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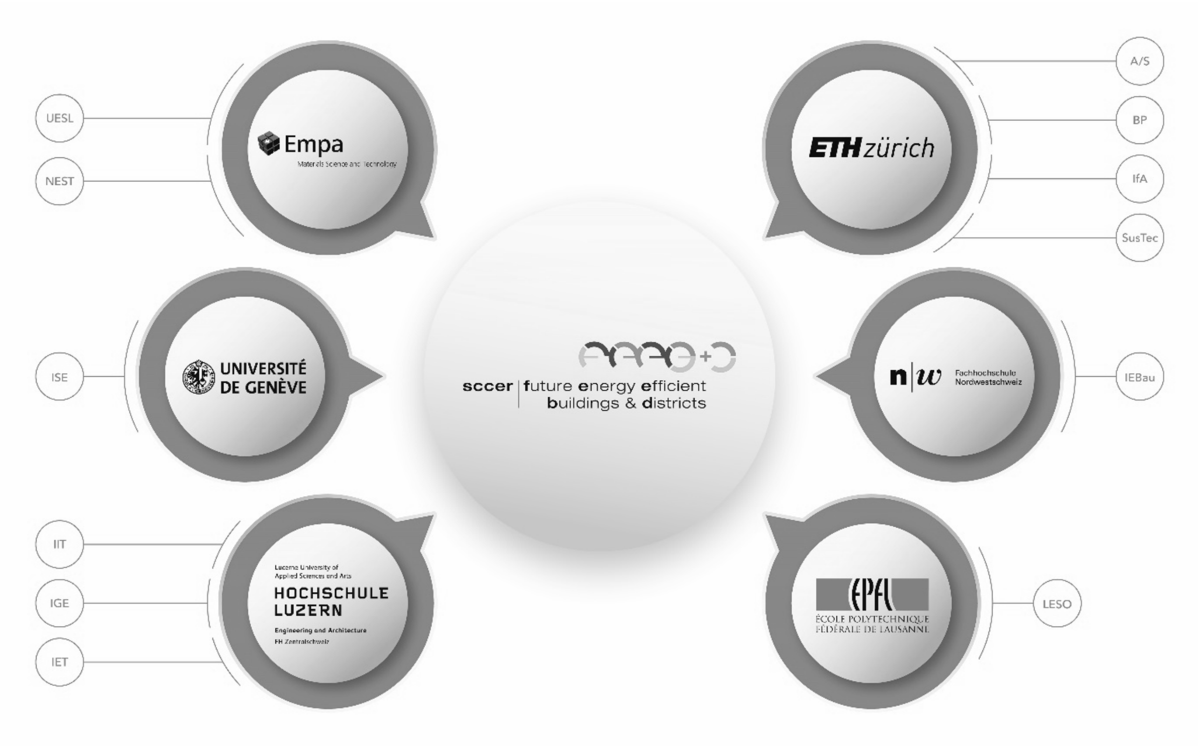
Whitepaper Swiss Building Stock



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Reducing the energy-related CO2 emissions from buildings threefold

The Swiss Federal Energy Strategy 2050 (ES2050) defines the primary goals of nuclear phase-out and the reduction of CO_2 emissions. It focuses on increasing energy efficiency and the proportion of renewable energy. The retrofit of Switzerland's building stock harbors great potential. The SCCER FEEB&D Whitepaper reveals the major influencing factors and which topics are being researched.

Switzerland's building stock currently has an average specific end energy consumption (energy intensity) of around 180 kWh/m^2 per year for building services, including heating, cooling, domestic hot water and general electricity consumption. The buildings' energy is supplied via a mixture of fuels from fossil and renewable sources – electricity, heat/cooling, gas, oil and biomass. The present energy mix causes average CO_2 emissions of around 140 g CO/kWh (CO_2 intensity). In order to achieve the first milestone of the Swiss Federal Energy Strategy 2050 by 2035, the energy intensity must be slashed by 50% and the CO_2 intensity by 40%. This will result in a threefold reduction of the specific CO_2 emissions, i.e. from 25 kg CO_2/m^2*a to 7.7 kg CO_2/m^2*a[1], by 2035. The aforementioned influencing factors of energy and CO_2 intensity are presented in Fig. 1, derived from the Kaya identity (Mavromatidis et al., 2016[2]).

1 All levels in accordance with prognosis, 2012, 'new energy policy' scenario. The environmental impact of nuclear power stations is not taken into account directly as their phase-out is stipulated in the ES2050. This means that fossil power stations cannot be substituted with nuclear ones.

2 Mavromatidis, G., Orehounig, K., Richner, P. & Carmeliet, J. (2016) A strategy for reducing CO2 emissions from buildings with the Kaya identity – A Swiss energy system analysis and a case study. Energy Policy 88, 343–354.

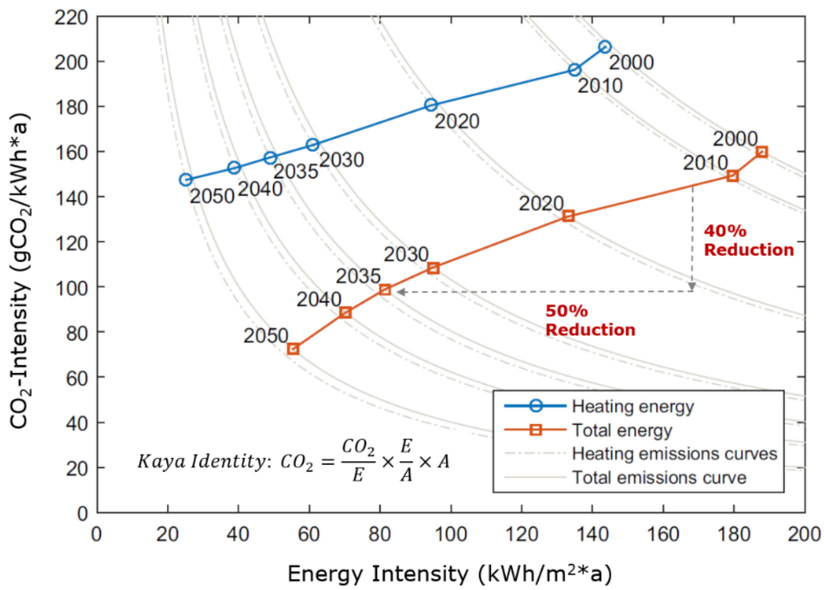

Fig. 1: Development of the CO_2 intensity and energy intensity to achieve the ES2050 targets for the building sector (Mavromatidis et al., 2016).

System innovation as the driving force behind the energy transition[3]

The following three influencing factors primarily support the achievement of the ES2050's 2035 targets:

1. Reducing the energy intensity by increasing the energy efficiency of buildings, e.g. thermal insulation for the building shell, installation of heat pumps and/or heat recovery systems.
2. Reducing the CO_2 intensity by replacing fossil fuels in Switzerland's energy system with renewable energy, e.g. installation of solar plants and/or wood pellet heating systems.
3. Increasing the renewal rate by renovating more buildings in part or in full from an energy perspective or replacing them with more energy-efficient new buildings.

[3] Broader systemic implications, including digitalization's ability to break down boundaries between various demand and supply sectors [might be] leading to even more potentially transformative impacts. (Digitalisation & Energy, OECD/IEA Report, 2017)

The interdependency between the three influencing factors are considerable: The higher the retrofit rate, the smaller the reduction in CO_2 and/or energy intensity may be. In other words: Renovating a handful of buildings up to passive house standard achieves the same effect as renovating several buildings to the minimum building standard in the same time frame. Another interdependency: The more renewable energy is fed into the energy system, the less the energy efficiency needs to be increased. The most effective combinations of measures to renovate buildings with a high cost efficiency are achieved via cost-benefit optimizations.

With these systemic considerations, the complexity increases. New materials, products and services which meet the systemic requirements and bring added value for the user have to be researched and developed. In order to deal with the increased complexity and its interdependency in the planning, construction and operations, new tools, methods and guidelines are necessary.

In the transformation of the building stock, buildings are increasingly assuming an active role in the energy supply at neighborhood, district and regional level, which are integrated into the Swiss and European energy system. This development requires radical innovations in the construction and energy industries. In these sectors, however, there is often a lack of research and development (R&D) structures and investments. Moreover, they need to factor long life cycles and guarantee periods into their business models[4]. These aspects dampen the companies' innovative spirit. Demonstrators and pilot projects can be used to reduce the risks for the industrialization of innovations and expedite the market launch of new products, services and methods.

[4] Broader systemic implications, including digitalization's ability to break down boundaries between various demand and supply sectors [might be] leading to even more potentially transformative impacts. (Digitalisation & Energy, OECD/IEA Report, 2017)

Research topics

SCCER FEEB&D conducts research in the following five topic areas to reduce the energy and CO_2 intensity based on the ES2050 and achieve the targets for 2035:

1. Narrowing the gap between planning and operating values (performance gap)[5]

Today, we are capable of planning and constructing energy-efficient buildings (Minergie, 2000-Watt Society, Swiss Sustainable Building Standard (SNBS) etc.). The solutions are gradually becoming more affordable and thus economical. The building industry and its suppliers have developed high-performance heat insulation, power-controlled heat pumps, daylight-sensitive lights etc. which may theoretically curb the energy consumption in buildings massively. In practice, the planned increase in energy efficiency in renovations is often not achieved and the savings actually measured are considerably lower than those calculated. This discrepancy between planned and measured savings is referred to as the "performance gap". Besides new solutions to curb energy consumption, the narrowing of the performance gap is a key requirement to achieve the ES2050 targets: How do buildings need to be renovated and operated to actually achieve the planned energy parameters?

The research at SCCER FEEB&D focuses on the following tasks to achieve the required national impact of effectively halving the energy intensity measured in practice. SCCER's key research and development contributions include (cf. Fig. 2):

- By 2020 novel glazing that enables high solar heat gains in the winter and low solar cooling loads in the summer should be developed and the process for industrial production defined. This novel glazing will improve the use of daylight and passive solar energy, as well as thermal and visual comfort. The dynamic glazing has high market potential as energy savings of up to 15% can be achieved at building level and thus savings in heating, ventilation and air conditioning (HVAC) systems and a reduction in the maintenance costs for shutters. However, developing such innovations into market ready products

[5] Digitalization could cut total energy use in residential and commercial buildings by around 10% by 2040. These efficiency gains are largest in heating and cooling, particularly through the use of smart thermostats and sensors. Smart lighting allows for potentially substantial cuts in lighting electricity demand. However, new services and comforts brought about by digitalization – as well as greater use of standby power by idle devices and appliances – could offset potential savings. […] The largest potential savings are in heating, cooling and lighting, which together represented more than 60% of total final energy demand in buildings in 2015. (Digitalisation & Energy, OECD/IEA Report, 2017)

also depends on the organizational structures of the companies involved.

– Forward-looking sensor technologies for novel sun protection, HVAC and electric lighting control strategies are being developed to reduce the energy demand and improve user comfort. User-centric control algorithms with integrated machine learning functions ensure that the controls adapt automatically to the users' needs. This includes the use of daylight and solar heat gains by controlling the building's lighting/shade facilities, heating, cooling and ventilation intelligently. A large proportion of this gap results because the user intervenes in the building control system as the expected comfort is not achieved.[6] This kind of automation system will go a long way towards reducing the performance gap. This development will be supported by innovative business models, which take the reduced energy demand as well as the new technologies into account.

– The decentralization of the energy supply, prompted by the development of renewable energy production, requires well-founded knowledge of the energy demand and renewable resources in terms of space and time, and their development in the coming decades at regional and national level. SCCER FEEB&D is developing a large number of models and databases that examine these issues. The initial elements include load curves for heat, electricity and cooling with a high spatial and temporal resolution and describing their development over time until 2035 and 2050. Changes in the heat and cooling demand due to climate change are especially taken into consideration for urban areas. This also includes a newly developed urban microclimate model, which reveals how the heat island effect can be tempered by changing the urban materials and surface colors, introducing vegetation or modifying urban geometry.

– Nowadays, many of these energy-efficient building technologies are already more profitable than their conventional alternatives. However, long investment horizons, unfavorable investment structures (e.g. landlord-tenant problem), rigid planning and construc-

[6] Help ensure that energy is consumed when and where it is needed, by improving the responsiveness of energy services (e.g. by using lighting sensors) and predictively with respect to user behaviour (e.g. through learning algorithms that auto-programme heating and cooling services). Predict, measure and monitor in real time the energy performance of buildings, allowing consumers, building managers, network operators and other stakeholders to identify where and when maintenance is needed, when investments are not performing as expected or where energy savings can be achieved. (Digitalisation & Energy, OECD/IEA Report, 2017)

tion processes, as well as partly hindering regulations act as barriers for a broader diffusion of these technologies. In such cases policy maker often intervene and subsidize specific technologies or prohibit others. The SCCER FEEB&D analyses and evaluates which policy instruments and combinations thereof lead most efficiently and effectively to a high diffusion of energy-efficient building technologies.

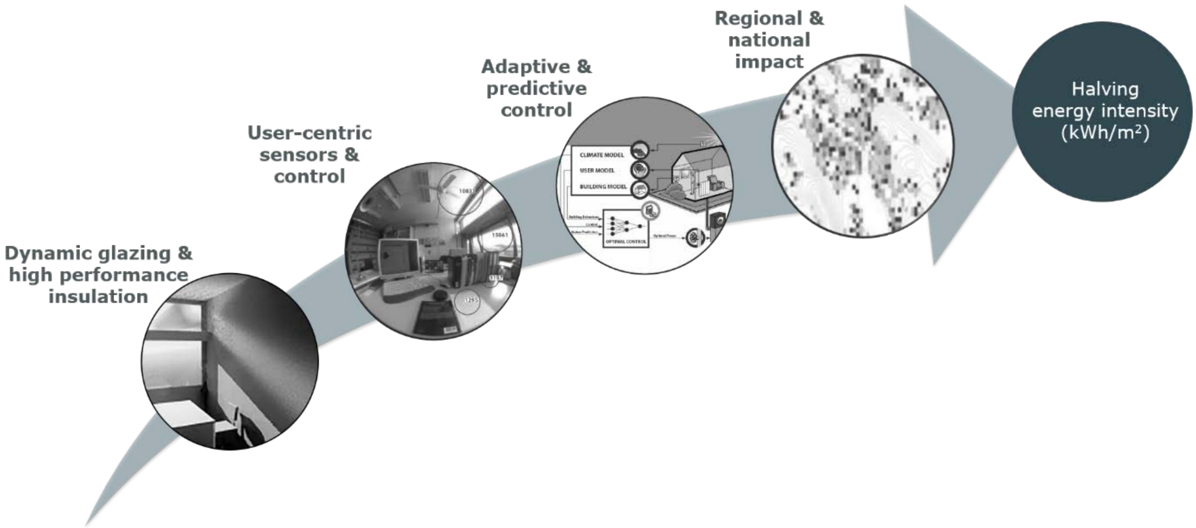

Fig. 2: Research tasks at the SCCER FEEB&D to increase energy efficiency and reduce the performance gap.

2. Active role for buildings in the energy system[7]

The duties of buildings in Switzerland's energy system are set to change through the decentralization of the energy supply in future (see Fig. 3). Presently, the transition from buildings as pure consumers to so-called "prosumers" that produce and consume energy themselves and draw it from the grid is underway. In future, buildings will become energy service-providers and ultimately an active hub in a decentralized energy system. These hubs will be involved in a constant bi-directional exchange with other hubs and differ from today's duties in the tiered organized energy supply. The more renewable energy is used in the system, the more the variable energy costs drop, i.e. the marginal

[7] Digitalization can enable the active participation of consumers from all demand sectors in energy system operations. By 2040, 1 billion households and 11 billion smart appliances could actively participate in interconnected electricity systems, allowing them to alter when they draw electricity from the grid. This smart demand response could provide 185 GW of system flexibility – comparable to the currently installed electricity supply capacity of Italy and Australia combined. This could save USD 270 billion of investment in new electricity infrastructure that would otherwise have been needed to ensure security of supply. […] Digitalization can facilitate larger shares of distributed energy resources, turning consumers into "prosumers"; new tools such as blockchain may facilitate such local energy trading systems. (Digitalisation & Energy, OECD/IEA Report, 2017)

costs tend towards zero. Production plants for renewable energy cost almost the same to run, irrespective of whether they supply energy or not. Consequently, the energy supply can be understood as a manly logistical task in future. Therefore, the task involves supplying the exact quantity of energy ordered at the desired time and place. Which technical, infrastructural and business innovations are necessary to run such a decentralized energy system is being researched based on the following topics at SCCER FEEB&D:

- In reality, building-integrated photovoltaics (BiPV[8]) is very often still "building-supplemented photovoltaics" and thus especially rejected in urban contexts due to the lack of architectural integration. The development of novel design methods and integrated tools (Digital Design, CAD, Building Information Model (BIM)), improved aesthetics and design skills (colors, patterns, shapes) and structural and electrical integration will help overcome this obstacle.

- Based on spatial and temporal information about the energy demand and supply, buildings are being merged into renewable, decentralized energy systems (RDES[9]). These RDES can provide energy services for the neighborhood/district or for the overall grid through conversion, management, storage and distribution. Models for energy hubs and multi-energy networks are being developed that enable a neighborhood's ideal transformation path to be found based on multi-criteria optimization techniques and matching business models (see next research topic, 3. Decentralized Energy Systems).

- The difficulties for the development and marketing of energy-efficient building technologies are emphasized by industry specific aspects. In contrast to other industries, the construction industry is characterized by minimal margins, leading to very low budgets for research and development. In addition, the very long lifetime of buildings dis-incentivize testing of novel technologies in the market. On the other hand, question innovative energy-efficient building technologies the rigid structures in the construction industry, and therefore have the potential to fundamentally transform the sector. We develop recommendations for industrial and policy stakeholders how to deal with the challenge, and how to profit from the potential of such transformation.

[8] Building-integrated Photovoltaic (BiPV)
[9] Renewable Decentralised Energy System (RDES)

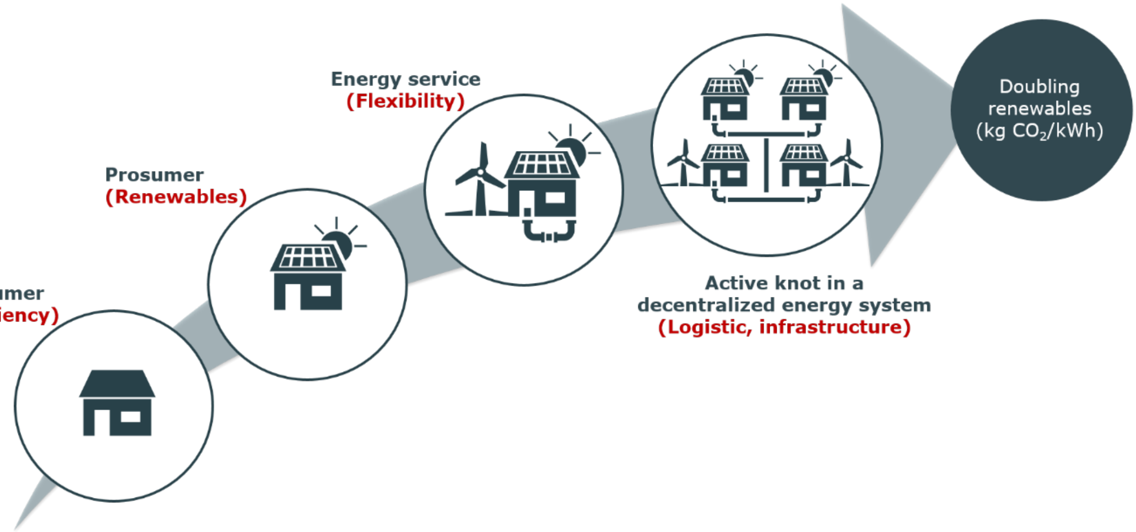

Fig. 3: Development of buildings' duties in Switzerland's energy system. The research tasks are mentioned in red.

3. Renewable, decentralized energy systems (RDES)[10]

If entire neighborhoods, districts or regions are taken into consideration as well as individual buildings, there are additional options to achieve the ambitious targets by 2035. Different buildings can assume different functions in the energy system. Depending on their characteristics, the buildings in these clusters are connected via electricity, heat, gas and/or data networks[11] and supplemented with conversion and storage technologies (see Fig. 4). These decentralized energy systems may reduce the CO_2 and energy intensity in the neighborhood, district and region – not by optimizing every single building per se, but by searching for the optimum solution for the neighborhood, district and region as a whole.

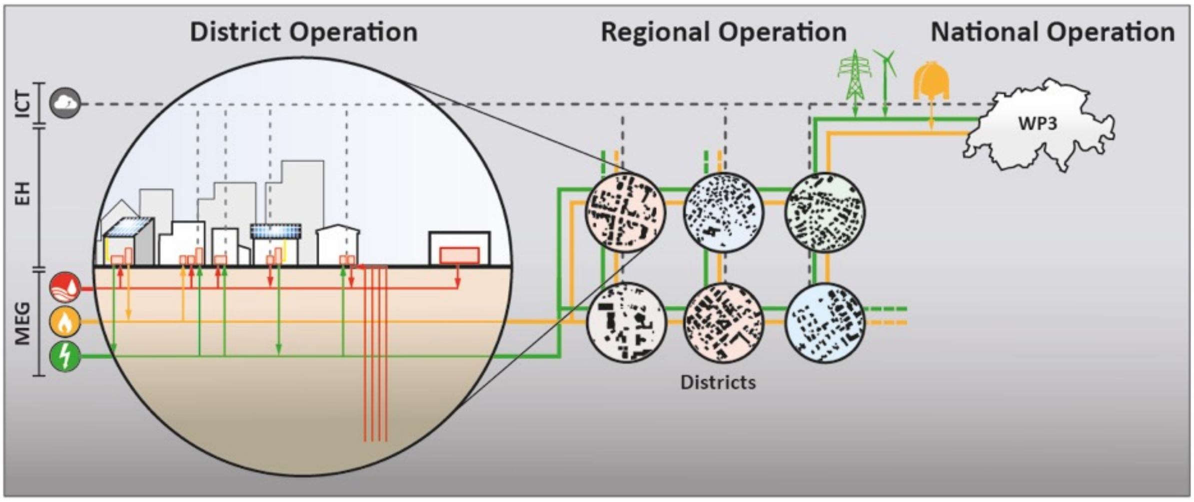

Fig. 4: Multi-energy grids (MEG) connect energy hubs (EH) to renewable district energy systems (RDES). Different RDES shape the energy system at regional and national level.

The example of the Suurstoffi district in Fig. 5 illustrates one such holistic concept. The individual buildings almost meet the Minergie standard. The district's energy supply with geothermal storage, an anergy grid, hybrid solar systems and decentralized heat pumps reduced the entire environmental footprint to such an extent that the district remained below the targets of the 2'000-watt society in terms of operating power. The relating costs in meeting the ES2050 target is reduced further

10 The greatest transformational potential for digitalization in energy is its ability to break down boundaries between energy sectors, increasing flexibility and enabling integration across entire systems. (Digitalisation & Energy, OECD/IEA Report, 2017)

11 Network convergence or multi-energy grids

with this overall assessment. How large the building clusters selected need to be for the global optimum to produce a more effective solution than the sum of the local optimums depends on the neighborhood, district and regional structure. Computer-based planning tools enable local concepts to be developed (HUES Platform, https://hues.empa.ch). The economic feasibility always needs to be borne in mind and examined, too.

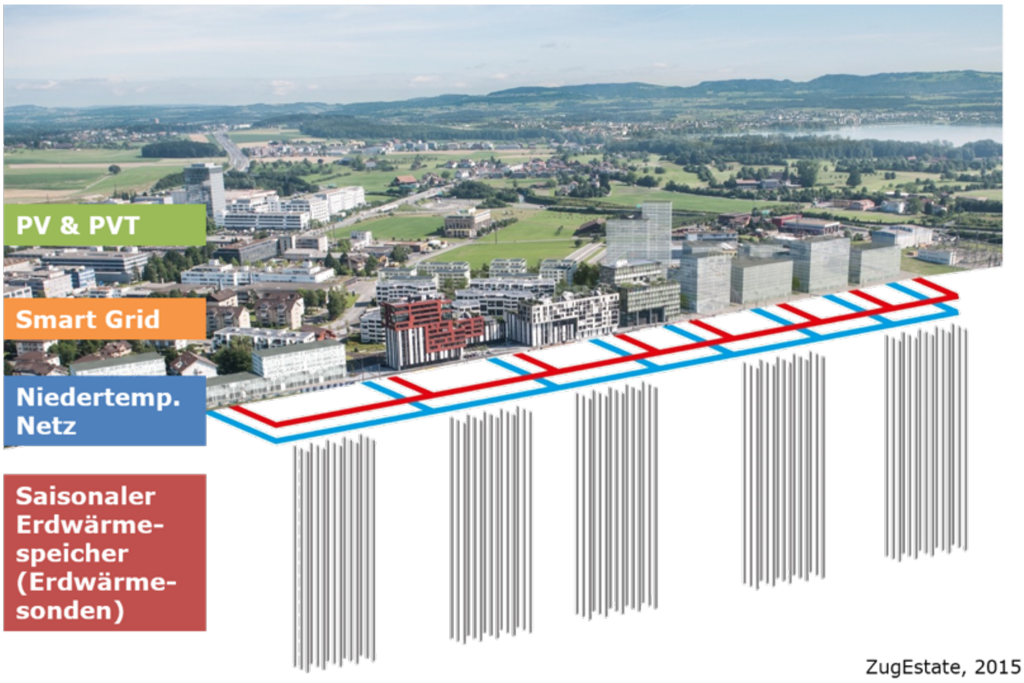

Fig 5. Holistic concept of a decentralized energy system based on the example of the Suurstoffi district.

The sectors involved (construction, energy, mobility, but also finances and information and communication technology (ICT)) in the network convergence of decentralized energy systems enable new business models to be developed. By linking sectors in this way, the market diffusion of e-mobility, for example, can be expedited. Fluctuating electricity production from renewable energy sources requires flexibility and storage capacity. Electric vehicles, coupled with the charging infrastructure, can act as aggregated storage systems and provide this kind of capacity. Furthermore, the gas or heat infrastructure can be used to store energy long term (power-to-X). As a result, new business models will develop beyond industry boundaries and help new technologies to break through. The following research projects are being conducted at SCCER FEEB&D in the field of RDES:

- At neighborhood and district level, the planning, realization and operation of an RDES is a far away from being an established standard process as the current design tools, technologies and automation systems are not suitable for handling such complex systems.

SCCER FEEB&D will provide tools to tackle this challenge. Dynamic models for the energy demand and supply at neighborhood and district level are being developed that factor in the individual building's specifics, such as access to renewable energy sources, usage flexibility, storage capability etc. This includes defining the most important boundary conditions under which an RDES needs to be designed and operated. We also develop recommendations how innovative organizations (e.g. investors, developer, designer, contractors) can address the challenges raised by the planning and implementation of RDES. The models are being integrated in the optimization tool "HUES Platform". HUES is simultaneously being transformed from an academic tool into a platform that industry can use in real projects. In addition, the new structures and processes in planning and implementation of RDES projects will be analyzed, which successfully handled a high integration of multiple technologies.

– Operating an RDES requires a sophisticated control architecture, which require large amount of RDES data from optimally designed monitoring concepts. A control system for operating energy hubs and multi-energy grids is being developed which balances out conflicting and cooperative goals for several energy grid agents, including issues such as different economic goals, social obligations, data protection requirements and operational constraints. Additionally, methodologies are developed, which support the selection and the development of appropriate business models that overcome the named constraints.

As mentioned above, grid convergence and sector coupling form the foundation for building decentralized energy systems (see Fig. 6). The energy hub method was designed to develop concepts for such systems (Geidl, Andersson, 2005[12]) and can be used for both existing neighborhoods and new development areas. Demonstrators enable new concepts in the building, energy and mobility sectors to be tested, validated, improved, and guidelines derived. Examples are:

– NEST and move at Empa in Dübendorf
– NODES (New Opportunities for Decentralized Energy Systems) at Lucerne University of Applied Sciences and Arts in Horw

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12 Martin Geidl and Göran Andersson. 2005. Optimal power dispatch and conversion in systems with multiple energy carriers. Proc. 15th Power Systems Computation Conference (PSCC).

– ERL (Energy Research Lab) at the University of Applied Sciences and Arts Northwestern Switzerland in Muttenz

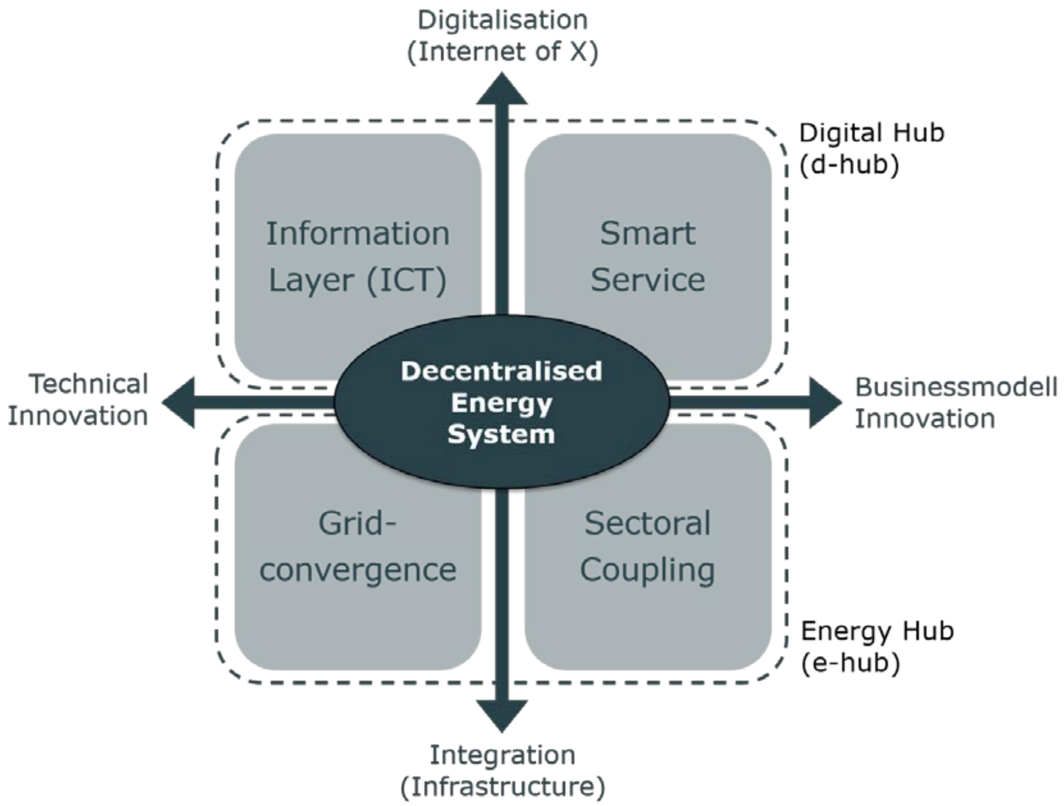

Fig. 6: Overview of the solutions space for decentralized energy systems and its most important development drivers (technical innovation, business model innovation, integration and digitalization).

4. Digitalization[13]

Another driver for the development of efficient and active buildings and RDES is digitalization. Information from buildings and their technical installations and sensors can be used to organize and operate the decentralized energy supply more effectively and efficiently. This kind of local information is increasingly being used in various information systems, such as building information models (BIM), energy management systems (EMS), device-specific cloud platforms or low power networks (LPN).

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[13] The cornerstone of the transformation of the electricity sector will be the emergence of new business models that monetise the cross-sectoral linkages explored in this chapter. These are set to reshape the experience of energy consumers, as digitalization redefines their interaction with energy suppliers. The fundamental shift may be away from energy-only, asset-intensive business models to platforms that enable the exchange of services. For instance, the sale of electricity, energy management technologies that allow consumers to optimize their in-house consumption, EV charging and other services can be packaged together. (Digitalisation & Energy, OECD/IEA Report, 2017)

Access to such systems facilitates the development of new services. We identify trends of digitalization in the building sector to evaluate their energy-saving and market potential.

Such intelligent services enable for instance, smart services can be used to exploit the thermal flexibility of heat pumps or cooling systems on the electricity market (warmup, Werlen et al., 2016) or individual electricity purchasers can cover their energy needs for 15 minutes precisely from selected hydroelectric power stations (e-can suisse, Sulzer, et al, 2017). Moreover, operating optimizations can be offered effectively and at affordable prices. Deviations from the target state are swiftly identified and prioritized to take appropriate measures. The development of such information systems and smart services must go hand in hand with the development of cyber security and data protection. Moreover, the aim is to organize the access to smart services simply and barrier-free. This will create a thriving, digital economy that echoes the one available today in the real world.

The decentralization and digitization of the energy supply puts the users and their needs at the center of the business models, not the technology. In future, users will play a more active role in the energy market and decide which products and services they want to buy or sell. Customers want to be able to choose from attractive ranges of services, not be supplied. Wherever this is not possible from present market players, new companies to the industry which understand the customer focus and digitalization better will provide these services. They will combine energy-specific services and non-energy ones into bundles and offer them at attractive prices. Google, Apple, Amazon & co. are working swiftly to develop their bundles. In the process, the energy services assume a complementary role, i.e. the bundle will be driven by a financial product or insurance service, the energy service supplements the financial product. Future energy services at building, district or regional level must take into account this development to survive in the digital world. For this reason, as of 2019 another work package will be added to the research at SCCER FEEB&D that examines digitalization in the energy and building sector more intensively.

5. Smart & resilient cities/communities

Digitalization alone will not be able to overcome the challenges of the urban sphere in future. Changed boundary conditions require intelligent urban planning that responds effectively and resiliently to potential future risks such as climate change, weather hazards, resource shortages and changed regulatory and market-related uncertainties. In order to take these risks into account adequately, technical solutions need to adapted for buildings and cities. The urban development strategies include protecting the population against negative effects on health and comfort through local overheating, for instance.

With the trend towards urbanization and the growing population, the urban sphere is becoming denser. Topics such as the influence of densification and urban form on the overall energy efficiency of buildings, the micro-climate and natural resources need to be addressed scientifically. The main goal of future urban design is to reduce CO_2 emissions cost-effectively. Cities compete globally as regards attractive living conditions. However, it is unclear whether low-carbon energy supply technologies or greater energy efficiency for different urban forms in Switzerland are sufficient to achieve the CO_2 emission targets. With increasing outdoor temperatures, the switch to active cooling and, with it, a major increase in the building energy demand is becoming increasingly important. From 2019 these research topics will be incorporated into SCCER FEEB&D and conducted as a separate work package.

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Transformation to sustainable buildings and neighborhoods

The research projects at SCCER FEEB&D will be supported by knowledge and technology transfer activities to facilitate straightforward access to the results. The market diffusion of the research results is being forced in both directions (see also Fig. 7):

- **Top-down**, by deriving new parameters, planning methods and planning tools from our research results. As a result, we help the public sector, spatial planners, energy planners, architects, engineers and real estate developers to factor the interdisciplinary and cross-sectoral requirements for the future energy system into their work.
- **Bottom-up**, by researching and developing new materials, products, systems and services. As a result, we enable manufacturers and service-providers from various industrial sectors to launch new products on the market with a view to converting the energy system.

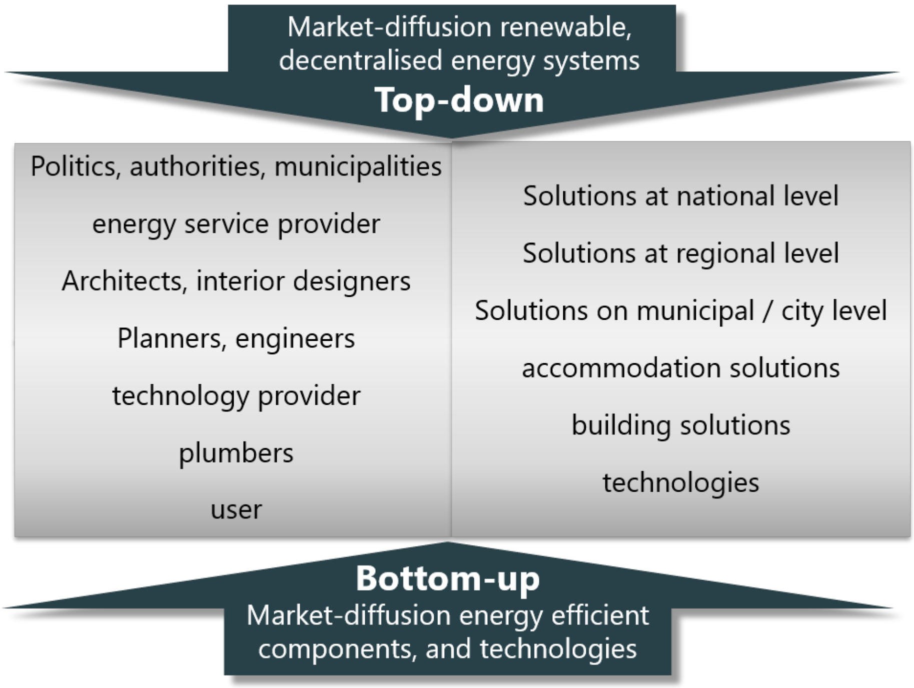

Fig. 7: Market diffusion research results SCCER FEEB&D

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