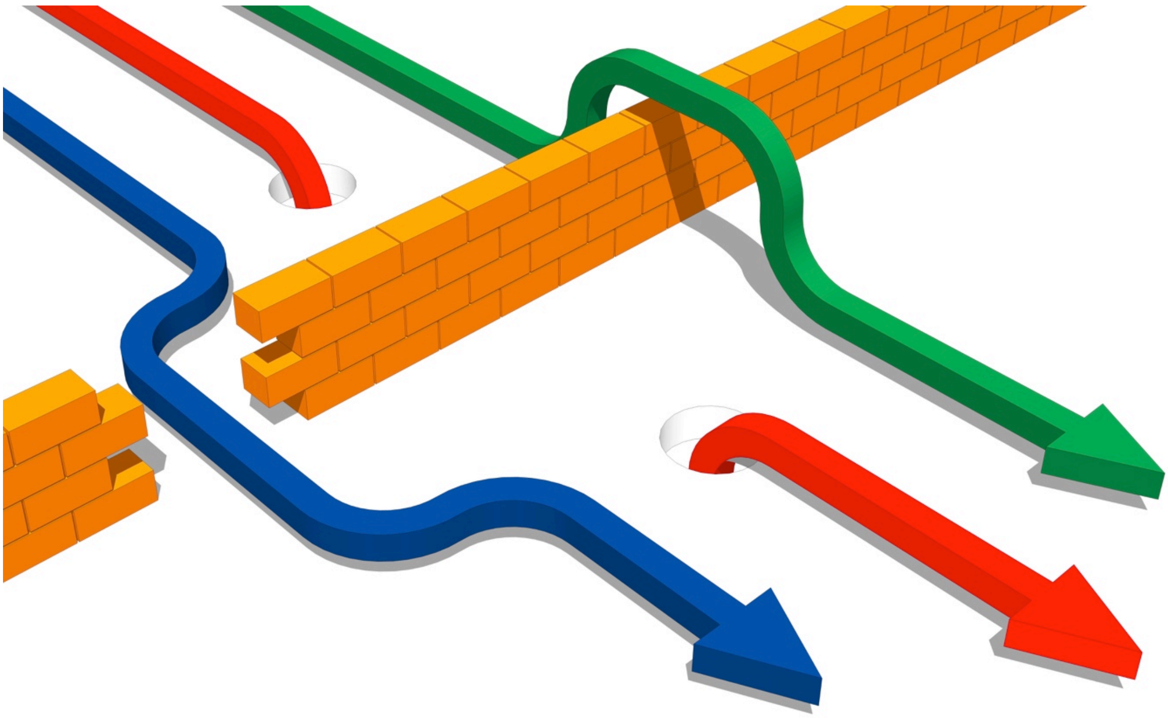
Swiss Competence Center for Energy Research

Future Energy Efficient Buildings & Districts

Research and Innovation Roadmap 2017-2020



In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

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Vision

The vision of the SCCER FEEB&D is to develop solutions for the Swiss building stock which will lead to a reduction of the environmental footprint of the sector by a factor of three by 2035.

Innovation Update and Challenges

Corner stones of the Energy Strategy 2050 of the Swiss Confederation are the increase in the share of renewable energies, the increase in energy efficiency as well as the enhancement of domestically created added values and the reduction of the dependence on foreign countries. Holistic and integrated solutions are required in order to meet these ambitious goals.

The building stock can and will contribute more than any other sector to the fulfilment of these goals. The reasons are the importance of the sector in terms of energy demand and CO_2 emissions and the techno-economic potential of new solutions. Innovation is needed in order to reduce the energy demand for the operation of buildings, to optimize the operation so that user needs are satisfied and to cover the remaining energy demand as much as possible with renewable energy, with a strong focus on locally harvested energy. All of this has to be achieved in an economic manner. By 2035 the environmental footprint of the building stock should be reduced by a factor of three.

The main challenge regarding **efficiency at building scale** is the performance gap. The transformation of the building stock is already hampered by a low renovation and replacement rate of existing buildings. Results from our own work and from other groups reveal now that the target values in terms of energy are sometimes missed by up to 70%. The performance gap has to be quantified in more detail and the causes have to be understood. Countermeasures include the upscaling of the concept of dynamic glazing since buildings with a high proportion of glazed façades are especially prone to the performance gap. Human centred control should make sure that the expectations of the user are met and that this is achieved in an energy-efficient manner. And finally, a higher share of on-site renewable energy generation facilitated by Building-integrated PV enables buildings to mitigate the environmental effects of the performance gap. For this, Building-integrated PV needs to be better integrated in overall buildings systems as well as in the architectural design.

At the **district scale** the highest potential in terms of energy efficiency and decarbonisation identified in phase I is the connection of blocks of buildings by modern renewable decentralised energy systems (RDES). While the case studies done so far reveal the potential of the approach, the process to gather the needed information and to evaluate different scenarios is by far too time consuming and cost intensive. The main challenges are the development of tools and guidelines that support the development of transformation scenarios for districts efficiently. Furthermore, control strategies for such complex distributed systems have to be developed in order to fully exploit their potential during operation. Since this approach is still rather new, pilot and demonstration projects are needed both to reach a better understanding of the concept of RDES but also to prove and demonstrate the potential to all stakeholders.

The challenge at the **regional and national scale** is to provide energy demand and supply data with a high spatio-temporal resolution. This data is required to develop RDES solutions at the district scale (thereby also accounting for insights from urban climate modelling) and it is then used to evaluate the impact of RDES on the energy system at regional and national scale. Furthermore, consistent transformation scenarios at this scale are still lacking. Once the scenarios have been developed they have to be evaluated from an economic, environmental and social point of view and recommendations for their implementation have to be developed. Modelling the increase of the heat island effect due to climate warming and developing counterstrategies in order to mitigate the effect is another important research question at the regional scale.

We can reach our goals only when the **diffusion of new technologies** is accelerated. Several factors have been identified in phase I regarding their influence on the diffusion rate in *qualitative terms*. A *quantitative* model to predict the impact of different measures on the diffusion rate of energy efficiency technologies is needed to properly select the most effective actions at the level of firms or politics. An open issue with RDES is their economic viability. A better understanding for the relevant cost factors is required but also an understanding of the potential impact of the learning curve, organizational matters and future technology development on the overall costs of RDES. Finally, attractive business models for the development and operations of RDES under various boundary conditions (utility driven, community owned, PPP, etc.) have to be developed and evaluated.

Innovation Potential

The combined impact of all activities of the SCCER lies in a reduction of the energy used to operate the building stock and the decarbonisation of the energy used for this purpose.

At the **building level,** the significant performance gap in retrofit projects identified in phase I will be further investigated in order to deliver guidelines and methods for countermeasures. A series of new aerogel based high performance insulation products with proven durability will be introduced in the market by 2020 and beyond based on a new synthesis route for aerogels developed in phase I.

By 2020 novel glazings which allow for high solar heat gains in winter and low solar cooling loads in summer will be developed at the prototype scale and the process for industrial fabrication will be defined. This new type of glazing will enhance the use of daylight as well as passive solar energy and improve both thermal and visual comfort. Such glazings have a high market potential because up to 15% reduction in energy demand and therefore savings on heating, ventilation and air conditioning (HVAC) installations as well as reduction of maintenance costs of blinds and shades can be achieved. Furthermore, they will help to mitigate the performance gap of highly glazed buildings, which is due to the fact that the anticipated solar gains in winter are not met due to visual/thermal discomfort of the users and the resulting activation of the solar blinds.

Building-integrated PV (BiPV) is still in reality very often "Building-added PV" and therefore rejected especially in urban contexts, just for lack of architectural integration. The development of novel design methods and integrated tools (digital design, CAD, BIM), improved aesthetics and design capabilities (colours, patterns, shapes) as well as simplified structural and electrical integration will help to overcome this barrier. This shall lead to a product development roadmap and a demonstration of successful products in a pilot project, such as NEST, which can cover 40% or more of the energy demand of office spaces.

Advanced sensing technologies within novel sun-shading, HVAC and electric lighting control strategies will be developed resulting in a substantial reduction in energy demand and improved user comfort. User centred control algorithms with integrated machine learning capabilities will ensure that the building controllers automatically adjust to the users' needs. This includes the use of daylight and solar heat gains by a smart control of lighting and shading devices, heating, cooling and ventilation of the building. The validity of these concepts will be proven by installations in NEST and other P&D projects by 2020; market deployment should begin for certain technologies even before 2020. If successful, this will contribute substantially to the reduction of the performance gap in terms of measured energy demand compared to planning values. A large part of this gap originates from the user interfering with the building control system since the expected comfort level is not met.

At the **district level,** the planning, realization and operation of a RDES is far from being a well-established standard process because present design tools, technologies and control systems are not adapted to handle such complex systems. The SCCER FEEB&D will provide numerous elements in the coming years to overcome this challenge. Dynamic models for energy demand and supply at district scale accounting for individual building specifics (access to renewable energy sources, usage, physical characteristics) will be developed. This comprises the definition of key boundary conditions under which a RDES has to be designed and operated. The models will be integrated in the Holistic Urban Energy Simulation (HUES) platform. At the same time HUES will be further developed from a tool used by academia to a platform that industry can use in real projects. All models and simulation tools mentioned below will be realized within HUES. Thanks to this approach, a powerful open access modelling environment will become available for all stakeholders.

Based on energy demand and supply information, the typology of a RDES has to be defined to provide energy services for the district or higher-level grid through supply, transformation, management, storage and distribution. Models for EHs and MEGs will be developed which allow the assessment of the ideal transformation path of a district based on multi-criteria optimization techniques. This is complemented by a simulation infrastructure for EHs and MEGs on a technical level. Detailed technical simulations of

EHs and MEGs will give insights into the dynamics of specific systems and provide feedback to the aggregated optimisations.

The operation of a RDES requires a sophisticated control architecture. A control system will be developed for the operation of EHs and MEGs which balances competing and cooperative goals for multiple energy network agents, including issues such as differing economic objectives, social obligations, privacy requirements, and operational constraints. This system will be validated on demonstration platforms built up in phase I (NEST, NODES, ERL). In order to make such validations as realistic as possible, the three demonstration platforms will be connected virtually via a live-link to enhance the space of operation for the control system. This virtual lab will help to deploy the RDES concept in real cases as specific configurations can be modelled, tested and validated upfront in order to accelerate the market penetration.

Renewable energy sources such as solar, wind, biomass and geothermal heat as well as waste heat do not occur at a few locations, but are characterized by rather scattered and small-scale potentials. With the increased utilization of these energy sources a multitude of new entry points to the Swiss energy system are inevitably created. This change leads from a predominantly central power supply to a more decentralized energy system. To facilitate the development of RDES, archetype districts will be defined and benchmarked against conventional solutions. The benchmarking will include future climate scenarios since a shift from heating to cooling loads has an important effect on the ranking of different approaches. The monitoring and performance assessment of EHs and MEGs in demonstration projects and real cases will be the basis of continuously updated guidelines which document the technology potential in exemplary scenarios for different district topologies.

A massive integration of renewables to reach ambitious CO_2 reduction targets requires profound knowledge of energy demand and renewable resources in terms of spatial and temporal characterisation and their development over the coming decades **at the regional and national scale**. The SCCER FEEB&D is developing a variety of models and databases which will address these issues. A first element will be load curves for heat, electricity and cooling with high spatio-temporal resolution and a description of their evolution over time until 2035 and 2050. Especially for urban areas, changes in heating and cooling demand due to climate change will be incorporated. This will include a newly developed urban microclimate model which will reveal how the heat island effect can be mitigated as a result of changes in urban materials and surface colours, introduction of vegetation or the modification of urban geometry. This will be accompanied by monitoring and analysing the development of the heat demand reduction in the residential sector in selected cantons. Such data are necessary to assess whether the evolution of the building stock is in accordance with the Swiss Energy Strategy.

The geo-spatial modelling of the potential of renewable energies will be further refined. A key element is the hybrid renewable energy potential. This includes combinations such as (i) solar PV, solar thermal and geothermal heat and cold, (ii) solar PV, wind and waste heat, and (iii) biomass, wind and solar PV. The advantage of such hybrid systems is a reduction in the stochasticity of the supply potential. As a result, real-time forecasting of hybrid renewable energy systems and uncertainties will be provided depending on location and time.

For dense urban areas, selected energy integration strategies will be analysed which are applicable to several larger cities in Switzerland. Simple combinations of technologies will be chosen and simulated, partly inspired by existing systems and partly by expert insight. Most of these combinations – referred to here as archetypes – are grid connected, thereby making use of the high population density and specific local circumstances. Thanks to links to other SCCERs (SoE, Furies, HaE, Mobility, etc.) the convergence of energy systems will be taken into account as well.

Finally, the impact of large scale penetration of renewable energy in combination with energy efficiency improvement will be quantified and compared to the resulting projected energy use at the national level under the goals of the Energy Strategy 2050. The modelling approaches outlined above are innovative in themselves. Their combination (partially linked/softlinked) will offer a good understanding of the innovation potential in the built environment and the related trade-offs (esp. costs). Innovation solution pathways, which are meant to inform decision makers, will be developed at the level of energy hubs, for the regional and national scale.

The transfer of FEEB&D concepts and technologies is supported by providing knowledge in form of tools and recommendations, which enable policy and business decision makers to **accelerate the diffusion** of the new approaches. The contributions beyond state of the art include a model to evaluate how different policy instruments or improvements in technology performance influence their market share by 2035. Regarding the evaluation of district level technologies, a significant improvement of the understanding of processes leading to cost reduction with increasing cumulative capacity will be achieved. The generic business models developed in phase I will be adapted for specific implementations in a transdisciplinary approach together with utilities.

Top Innovation Chart