NRP

Energy

National Research Programmes 70 and 71

Synthesis

Buildings and Settlements

Buildings and Settlements

Buildings account for around 40 percent of Switzerland's overall energy requirement. They are therefore of great importance with respect to measures to increase energy efficiency and foster the decentralised use of new renewable energy. A variety of NRP 70 and NRP 71 projects focus on these challenges at both the technological and the socio-political level.

1. A great deal of detailed work to be done

Around 40 percent of the energy consumed in Switzerland can be attributed to the construction and running of the country's building stock. Buildings and settlements will thus play a prominent role in the transformation of our energy system. Numerous steps for the future have already been initiated – but there still remains a great deal to do.

1.1. Core messages

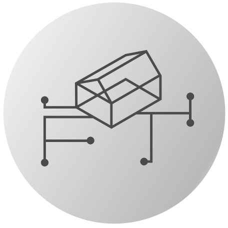
The following three core messages with respect to buildings and settlements can be derived from the research work conducted by the NRP Energy:

1. Technical measures alone will not suffice in order to achieve the objectives of Energy Strategy 2050 in the area of buildings and settlements. In addition to accompanying regulatory measures implemented by the state, a change in behaviour among the main stakeholders, primarily building users and owners, will be required.
2. At present, the renovation rate with respect to the existing building stock stands at only approximately 1 % a year. In order to achieve the objectives of Energy Strategy 2050 on schedule, the renovation rate will have to be increased significantly.
3. Decentralised multi-energy hub systems can – primarily in peri-urban and rural areas – make a substantial contribution to the implementation of Energy Strategy 2050 thanks to the integrated use of energy provided locally.
4. To allow innovative technologies and new organisational solutions to quickly gain access to the market, focussed and dynamic construction- and planning-relevant laws, ordinances and standards will be required.
5. Greater and improved knowledge about the issue of energy – among both specialists and building owners as well as the population at large – will be required for the timely implementation of Energy Strategy 2050 in the area of buildings and settlements.

1.2. Key recommendations

Strategically position the optimisation of energy efficiency!

Building owners develop a long-term strategy for optimising the energy efficiency of the building stock. The objectives of the strategy include achieving a substantial improvement in terms of energy efficiency, eliminating CO_2 emissions, ensuring cost-effective operations and preserving the value of the building stock.



Initiate decentralised multi-energy hub systems

On their own initiative, energy suppliers identify perimeters within their sphere of influence that are suitable for the use of decentralised multi-energy hub systems (DMES) and create a DMES concept for each of them as well as a technical, environmental and financial feasibility study.

Focus and simplify regulation

The energy-relevant regulations that were formulated in a different context are no longer adequate for the current requirements and opportunities.

All recommendations relating to the topic of “buildings and settlements” are formulated in full in the “Recommendations” section of this synthesis. From this collection of recommendations, the programme management of the NRP Energy, together with the echo group, have selected three key recommendations that are of great relevance with a view to the successful implementation of Energy Strategy 2050.

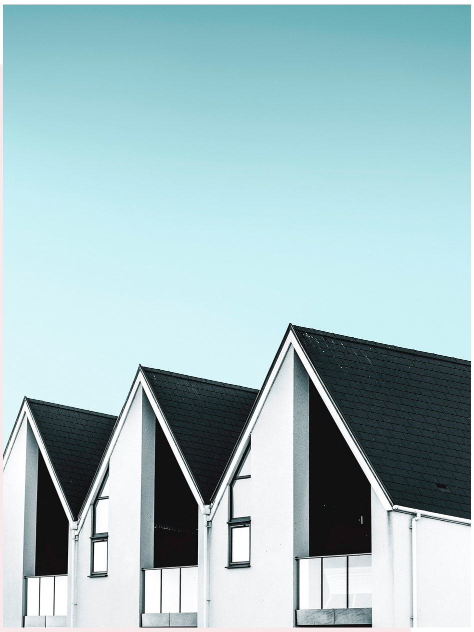
Strategically position the optimisation of energy efficiency! Building owners develop a long-term strategy for optimising the energy efficiency of the building stock. The objectives of the strategy include achieving a substantial improvement in terms of energy efficiency, eliminating CO_2 emissions, ensuring cost-effective operations and preserving the value of the building stock. For the financing of the investments derived on this basis, a long-term financial plan is drawn up and the supply of funds for the maintenance fund is adjusted. The implementation of this strategy is monitored on an ongoing basis, with the strategy itself being reviewed and updated periodically.

Initiate decentralised multi-energy hub systems! On their own initiative, energy suppliers identify perimeters within their sphere of influence that are suitable for the use of decentralised multi-energy hub systems (DMES) and create an DMES concept for each of them as well as a technical, environmental and financial feasibility study. In the case of a positive result, the energy supplier notifies the local municipal authorities as well as the building owners and initiates the next steps: it informs the population, establishes an energy cooperative and initiates the required approval processes. The energy supplier remains co-owner of the DMES and takes on responsibility for its operations.

Focus and simplify regulation! The energy-relevant regulations that were formulated in a different context are no longer adequate for the current requirements and opportunities. The cantons therefore need to focus their planning, construction and energy-related legislation with a view to the quick and economic implementation of Energy Strategy 2050 and simplify the authorisation and approval procedures. The next revision of the model provisions of the cantons in the energy sector (MuKEn) and their systematic implementation is of particular significance. The MuKEn should focus on a few clearly defined and understandable target values.

2. Buildings need to provide more energy – and consume less

The Swiss building stock will play an important role within the framework of Energy Strategy 2050. A great deal has already been achieved and good progress is being made in many areas – however, very significant efforts are required to make buildings and settlements fit for the future.



Building # CO2 / greenhouse gases

2.1. The Swiss building stock

In Switzerland, there are currently around 1.8 million heated buildings with a floor space totalling 800 million m^2. Their insurance value stands at approximately CHF 2,500 billion.[1] In 2016, the so-called energy reference area – i.e. the floorspace within the thermal building envelope that needs to be heated or air conditioned – was 745 million m^2.[2] Some 1.5 million buildings are residential buildings with a floorspace of 510 million m^2.[3]

Buildings and settlements play a decisive role in shaping the space in which we live and conduct business: what, where and how we build and use structures has a significant impact on the consumption of land and other resources as well as CO_2 emissions. Especially impressive is the energy consumption of the country's building stock: it accounts for around 50 % of the energy consumed in Switzerland. Some 10 % is used for construction processes and building materials, with 40 % being used for operations.

Notes and References

1 Rütter H and Staub P 2018; Die volkswirtschaftliche Bedeutung der Immobilienwirtschaft. Swiss Homeowner Association (Hauseigentümerverband – HEV Schweiz), Zurich
2 Swiss Federal Office of Energy (SFOE); Indicator ID QU048
3 Swiss Energy Foundation (SES), www.energiestiftung.ch (as at 22 April 2019)

Energy efficiency

2.2. The building stock and Energy Strategy 2050

Because the energy consumption of the building stock is high, it plays an especially important role in Energy Strategy 2050. The goal is to increase the energy efficiency of buildings and increasingly ensure they are run with renewable energies. The energy strategy specifies the ambitious objectives for three time horizons, namely 2020, 2035 and 2050. For example, Energy Strategy 2050 states that in 2035 energy consumption for heating, cooling and warm water should be around 40 % lower than the value recorded in 2010 despite the resident population being forecast to grow by approximately 13 %. The goal is thus no less than to halve pro capita consumption.

The building stock will also play a key role in achieving the changeover from fossil energy sources to renewable energies and in reducing CO_2 emissions. In future, heat pumps, wood-fired systems, waste heat generated from industrial activities, geothermal energy and solar cells should provide heating and hot water. In the foreseeable future, building-integrated photovoltaics (BiPV) will also generate more electricity in Switzerland than required by the building stock. In the case of new buildings, corresponding measures are generally already implemented. For existing buildings, however, considerable action still needs to be taken.

Energy Strategy 2050 is based on the figures of the Energy Perspectives for 2050 published by the Swiss Federal Office of Energy in October 2013. The assumptions and target figures applied therein have been made obsolete by more recent developments and do not correspond to the agreement also signed by Switzerland at the Paris Climate Summit at the end of 2015. The Energy Perspectives are therefore currently being revised and are set to be republished in 2020. The Federal Council will also have to rethink its energy strategy in light of the Paris Agreement.

Steering / promotion

2.3. A great deal has already been achieved

The world's first energy self-sufficient multi-family dwelling in Brütten (canton of Zurich) in 2014. The building manages with no external power connections whatsoever.
Source: rené schmid architekten ag

There are already many programmes, regulations and instruments aimed at improving the energy efficiency of the building stock. In 1990, an Energy Article was anchored in the Federal Constitution. In the same year, the federal government launched the RAVEL ("Rational Use of Electricity") stimulus programme, which was followed a year later by the PACER ("Renewable Energy Action Programme") stimulus programme. In 1992, the Conference of Cantonal Energy Directors (EnDK) issued the "model ordinance on rational energy use in buildings", followed by the "model provisions of the cantons in the energy sector" (MuKEn) from 2000. As early as 1997, the Swiss parliament passed the Energy 2000 investment programme.

In the private sector, the Minergie Switzerland association has been campaigning for a reduction in heating consumption for more than 20 years. In the 1990s, the Swiss Society of Engineers and Architects (SIA) already moved to publish numerous technical standards relating to heating consumption in buildings. These have been improved and expanded on an ongoing basis since this time. In 2006, it also published the "Energy Efficiency Path" guideline.

Many measures aimed at improving energy efficiency have already been implemented, especially in new buildings. Between 1990 and 2016, for example, this led to the total energy consumption of Swiss households per square metre of energy reference area being reduced by around 27 %.[1] Numerous pilot projects for so-called plus-energy buildings, which produce more energy than they require and manage without fossil energy sources, have already been implemented. However, all problems are far from having been solved.

Notes and References

1 Swiss Federal Office of Energy (2017); Swiss Overall Energy Statistics. Ittigen – Federal Office for the Environment; Indicator QU048 energy reference area. Ittigen

Behaviour

2.4. A great deal of action still needs to be taken

If the energy efficiency of the building stock is to be increased, measures will be required, in particular, in two areas: for energy-optimised building shells and the intelligent management of energy supply and demand.

Users can also make a significant contribution. They should not necessarily have to forgo comfort and, for example, keep the room temperature low. Instead, they should use energy intelligently. This may be achieved, for instance, by optimising artificial room lighting or using energy-saving household and office appliances.

In Switzerland, energy consumption is also significantly influenced by the mobility of people and goods. These are in turn affected by the building stock to the extent that people live, work and enjoy leisure activities in different places.

2.5. Seven big questions

With respect to buildings and settlements, there are currently seven questions that urgently need to be addressed:

1. How can the energy efficiency of existing buildings be substantially and economically increased in a reasonable time?
2. How can power, heat and cold be stored seasonally in a cost-effective way?
3. Under which conditions do decentralised hybrid energy systems have a future – and how should these systems be organised and financed?
4. How can state-of-the-art solar cells and photovoltaic elements be integrated in the building shell in an aesthetically and economically acceptable manner?
5. What contribution can be expected from digitalisation?
6. What contribution are building owners and users able to make to energy efficiency and what contribution do they want to make here?
7. What role should the state play in the conversion of building stock with respect to energy efficiency?

The National Research Programme (NRP Energy) cannot provide either a complete or definitive answer to these seven key questions – even more research projects would be required to this end. This synthesis therefore focusses on the questions looked at in the NRP Energy on “buildings and settlements” and the generated results. They chiefly provide answers to questions 3, 4, 6 and 7.

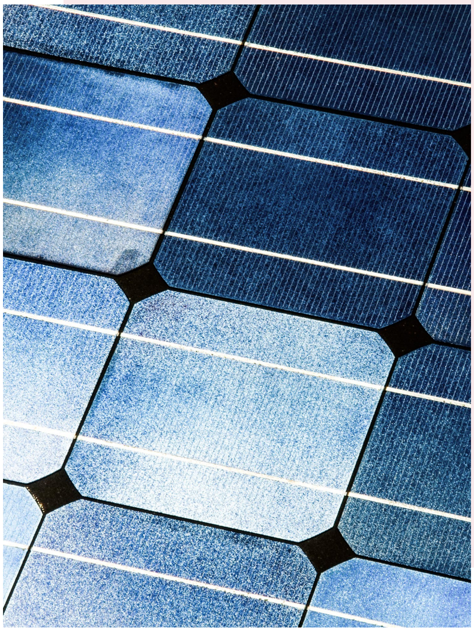
2.6. Multi-stage synthesis process

This synthesis on the main topic of “Buildings and Settlements” was created as part of a multi-stage process. In October 2016, when the researchers were still in the middle of performing their project work, they exchanged information on their research questions, methods and solutions in order to identify interdependencies and potential synergies. Half a year later, the researchers met with representatives from associations, federal offices, cantons and relevant NGOs in order to find out more about the expectations placed on the research results and their dissemination.

On the basis of these findings, the Steering Committees of the NRP “Energy” developed a synthesis concept for each of the six main topics. An initial draft of the synthesis on “Buildings and Settlements” was developed on the basis of this concept by Hans-Rudolf Schalcher, scrutinised within the Steering Committees of the NRP “Energy” and edited by a science journalist.

In May 2019, an echo group comprising nine specialists from the worlds of administration and business came together in order to reflect on and assess the draft synthesis (see “Publication details”). They also evaluated the recommendations with a view to their impact and feasibility. Following further revisions and additions, the synthesis was approved in September 2019 by the Steering Committees of the NRP “Energy”.

3. Three focus areas



The results of the around 40 or so research projects on the topic of "buildings and settlements" were assigned to three focus areas as part of this synthesis:

- Decentralised multi-energy hub systems
- Building-integrated photovoltaics
- The behaviour of building users

These focus areas do not represent the only challenges with respect to the energy balance of buildings and settlements. The increasing level of energy efficiency, especially in connection with heating and cooling, is given equal importance. In this area, the potential for increasing efficiency is chiefly found in the building shell – roofs, walls, windows – where insulation, the use of daylight and shade are key. These aspects were, however, not researched as part of the NRP Energy.

3.1. Decentralised multi-energy hub systems

The term decentralised multi-energy hub systems (DMES) is used to denote networks of local energy providers of any size that either do or don't have access to public energy grids and make a real contribution to covering energy consumption thanks to more affordable and ever-more-efficient technologies.

3.1.1. What is a decentralised multi-energy hub system?

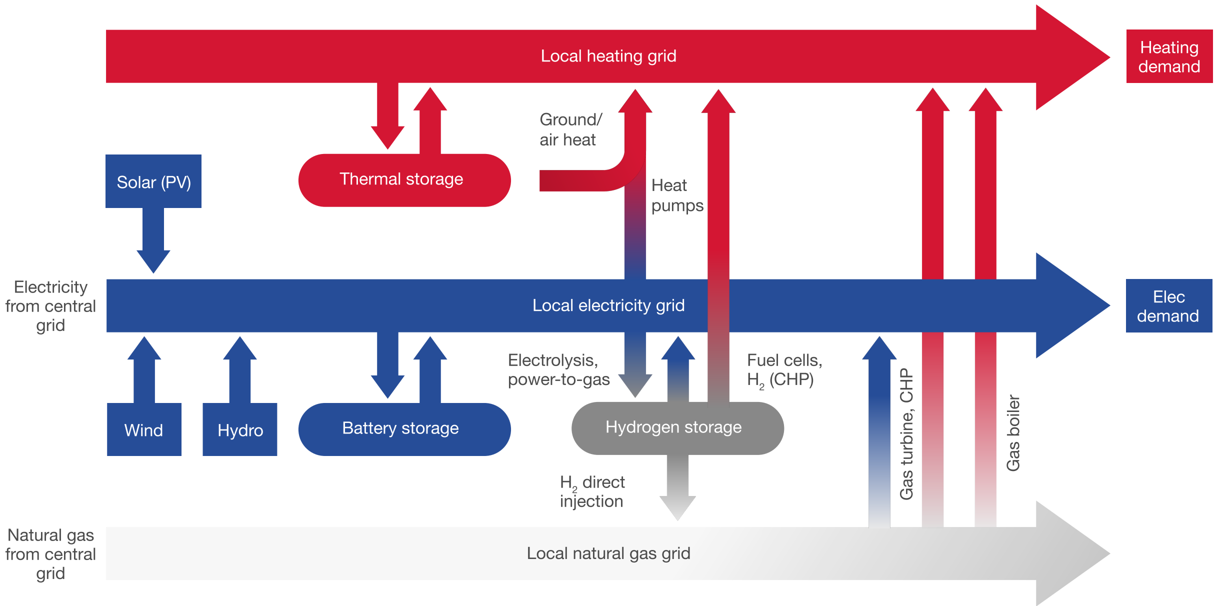


Illustration of performance of a DMES. *Source: Orehounig 2018*

Traditionally, electricity in Switzerland has been produced at central plants – at hydropower and nuclear power stations. Where necessary, this electricity supply is supplemented by imports from Europe. Via a nationwide grid comprising high-, medium- and low-voltage levels, electricity is supplied to end consumers.

Heating, on the other hand, is primarily produced on a decentralised basis: around 65 % of the heating energy required across Switzerland is now generated locally from fossil energy sources such as heating oil and gas. Only around 3 % of buildings in Switzerland are connected to a district heating grid; most of these grids are currently fed by waste incineration plants, heating plants or sewage treatment plants.[1]

The term decentralised multi-energy hub systems (DMES) is used to denote networks of local energy providers of any size that either do or don't have access to public energy grids. These include, for example, photovoltaic plants, small hydropower plants, cogeneration plants, biogas plants, sewage gas plants, wood burning plants and waste incineration plants as well as fuel cells and wind turbines. Storage systems are also part of the DMES and are essential for their smooth functioning: rechargeable batteries – including those found in electric vehicles – as well as power-to-gas systems, boiler systems, underground storage tanks and compressed air reservoirs.

While DMES for a long time tended to be for pioneers or technology enthusiasts, they can today make a real contribution to covering energy consumption thanks to more affordable and ever-more-efficient technologies. This has been shown by studies conducted as part of the NRP Energy.

Legislative changes are supporting the development: the revised Energy Act (EA), which came into force on 1 January 2018, not only allows for producers to use self-generated energy themselves, but rather also to sell it locally to third parties without the involvement of the local energy supplier. The first projects are already benefiting from this option. Huttwil in the canton of Berne is home to a development with 22 buildings and 100 residential units situated at a sunny hillside location. The so-called private consumption community stores and consumes the self-generated energy within the development – and feeds any surplus into the public grid.[2]

Notes and References

1 www.fernwaerme-schweiz.ch
2 www.energiequartier-hohlen.ch

3.1.2. The contribution of DMES to the implementation of Energy Strategy 2050

Decentralised multi-energy hub systems (DMES) will play an important role in the replacement of nuclear and fossil energy with new renewable energies. How large their contribution can be depends greatly on the local situation. This is illustrated by a study for which various DMES configurations were simulated based on the example of a residential district in Zurich-Altstetten and in the municipality of Zernez in the Lower Engadine.[1]

Building stock and solar radiation in the example cases of Zernez and Zurich-Altstetten.

Source: Project "Multi-energy hub systems"

In the model, it should be demonstrated that DMES can replace the current share accounted for by nuclear and fossil energy with renewable energies. The theoretical technology mix comprises photovoltaic systems on building roofs, fuel cells, micro gas turbines, natural gas tanks, a small hydropower plant (Zernez only), low wind turbines, heat pumps, hydrogen storage, lithium-ion batteries and warm water boilers. The simulations were based on three different global warming scenarios up to 2050 and took account of the relevant market- and technology-based parameters.

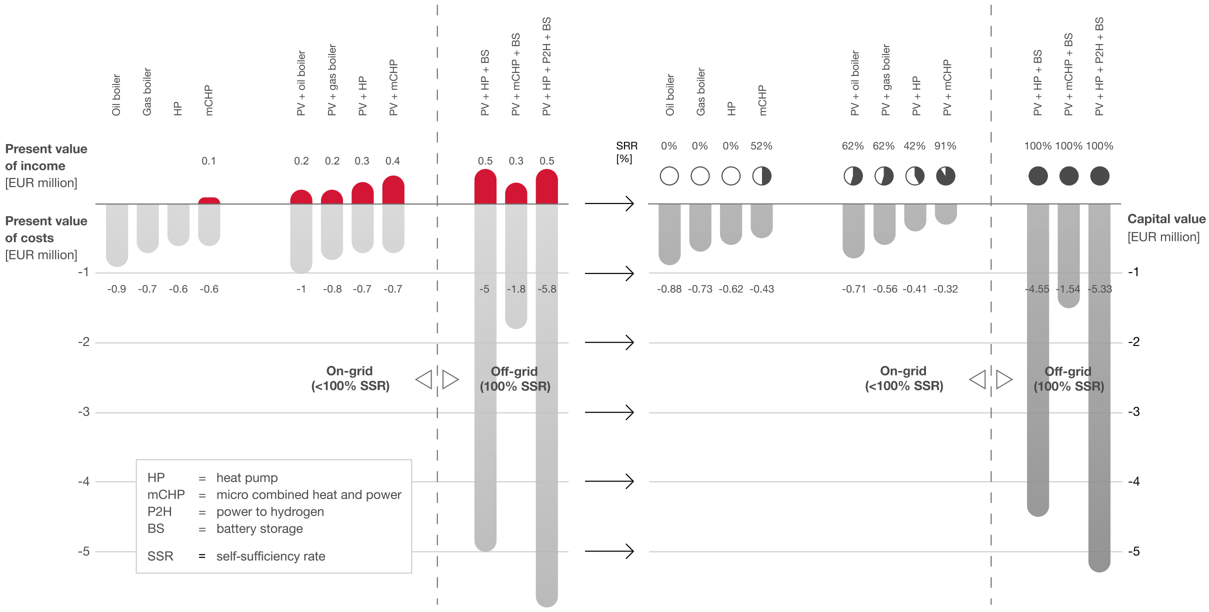
It was shown that the objectives of Energy Strategy 2050 can be achieved at a reasonable cost in areas such as Zernez – with high potential for renewable energies and a relatively low building density. At the same time, CO_2 emissions can be reduced by up to 75 %. In the urban example case of Zurich-Altstetten, however, the objectives of Energy Strategy 2050 were not achieved in any of the investigated scenarios – unless the renovation rate is increased to more than 2 % per year or additional renewable energy is imported.

Notes and References

1 Project “Multi-energy hub systems”

Costs / benefits

3.1.3. The optimal configuration of a DMES



Profitability comparison of various DMES configurations for a fictive example in Berne.
Source: Project "Economics of multi-energy hub systems'

When it comes to the composition of a DMES, there is no universal solution. The optimal combination of energy providers and storage systems with respect to creation and operating costs and the reduction of CO_2 emissions primarily depends on:

- the local circumstances (existing buildings, climate conditions, etc.);
- the future development of primary energy prices;
- subsidies (feed-in remuneration);
- incentive taxes (CO_2 levy certificates).

In the project "Economics of multi-energy hub systems"[1], the economically most advantageous configuration was identified for a fictive settlement in Berne using a techno-economic model. The settlement comprises three single-family homes and three multi-family homes as well as a small office building. The theoretical total annual electricity requirement is 115.5 MWh, while the total annual heating requirement stands at 388.9 MWh.

Various configurations of photovoltaic plants, oil and gas boilers, heat pumps, fuel cells, batteries and power-to-hydrogen systems were investigated: eight with grid access (on-grid, with different degrees of self-sufficiency) and three without grid access (off-grid). The current economic circumstances were used as the underlying framework conditions: the current primary energy prices, the feed-in remuneration as well as the procurement and operating costs of the components. The analysis exclusively looked at the present value of all payment streams – on condition that all energy demands are covered; the CO_2 emissions were not taken into account.

All configurations – including the conventional systems operated with oil or gas – had a negative present value. In all cases, the costs exceeded the income and/or savings. In some instances, however, the DMES had less negative present values than the traditional systems. The off-grid solutions, in contrast, showed negative present values that were five to ten times higher than those of the on-grid solutions. As regards the on-grid solutions, the combinations comprising photovoltaic systems and fuel cells or heat pumps – without the use of any storage systems – proved to be the most favourable configurations.

In summary, it can be said that a DMES has to be specially configured for each situation – and that, as part of the NRP Energy, models and methods were developed for the simulation of various configurations under specific framework conditions.

Notes and References

1 Project "Economics of multi-energy hub systems"

Guidance

3.1.4. Testing of DMES controls

Demonstration of real-time control of electricity flows in the real microgrid of the EPF Lausanne. *Source: Project "Real-time control of power flows'*

To allow for all components in a DMES – irrespective of whether it has access to public grids or not – to work and interact optimally with one another, sophisticated control systems are required that regulate the interplay between the difficult-to-forecast provision and use of electricity and heating. It is clear that all DMES need control systems that are tailored to their individual composition and environment: one for the internal processes and procedures and one for the possible interplay with the higher-level national energy system. Both control levels were investigated in the NRP Energy.

On the basis of the two example cases of Zernez and Zurich-Altstetten, algorithms were developed and tested for the distributed control of DMES.[1] The objective was optimally to control various renewable energy sources and to compare stochastic energy purchases under specific technical framework conditions. This approach has the benefit that it simplifies the future expansion of DMES and increases the level of data security. The disadvantages are almost negligible. The evaluation of the example cases shows that the developed control algorithm works.

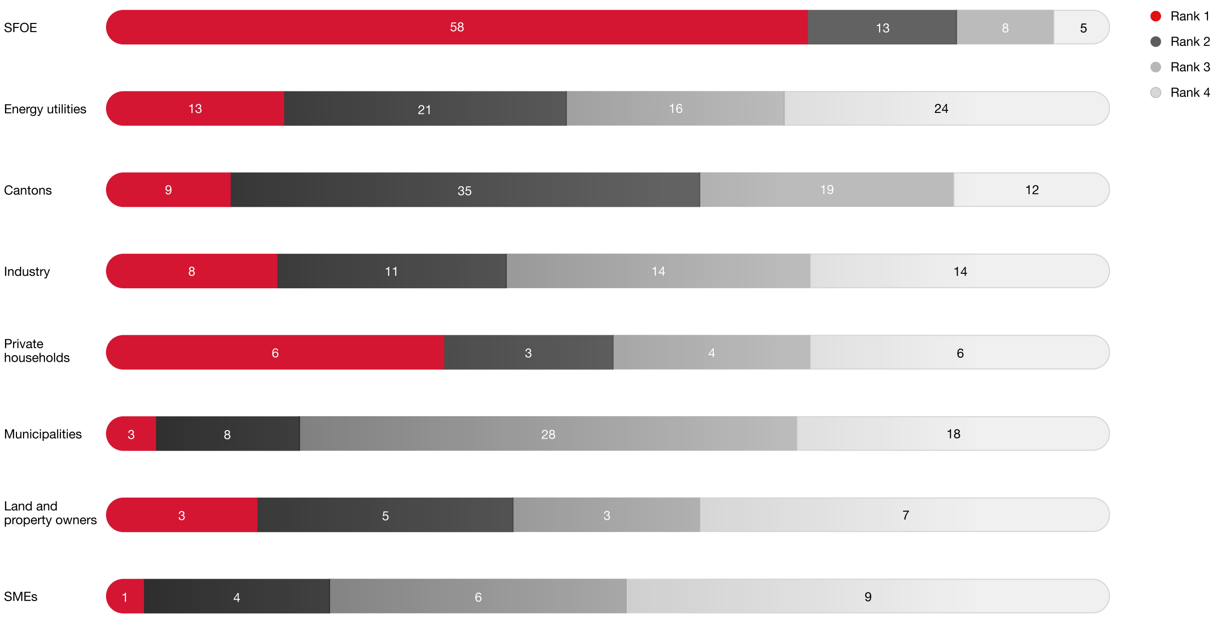
In the project "Real-time control of power flows"[2], an agent-based control system was developed in an existing microgrid[3] at the interface of various DMES and the national electricity grid. Viewed on a one-to-one basis, it was shown that a DMES can be operated and controlled as an active local electricity grid. As such, the grid reinforcements that would be made necessary by an increased number of photovoltaic systems or the electrification of road traffic are avoided or greatly reduced. The control of active local electricity grids also contributes to the stabilisation of the superordinate grid. The developed algorithms can be used on a general basis and do not need to be recalculated each time for the specific case in question.

Notes and References

1 Project “Control of multi-energy hub systems”
2 Project “Real-time control of power flows”
3 A microgrid is a grid that can work without an electrical connection to the national grid. A microgrid can typically be a village or a residential district. Normally, the microgrid is connected to the national grid. However, stand-alone operation is also possible.

Energy cooperative # Financing

3.1.5. Organisation and financing of DMES



Responsibility for the implementation of Energy Strategy 2050. *Source: Project "Multi-energy hub systems and society"*

A survey[1] revealed the following: the vast majority of the population assume that the measures for the implementation of Energy Strategy 2050 – and thus also the initiatives for the realisation of DMES – should originate from the Swiss Federal Office of Energy. Only then do the cantons and energy providers follow.

This contradicts the finding that municipalities and their plants are key with respect to the foundation and management of energy cooperatives.[2] In Switzerland, there are currently around 280 energy cooperatives entered in the commercial register, some of which have existed for more than 100 years. A marked increase was recorded between 2006 and 2012 – boosted by the introduction of compensatory feed-in remuneration (KEV) on 1 January 2019. Since 2012, the number of newly established energy cooperative has declined considerably, a development that can presumably be attributed to the increased level of uncertainty with respect to promotion measures.

Nevertheless, energy cooperatives remain an important business model in connection with the organisation and financing of DMES. For example, the project "Collective financing of renewable energy"[3] showed that the cooperative approach has some benefits over economic approaches. Energy cooperatives enjoy a greater level of acceptance than other organisational forms. They also promote the development of the local economy, while participation increases the public's level of awareness vis-à-vis energy issues. A broad-based survey conducted as part of the project "Overcoming opposition to PV"[4] confirmed that around two-thirds of the more than 400 questioned households would be prepared to participate financially in a communal collective facility for the production of solar power.

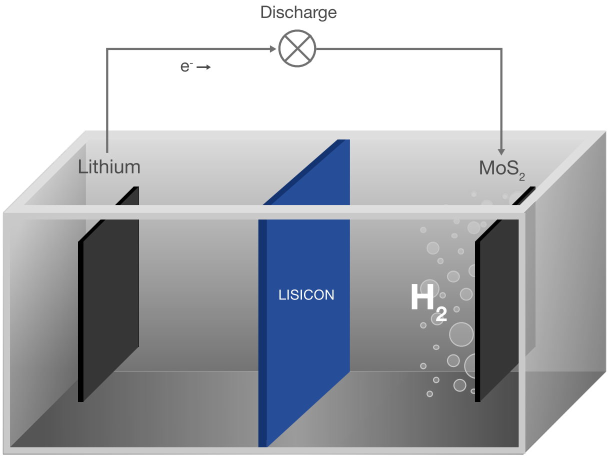
The high level of acceptance among the population as regards the provision of new renewable energy at a communal level is enhanced further if the municipality or its plant is financially involved in an energy cooperative and participates actively in the management of such plants.[5]

Notes and References

1 Project "Multi-energy hub systems and society"
2 Project "Collective financing of renewable energy"
3 Project "Collective financing of renewable energy"
4 Project "Overcoming opposition to PV"
5 Rivas, J, Schmid, B & Seidl, I 2018, Energiegenossenschaften in der Schweiz. Ergebnisse einer Befragung; WSL Berichte, Heft 71, WSL Birmensdorf

Battery # Energy storage

3.1.6. Electricity storage with new batteries



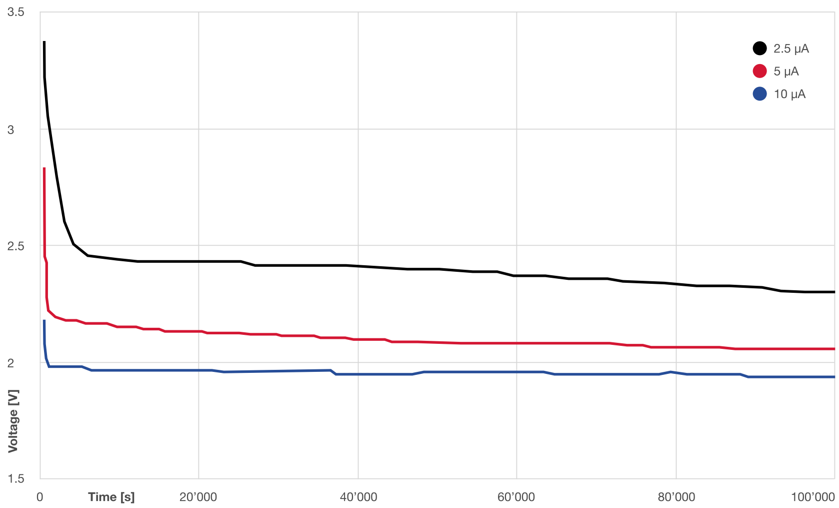
Schematic of a Li-water battery cell. *Source: Project "New materials for future batteries'*

Efficient and affordable electricity storage is key to bringing about the broad-based use of new renewable energies. While energy storage systems already exist, these are expensive and inefficient. A great deal of research and development is still needed. Various storage approaches were also researched as part of the NRP Energy. However, this was primarily for day/night balancing and for the short-term bridging of periods with poor weather.

In the project "New materials for future batteries"[1], new components for lithium-metal high-energy batteries were developed that are superior to the components already available on the market. These are molybdenum (IV) sulphide (MoS2) membranes and crown ether-based ionic liquids as a new class of compounds for battery electrolytes. Such rechargeable lithium-water and lithium-oxygen batteries have at least a 10 to 30 times higher theoretical energy density than conventional rechargeable batteries. The challenge with these systems is ensuring their charging and discharging capacity over a long service life.

The project "Nanostructured lithium-ion batteries"[2] adopted a completely different approach and researched brand new materials for high-performance electrodes of lithium-ion batteries. Focus was placed on the development of nanoporous microparticles that were used as building blocks for the production of new electrodes. The practical applicability of these new nanostructured materials was demonstrated using a lithium iron phosphate (LiFePO4) cathode and a lithium titanium oxide ($Li_4Ti_5O_{12}$) anode. The replacement of the usual graphite anode with $Li_4Ti_5O_{12}$ increases the safety of lithium-ion batteries through the prevention of a "thermal runaway". In particular, this is essential for large battery installations (e.g. in buildings or DMES). Combined with a $LiFePO_4$ cathode, a battery is thus produced that can be operated over a very wide range of temperatures. This project demonstrated outputs for both of these electro materials that were very close to the theoretical optimum.

Discharge curves for different currents.



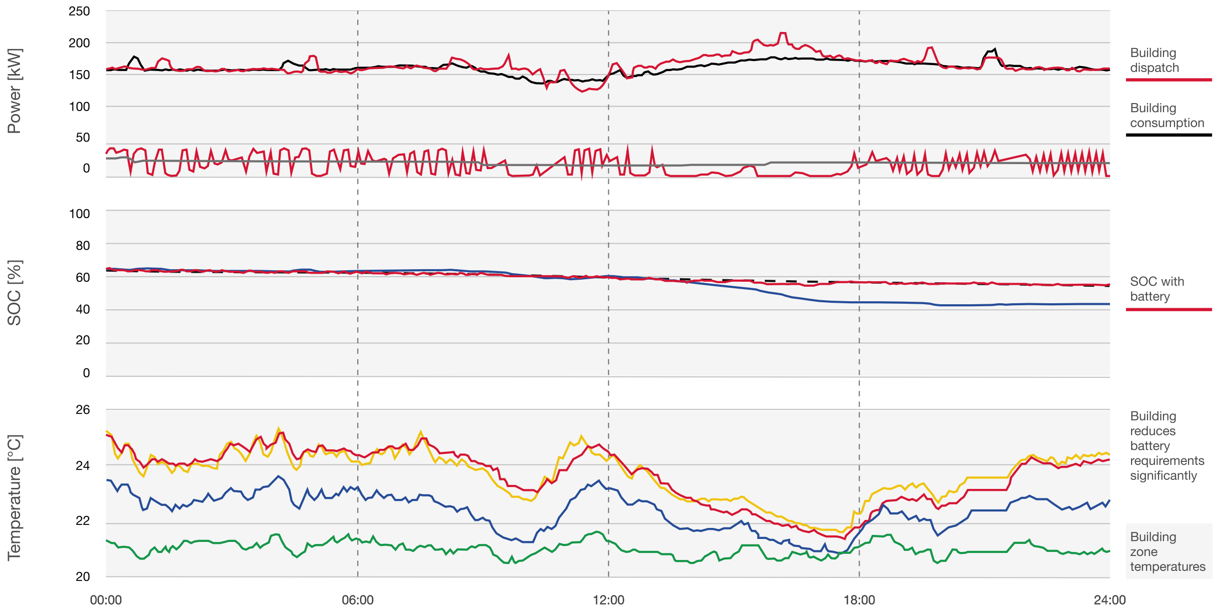
Source: Project "New materials for future batteries"

Notes and References

1 Project "New materials for future batteries"
2 Project "Nanostructured lithium-ion batteries"

Battery # Energy storage

3.1.7. Buildings as storage vessels



One day of operation combining the virtual storage of the thermal inertia of a building with a physical electrical battery. This combination reduces the requirements for expensive electrical storage significantly. *Source: Project "Demand and storage in electricity networks"*

In the project "Demand and storage in electricity networks"[1], it was demonstrated using model calculations and small-scale prototypes that the intelligent use of the thermodynamic inertia of a building can contribute a great deal to the decentralised storage of electricity and heat.

With a secondary control system at the interface between the inert building and the super dynamic supply network, the need for decentralised batteries can be significantly reduced and the ongoing costs of energy provision can be cut by up to 27 % – without any loss of comfort for the building users.

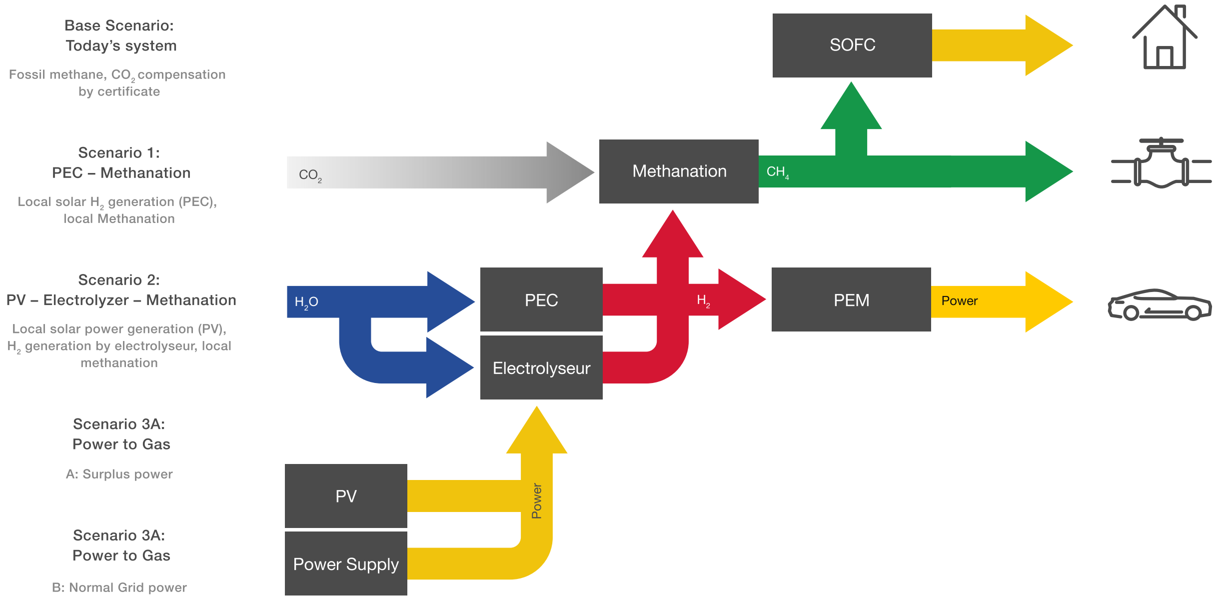
In order to determine the optimal configuration of the local energy system depending on the building typology, optimisation software has been developed. This can also be applied to entire settlements as well as in a national context.

Notes and References

1 Project "Demand and storage in electricity networks"

Methane / methanation # Energy storage

3.1.8. Storage with power-to-gas



Overview of investigated energy pathways: Base - fossil fuel combustion, 1 – PEC|CO_2 methanation, 2 – PV|electrolysis|CO_2 methanation, 3A – PtM from surplus electricity, and 3B – PtM from Swiss grid mix. *Source: Project "Sustainability of methanation"*

A promising approach is the storage of energy using power-to-gas. Water is converted into oxygen and hydrogen by means of electrolysis – using excess electricity – or photocatalytic water splitting. The hydrogen is fed into the public gas network. If hydrogen is stored in a separate tank, it can, where required, be converted back into electrical and thermal energy via a fuel cell.

Should the hydrogen be combined with the greenhouse gas CO_2 – which can either be gained directly from the atmosphere or from industrial processes such as the production of cement – methane and water are created. Methane can be used as a fuel for combustion engines and for the heating of buildings.

In the project "Catalytic methanation"[1], the process of methanation was significantly optimised through the use of an innovative sorption catalytic converter: CO_2 is almost fully converted here.

Both electrolysis and methanation are already applied in many areas. However, both processes also have crucial disadvantages. Methanation requires temperatures of between 300 °C and 700 °C, while electrolysis requires a high amount of energy.

Photocatalytic water splitting for the production of hydrogen promises substantial energy savings.[2] Investigations show that with an improved transparent photocathode based on copper oxide (Cu_2O), efficiency of more than 4 % can be achieved under natural sunlight.

With the help of HIT solar cells (HIT = heterojunction with intrinsic thin layer), efficiency of around 9 % is even possible. In the case of natural plant photosynthesis, the level of efficiency stands at just 1 %.

Notes and References

1 Project “Catalytic methanation”
2 Project “Photoelectrochemical water splitting”

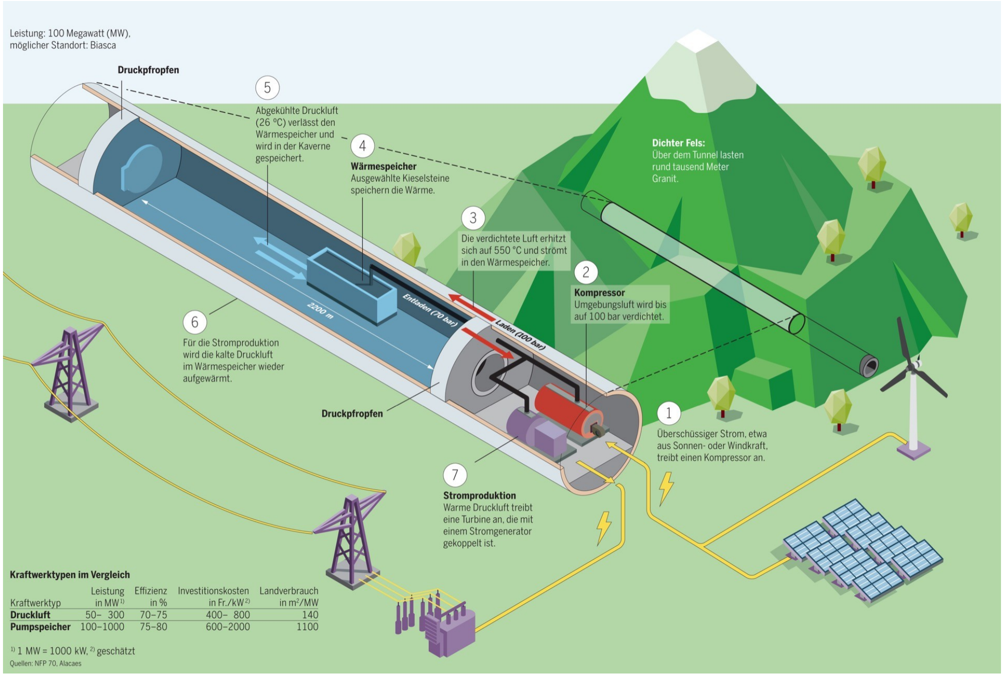
Energy storage

3.1.9. Electricity storage in mountains

An energy storage approach that has not been tested to date is adiabatic air compression[1]. The benefit it offers over pump storage facilities is that it achieves similarly high levels of efficiency without necessitating any impact on the landscape. A pilot plant in a redundant gravel tunnel of the Gotthard Base Tunnel demonstrates the fundamental feasibility of this process. A 120-metre-long tunnel section was clad with shotcrete and sealed at both ends with massive concrete plugs. By means of compression, air was fed into the tunnel with a pressure of up to 33 bar. The compression is adiabatic as the heat generated during the compression process is not released into the surrounding environment, but rather stored in a container filled with rubble and converted into electrical energy when the tunnel is unloaded. The compressed air is discharged via a turbine which drives a generator and produces electricity. A level of efficiency of 70 % to 75 % can thus be achieved.

Theoretical calculations show that around 500 MWh of electricity could be stored with air compression and a storage capacity of 50,000 m^3 – this equates to the electricity needs of the city of Lugano during a period of approximately 12 hours.

Illustration of a commercial adiabatic compressed air storage system



Kraftwerktyp	Leistung in MW 1)	Effizienz in %	Investitionskosten in Fr./kW 2)	Landverbrauch in m²/MW
Druckluft	50– 300	70–75	400– 800	140
Pumpspeicher	100–1000	75–80	600–2000	1100

Source: ALACAES SA Luganc

Notes and References

1 Project "Optimising compressed air storage"

Cold / heat

3.1.10. Many approaches for non-fossil-fuel heating

At our latitudes, around 80 % of the building stock's total energy consumption is accounted for by the provision of heating and warm water. If energy efficiency is to be increased and CO_2 emissions cut, measures are required here.

Gaining **heat from solar energy** is the oldest application of new renewable energies. At present, developments are heading in the direction of hybrid solar cells which produce both heat and electricity.

The generation of **heat from waste** also has a long history. For more than 80 years, excess heat generated from the waste incinerated at Switzerland's first refuse incineration plant has been fed into local district heating systems. However, there is still considerable potential when it comes to the generation of heat from municipal waste, a fact highlighted by the joint synthesis "Waste management to support the energy turnaround"[1].

The sourcing of **heat from the environment** has become a matter of course due to, in particular, the rapid spread of heat pumps in new buildings. In the project "Economics of multi-energy hub systems"[2], it was shown that heat pumps fed by both borehole heat exchangers and air play an important role in DMES. The joint project "Heat utilisation with solid sorption technology"[3] reveals how the profitability of heat pumps can be increased.

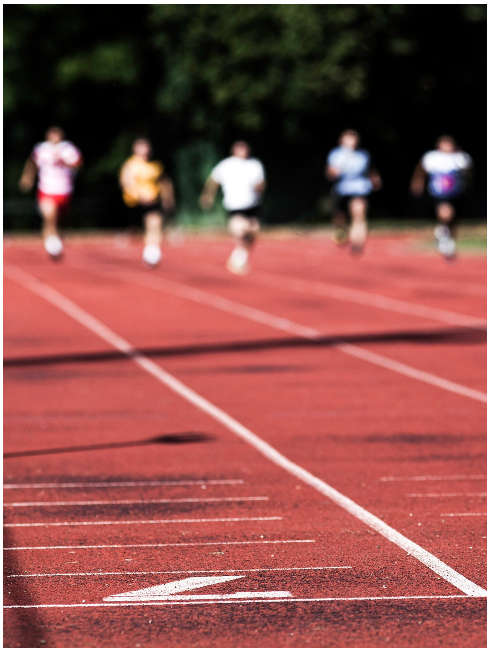
The gaining of **heat from the earth's crust** (deep-heat mining) is still in its infancy in Switzerland. Following the first demonstration projects in Basel and St. Gallen, which led to considerable ground shaking and damage to buildings, there is a great deal of hesitation in this field. The project "Deep-heat mining"[4] investigated this phenomenon and the suitability of various geological formations in Switzerland for deep-heat mining in detail. The research conducted as part of the project “Deep underground heat reservoirs”[5] revealed that there are numerous areas of potential in Switzerland for the sourcing of heat from deep sites that could be coupled economically with, for example, DMES.

Notes and References

1 Project “Waste management to support the energy turnaround”
2 Project “Economics of multi-energy hub systems”
3 Project “Heat utilisation with solid sorption technology”
4 Project “Deep-heat mining”
5 Project “Deep underground heat reservoirs”

Cold / heat # Wood

3.1.11. Getting closer to the goal with new technologies



In the NRP Energy, new technologies were also developed which provide effective support for the implementation of Energy Strategy 2050 in the area of buildings and settlements.

- The project “Technical evaluation of multi-energy hub systems”[1] makes statements on the suitability and improvement of fuel cells (CHP = combined heat and power units) and power-to-gas technologies for DMES. The attempts at improvement primarily aim to optimise investment and operating costs, the service life and thermal efficiency. The modelling of these components was also developed with a view to the simulation of various DMES configurations. These simulations have shown, for example, that while such technologies are more expensive than conventional solutions, their integration in the distribution network leads to a reduction in the energy system’s CO_2 emissions and can increase the resilience of the system without giving rise to significant changes to the network structure.
- The joint project “Heat generation with solid sorption technology”[2] dedicated itself to the further development of thermally driven adsorption heat pumps for the utilisation of waste heat and renewable heat sources (e.g. geothermal energy) for heating and cooling purposes, especially in computer centres. The research work focussed on the following:
  - The development and demonstration of high-performance adsorption materials
  - The development and demonstration of processing procedures
  - The integration of high-performance adsorption layers in heat pumps

  - Pilot applications with up to 10 kW cooling capacity

A structure for the assessment of the sustainability and costs of adsorption heat pumps was also developed.

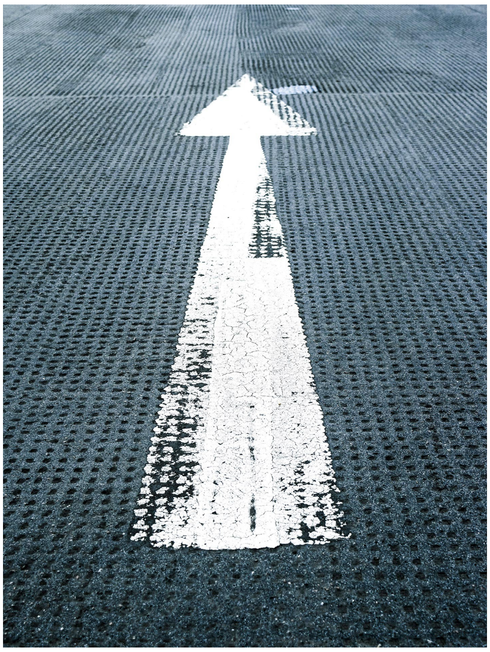
- In Switzerland, wood is an easily available, popular and renewable energy source. However, the burning of wood to generate heat causes considerable air pollution. The project “Minimising pollutants in wood combustion”[3] shows that automatic wood burning plants with high temperatures and an optimal air-to-fuel ratio emit up to 2,400 times less CO, NMVOC, eBC and POA than manually operated systems. Nevertheless, they require a suitable operating procedure.

Notes and References

1 Project “Technical evaluation of multi-energy hub systems”
2 Project “Heat utilisation with solid sorption technology”
3 Project “Minimising pollutants in wood combustion”

Sustainability # Incentives

3.1.12. Expansion of DMES: drivers



- **General interest in sustainability**: In Switzerland, there is currently great interest in the subject of sustainability. This is decisive for the implementation of DMES.[1]
- **Idealism of building owners**: Private real estate owners, in particular, are increasingly prepared to make energy-relevant investments with unusually lengthy amortisation periods or even with a slightly negative cash flow in both new buildings as well as when renovating existing properties. In general, the driver here is idealism.[2]
- **Participation**: If households, owners and companies are actively involved in the expansion of DMES as prosumers (producers and consumers of energy), this increases the level of potential and feasibility.[3]
- **Incentive systems**: Incentives systems of all kinds – public sector investment contributions, feed-in tariffs, tax deduction possibilities, subsidised mortgage loans, etc. – are strong drivers, especially in the case of homeowners.[4]

Notes and References

1 Rivas, J, Schmid, B & Seidl, I 2018, Energiegenossenschaften in der Schweiz. Ergebnisse einer Befragung. WSL-Berichte, Heft 71, WSL Birmensdorf
2 Project “Multi-energy hub systems and society”
3 Project “Multi-energy hub systems and society”
4 Project “Overcoming opposition to PV”

3.1.13. Expansion of DMES: obstacles

- **High level of system complexity**: New efficient plants and their linking to reliably functioning DMES are highly complex. The temptation to rely on proven systems is considerable. The high level of complexity is also difficult to convey to property owners, the authorities, planners and installers.[1]
- **Development of framework conditions**: In many respects, it is still uncertain how the framework conditions of Energy Strategy 2050 will develop. How will energy prices change? What subsidies, feed-in remuneration and incentive taxes can be expected? Will Switzerland conclude an electricity agreement with the EU? A study shows that open questions of this kind hinder the establishment of energy cooperatives.[2]
- **Uncertain economic viability**: The studies show that the economic development and operation of DMES with an acceptable amortisation period is currently only possible in very rare instances. Whether, how and when this will change depends on such a large number of factors that it is almost impossible to make confident predictions. Surveys show that economic viability is currently the main factor with respect to the use of DMES.[3]
- **Personal flexibility**: Many people no longer want to make lengthy commitments. For this reason, the level of willingness to make financial, geographic or organisational commitments over the long term is also tending to decline.[4]
- **Lack of a direct link**: Based on a survey, a study shows that responsibility for the implementation of the energy turnaround is currently primarily assigned to the Swiss Federal Office of Energy (SFOE), energy companies and the cantons.[5]

Notes and References

1 Project "Multi-energy hub systems"
2 Project "Collective financing of renewable energy"
3 Project "Multi-energy hub systems and society"
4 Project "Energy reduction potentials of elderly people's households"
5 Project "Multi-energy hub systems and society"

Information / communication

3.1.14. DMES: need for action

The research work conducted as part of the NRP Energy on “Decentralised multi-energy hub systems” revealed the following areas where action is needed:

- **Information**: In order to establish a broad basis for the acceptance and development of DMES, information on the subject needs to be spread proactively – among real estate owners, authorities, architects, engineers and installers[1]. Studies show that the concept of DMES already enjoys a good level of acceptance[2]; a bottom-up approach ensures that this acceptance and thus also participation will increase.

- **Framework conditions**: In order to eradicate the uncertainties of operators and investors, the future framework conditions for the energy turnaround must be defined as quickly as possible.[3] This was specified in the second set of measures of Energy Strategy 2050, which is to replace the current support and steering system. The future with respect to the calculation of water rates and the water rate maximum must also be clarified quickly.[4] Both the switch to a steering tax and the restructuring of water rates failed to find support in the Swiss parliament, however. The electricity agreement with the EU, which has been under negotiation since 2007 and would have defined Switzerland’s access to the European electricity market, also remains on the back burner. The longer that these framework conditions are not made mandatory, the more difficult it will become to achieve the objectives of Energy Strategy 2050 with respect to energy and CO_2 emissions in a timely manner.[5]

- **Energy renovations**: Heating energy consumption plays a key role in the energy requirements of buildings. The project “Multi-energy hub systems and society”[6] highlights that old, energy-inefficient buildings have such high heating energy requirements that they cannot be covered in an energy-efficient manner with a heat pump system. It is essential that these outdated buildings are therefore renovated to raise levels of energy efficiency – especially in urban areas. The current renovation rate of around 1.5 % will not suffice in order to bring the building stock up to an acceptable level with respect to energy efficiency in the medium term.

Notes and References

1 Project “Multi-energy hub systems”
2 Project “Multi-energy hub systems and society”
3 Project “Collective financing of renewable energy”
4
5 Project “Switzerland and EU energy policy”
6 Project “Multi-energy hub systems and society”

3.2. Building-integrated photovoltaics

Photovoltaic systems on roofs and facades are becoming ever more popular – in part because they are becoming increasingly affordable. However, in order to utilise the potential offered by this technology properly it will require more knowledge, new regulations – and innovation.

Photovoltaics

3.2.1. Boom thanks to a fall in prices, subsidies and a change in thinking

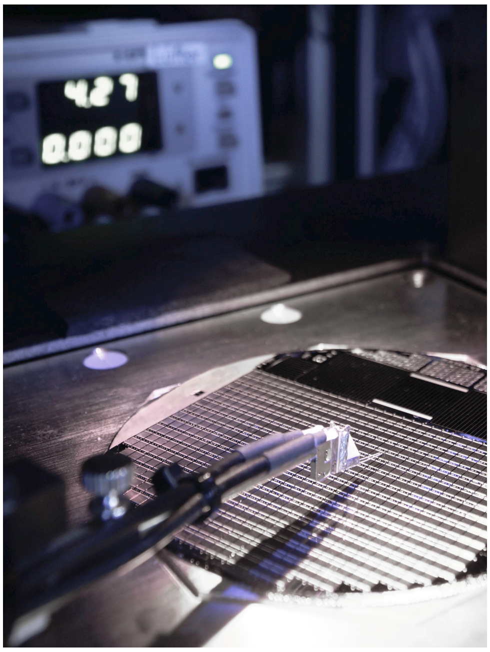
Average price per kWp of silicon solar cells for rooftop systems up to 10 kW_p. / Electricity from photovoltaics in GWh. *Source: German Solar Industry Association / SFOE, Swiss Overall Energy Statistics 2017*

Photovoltaics (PV) are enjoying an increasing level of popularity in Switzerland – following a relatively long start-up phase. Among other factors, this development can be attributed to the price of PV elements, which have fallen considerably in recent years due to fierce international competition and economies of scale. Alongside the fall in prices, generous subsidies and an increasing level of awareness as regards the energy problem have provided great impetus to the installation of PV systems.

A striking feature of this illustration is the marked increase in electricity from PV since 2011 as a result of the compensatory feed-in remuneration (KEV) introduced on 1 January 2009. In the five years from 2011 to 2016, the average annual increase was 233 GWh/a. However, in order to achieve the target value for 2050 of 11,100 GWh/a as set out in Energy Strategy 2050, an average increase of 287 GWh/a would be necessary. This does not seem impossible, but we must not let up – even though KEV expires in 2022.

Photovoltaics

3.2.2. Level of efficiency growing steadily



New record solar cell on a 100 mm wafer yielding approximately 500 concentrator solar cell devices. *Source: Fraunhofer ISE / Photo Alexander Wekkel*

The efficiency of solar cells is often deemed to be an important criterion when assessing the technology. At the outset of their development, an efficiency level of 5 % was viewed as being very good. Today, the efficiency levels of popular mass goods in Switzerland stands at between 16 % and 18 %, with the physically achievable maximum level of efficiency for silicon solar cells being around 29 %. There is thus still potential for improvement. Kaneka Corp., which is based in the Japanese city of Osaka, recently announced the development of a silicon solar cell with an efficiency level of 26.3 %; the Fraunhofer Institute for Solar Energy Systems in Freiburg has confirmed this figure.

Incidentally, this institute currently holds the world record: under laboratory conditions, an efficiency level of 46 % was achieved in 2019.[1] This figure was measured on a quadruple-junction solar cell for concentrating photovoltaics on the basis of II-V semiconductor compounds with a concentration ratio of 508 for the incident light. These, however, were theoretical results gained on very small samples that are still a long way from industrial production.

In parallel to this, new materials for solar cells are also being developed. Focus is placed on perovskites. These organometallic crystals are much cheaper than silicon. In a relatively short space of time, it was possible to increase the efficiency of perovskite solar cells from just a few percent to 22 %. As part of the NRP Energy, high-quality basic research was also conducted on perovskites in the projects “Novel generation perovskite devices”[2] and “Perovskites for solar energy"[3]. With tandem/perovskite solar cells, an efficiency level of 27 % to 30 % is expected. The main drawback of perovskites is their susceptibility to moisture and UV radiation. A great deal of research and development is still required until perovskite solar cells conquer the market.

Notes and References

1 Fraunhofer Institute for Solar Energy Systems in Freiburg ISE 2014; Press Release # 26, ISE. Freiburg
2 Project "Novel generation perovskite devices"
3 Project "Perovskites for solar energy"

Photovoltaics

3.2.3. Much research on promising improvements

Terra-cotta PV module as roof tiles. *Source: Project "ACTIVE INTERFACES - Holistic strategy for PV adapted solutions embracing the key technological issues."*

The fact that solar cells exhibit a high level of efficiency does not yet guarantee their market success. Decisive factors for their economic viability and environmental compatibility also include their service life, price, source materials and the heat and energy required during the manufacturing process. Intensive research was also conducted on these characteristics as part of the NRP Energy.

The project "Multi-junction solar cells"[1] chiefly focussed on the development of highly efficient tandem solar cells – perovskite directly on silicon – under better production conditions. Here, for example, it was possible for the first time to manufacture tandem solar cells with an efficiency level of more than 25 % (certified value: 25.2 %), whereby the temperatures for the perovskite remained under 150 °C.

In the project "Strategies for building-integrated PV"[2], focus was placed both on improving the appearance of PV modules and producing ultra-light solar modules. These are primarily intended for building-integrated photovoltaics on old buildings for which there is limited scope for the addition of extra weight. As part of the same project, a terra-cotta module for integrated roof systems was developed for architecturally sensitive buildings.

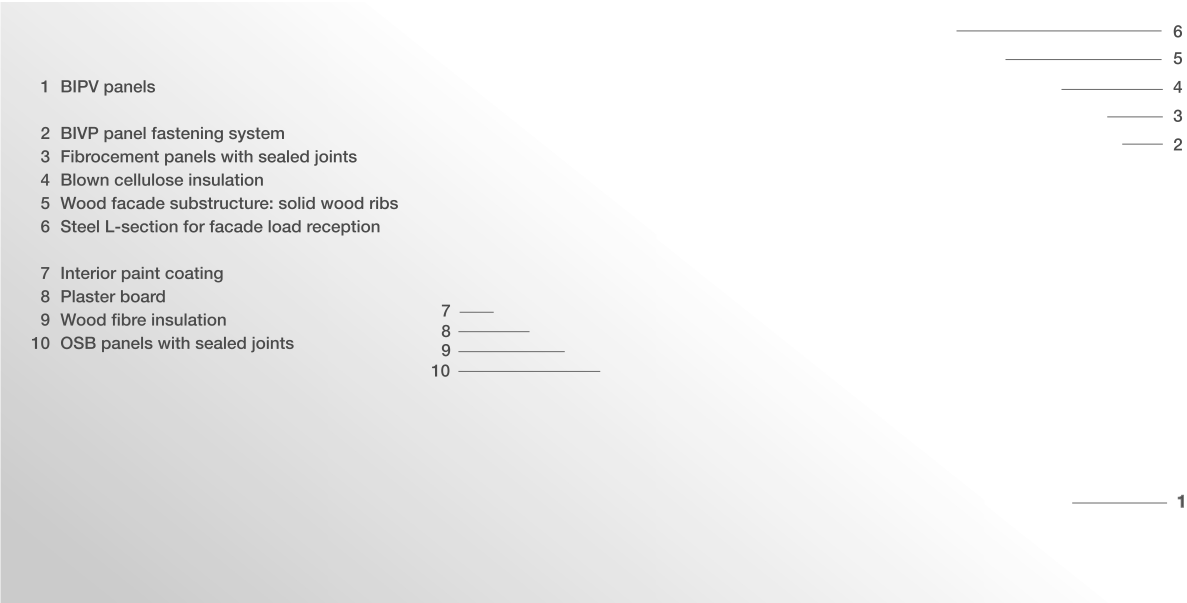
Notes and References

1 Project "Multi-junction solar cells"
2 Project "ACTIVE INTERFACES - Holistic strategy for PV adapted solutions embracing the

key technological issues."

Costs / benefits   # Photovoltaics

3.2.4. From the laboratory to the building site



Prefabricated facade system with building-integrated photovoltaics. *Source: Project “Highly efficient, integrated PV systems”*

While research is being conducted on the material properties of individual components of next generation solar cells, other researchers – such as those working as part of the project “Highly efficient, integrated PV systems”[1] – are already thinking about how these new technologies can make the leap to practical application. The starting point here is formed by the latest developments in the area of tandem/perovskite solar cells, whose long-term stability and service life are still raising questions. Using an innovative encapsulation method, the researchers were, however, able successfully to pass the steam/heat accelerated aging test for a four-inch tandem/perovskite solar cell in accordance with the EN 61215 standard[2].

On the basis of this innovative solar cell and 12 archetypal high-rise buildings, an integral prefabricated facade system (AAF Advanced Active Facade) was developed that comprises environmentally friendly thermal insulation materials, a wooden frame over the entire floor height, press boards with a fire-resistant layer on the interior as well as coloured or structured solar modules on the exterior.

A life-cycle analysis for the 12 archetypes with the new facade system revealed the following:

- The energy potential of the AAF facade with tandem/perovskite solar cells is a good ten times greater than grey energy bound in the facade.
- The total energy-saving potential relative to a conventional facade without PV is around 78 %.

- The AAF facade with tandem/perovskite solar cells costs around 33 % more than a conventional facade without PV.
- This additional price is, however, already amortised after around six years provided the property in question is a “zero-energy building”.

In the case of multi-family dwellings, the analyses also showed that conventional roof systems alone are not enough in order to achieve the objectives of Energy Strategy 2050. The building facade must become an energy provider.

Notes and References

1 Project “Highly efficient, integrated PV systems”
2 EN 61215:2006-02; terrestrial crystalline silicon photovoltaic modules – design qualification and type approval

Market # Behaviour # Photovoltaics

3.2.5. How does the market respond?

As part of the project “Overcoming opposition to PV”[1], a broad-based survey was conducted among homeowners facing a roof renovation. It revealed the following: some 43 % of those surveyed would never put a solar system on their roof; of the other 57 %, half would prefer a conventional, more cost-efficient system on their roof, while the other half would even be prepared to pay a premium of around 22 % for an integrated and aesthetically superior solution. This positive stance was confirmed by a survey in the project “Sustainability of PV systems”[2]. This revealed that the vast majority of the population and the authorities in German-speaking Switzerland welcome building-integrated photovoltaics (BiPV) and view them as being relatively risk-free. On a few occasions, the aesthetic impairment of the buildings and grey energy were cited as negative aspects.

Despite these figures, building-integrated photovoltaics (BiPV), in particular, are still having a hard time. According to the project “Accelerating PV applications”[3], the main reasons for this are as follows:

- Building owners, architects and engineers have too little knowledge when it comes to BiPV.
- BiPV are technically demanding and have to be included in plans at an early stage in a manner that incorporates all of the various disciplines.
- The additional costs of BiPV relative to conventional roof and facade constructions have a relatively long amortisation period.
- With respect to building renovations, BiPV have a particularly difficult time, as their use in old buildings is only worthwhile if a complete renovation of the building shell is pending.

Alongside these obstacles, however, there are also positive signs:

- The investment costs/kWp for silicon solar panels have reduced greatly in recent years.
- The construction of solar systems remains greatly subsidised for the time being and enjoys privileged tax treatment.
- The approval process has been simplified and self-produced electricity can be sold directly to third parties.

The end of compensatory feed-in remuneration in 2022 – in the absence of a follow-up programme – could also have an additional dampening effect.

Notes and References

1 Project "Overcoming opposition to PV"
2 Project "Sustainability of PV systems"
3 Project "Accelerating PV applications"

Sustainability # Steering / promotion # Photovoltaics

3.2.6. More BiPV: drivers

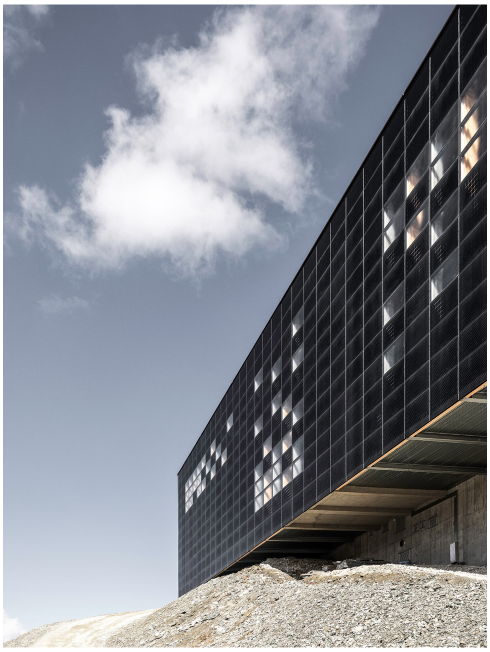
- **Energy requirements**: Due to aging and use, buildings require renovation on a periodic basis. Pitched roofing and windows have to be replaced after 30 to 50 years, while facades have to be replaced after 70 years. Renovation projects often provide an opportunity also to address the energy problem.[1]
- **Awareness of sustainability issues**: The increasing level of awareness in political, social and economic circles with respect to the finite nature of our resources and climate change is promoting long-term thinking and action, meaning that BiPV are also becoming more attractive.[2]
- **Steering tools**: A range of effective steering tools such as electricity tariffs with a bonus/penalty system or progressive CO_2 certificates for electricity from crude oil products would make BiPV more competitive.[3]

Notes and References

1 Project "PV and urban renewal"
2 Rivas, J, Schmid, B & Seidl, I 2018, Energiegenossenschaften in der Schweiz. Ergebnisse einer Befragung. WSL-Berichte, Heft 71, WSL Birmensdorf
3 Project "Energy efficiency in households"

Costs / benefits # Photovoltaics

3.2.7. More BiPV: obstacles



3S cableway station building facade. *Source: Zermatt Bergbahnen*

- **Lack of knowledge**: Building owners, architects and engineers have too little knowledge and experience when it comes to BiPV.[1]
- **Disciplinary planning**: Architects and engineers primarily think and plan within their disciplines. BiPV can, however, only be realised as part of very close interdisciplinary cooperation that needs to be initiated as part of initial design considerations.[2]
- **Uncertain economic viability**: Although the price of solar cells is continuing to fall, the economic viability of BiPV is still subject to a large degree of uncertainty. What is the service life of solar modules and what drop in performance can be expected? How will subsidies and remuneration for electricity fed into the grid develop?[3]

Notes and References

1 Project "Accelerating PV applications"
2 Project "Economics of multi-energy hub systems"
3 Project "Highly efficient, integrated PV systems"

3.2.8. BiPV: need for action

The research work conducted as part of the NRP Energy on “building-integrated photovoltaics” revealed the following areas where action is needed:

- **Education and training**: Of key importance for the rapid distribution of BiPV is the provision of professional education and training to architects, engineers and affected companies in the area of BiPV. [1]
- **Information**: Building owners need to be informed about BiPV as well as about the advantages and disadvantages they offer, technical innovations, attractive financing options and best-practice examples.[2]
- **Regulation**: Planning and construction legislation, related procedures and technical standardisation need to be made more open in order to ensure that BiPV and other technical innovations can be applied in a quick and uncomplicated manner.[3 4 5]
- **Reliable framework conditions**: Investments in energy-efficiency and new renewable energy must be calculable and are thus dependent on reliable framework conditions. These include, for example, the feed-in remuneration of plants, public subsidies, tax advantages and opportunities for recourse under construction law.[6 7] There is additional need for action in this regard due to the major differences between the cantons.

Notes and References

1 Project “Accelerating PV applications”
2 Project “Accelerating PV applications”
3
4 Project “Standards for photovoltaics”

5 Project “Energyscapes”
6 Project “Highly efficient, integrated PV systems”
7 Project “Economics of multi-energy hub systems”

3.3. The behaviour of building users

We all live and work in buildings. Our individual behaviour can make an enormous contribution to the achievement of the objectives specified under Energy Strategy 2050 – through the efficient use of devices, by leading a sufficient lifestyle and by utilising the benefits of digitalisation.

Standard of living # Behaviour

3.3.1. Living standards determine energy requirements

In 2017, Switzerland's average living space used per person stood at 46 m^2. This equated to 29 m^2 for one-room apartments, 42 m^2 for three-room apartments and 59 m^2 for apartments with six rooms or more.[1] This shows that large apartments are not primarily occupied by families with a large number of children, but rather by people with a higher living standard.

In offices, the spatial requirements per workstation range between 6 m^2 und 25 m^2 (main usable area). This does not take account of management offices. The City of Zurich, for example, aims for an average of 12.5 m^2 per workstation. At the workplace too, the rule still applies that those who have something to say need more space to perform their work.

It is, however, not only the number of square metres occupied that determines energy consumption for heating and cooling or warm water, for instance. With the increasing amount of living space used per person, energy requirements for all kinds of devices are also rising: refrigerators and freezers are bigger, ovens are supplemented with a steamer and microwave, while dishwashers, washing machines and tumble driers complete several cycles a day.

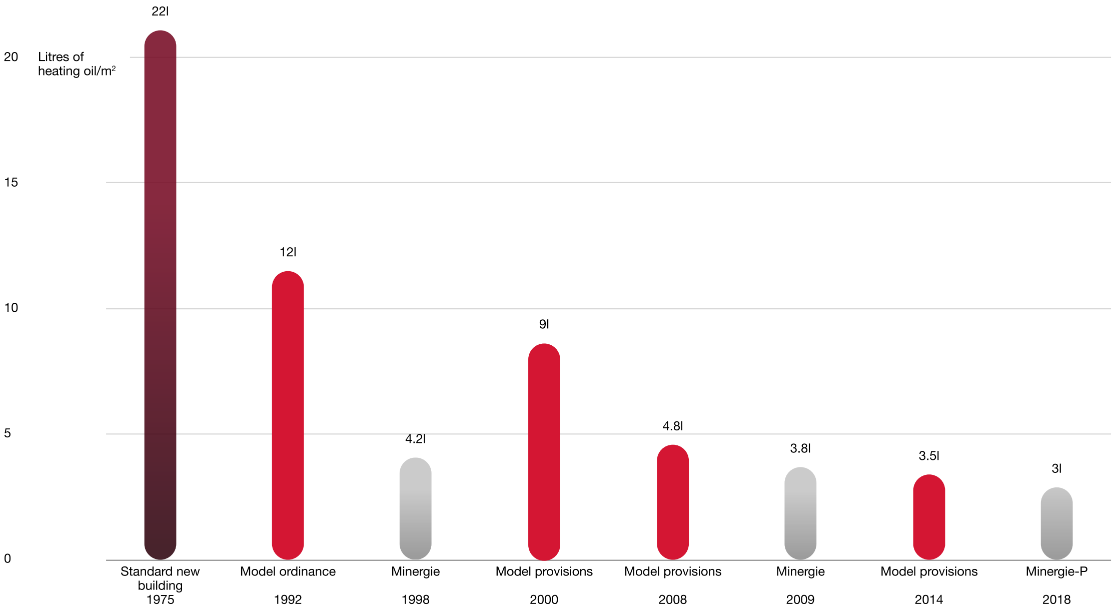
The situation is the same at the workplace: managers need more than one screen and require their own colour printer and scanner, two or even three mobile phones, a fully automated coffee machine, a refrigerator and much more. All of these small energy guzzlers together give rise to enormous primary and grey energy requirements in buildings and settlements.

Notes and References

1 Federal Statistical Office 2018; Buildings and Dwellings Statistics

Energy efficiency

3.3.2. More energy-efficient buildings not always preferred



Reduction of heating requirements for new buildings (heating and warm water) in the last 40 years. *Source: TEC21 31-32-33/2018*

New buildings consume considerably less energy than properties that were constructed before 1990. One reason for this is the continuous tightening of restrictions with respect to the energy consumption of buildings, including the model provisions of the cantons in the energy sector (MuKEn), cantonal energy legislation and the applicable standards of the Swiss Society of Engineers and Architects (SIA).

If the current renovation rate in Switzerland cannot be increased markedly from around 1.5 % per year, it will take many decades for all buildings with low levels of energy efficiency to be renovated. Owner-occupiers can determine the time and scope of an energy renovation themselves. In contrast, renters only have the option of moving into a more energy-efficient building.

As part of the project “Sustainable lifestyles and energy consumption”[1], around 3,500 apartment tenants in Lucerne were asked whether they had already seriously considered moving into a more energy-efficient building. Some 46.5 % of the 1,295 respondents indicated that they had never contemplated moving into an energy-efficient property, while 31 % had thought about taking this step and 11.9 % had actually opted for an energy-efficient building the last time they changed apartment – another 10.3 % had already been living in such a property for some time.[2]

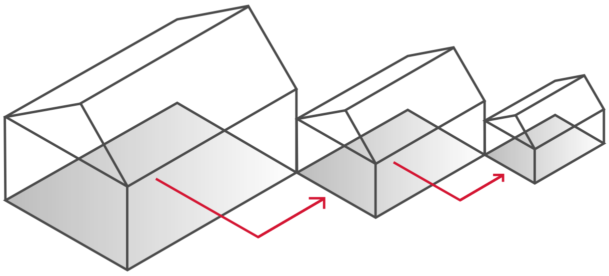
The study also analysed the decision-making behaviour of the respondents. Alongside social values and personal emotions, the decision to move into an energy-efficient building was primarily influenced by their individual room for manoeuvre, i.e. their ability actually to undertake such a move from a financial and other perspectives.

Notes and References

1 Project “Sustainable lifestyles and energy consumption”
2 Schaffner D., Ohnmacht T., Weibel Ch., Mahrer M. 2017; Moving into energy-efficient homes: A dynamic approach to understanding residents decision-making. Building and Environment 123, Elsevier Ltd.

Building # Sufficiency

3.3.3. Sufficiency is possible



Energy specialists declare time and again that the transformation of our energy system will only succeed if it does not lead to a loss of comfort or restrictions to personal freedom. However, implementing a transition under these conditions has its price – and requires a great deal of time. It is doubtful whether the required amounts of time and money are available. In other words, in the complete absence of sacrifice and restrictions the energy and climate goals will not be achieved in good time. The concept of sufficiency means only using as much as you really need. Experience with this concept has shown that going without unnecessary things can lead to satisfaction and does not therefore have to be viewed negatively.

The biggest influence on sufficiency in connection with buildings and settlements is the reduction of space consumption. For example, families can take action when their children leave the family home and rooms are no longer permanently used. The project “Energy reduction potential of elderly people’s households”[1] looked at this subject. It was shown that the space consumption of older people is considerably higher than that of younger people – and that the willingness of elderly individuals to move into a smaller apartment with lower energy consumption is relatively small. Surveys show that this fact is not primarily because people generally require or desire more living space. Instead, this situation can be attributed to strong ties to their current living environment, difficulties in handling the ageing process and financial uncertainties relating to a change of home.

The solutions highlighted in the study focus on information, advice and motivation. Top priority is not given to financial incentives, but rather to appealing to immaterial values such as environmental protection and social responsibility.

Notes and References

1 Project “Energy reduction potentials of elderly people’s households”

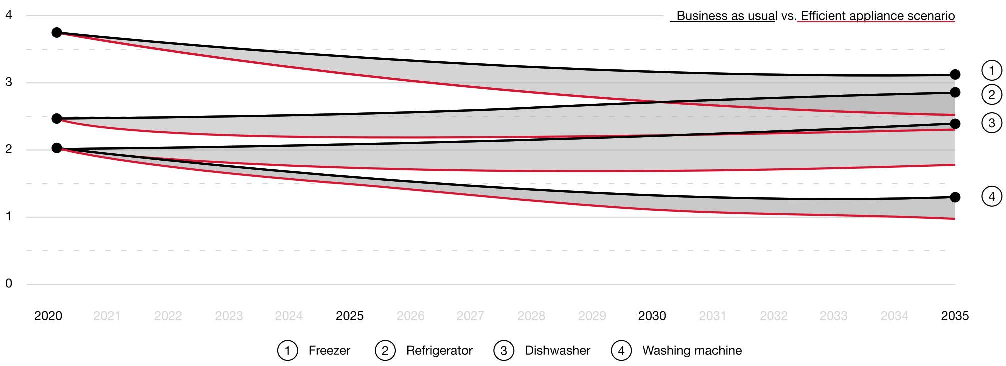
Energy efficiency # Behaviour

3.3.4. Use appliances more efficiently

Radiator with thermostat in a Zurich apartment. *Source: Christian Beutler Keystone*

Consumer behaviour has an enormous impact on energy efficiency. The targeted purchasing of products based on goods declarations such as the energy label for household appliances and the ENERGY STAR label for energy-saving IT is already widespread. The project “Energy efficiency in households”[1] shows, however, that the hope for ever more energy-efficient household appliances is not enough. Model calculations reveal that, for example, energy consumption across Switzerland for washing machines and dishwashers will only fall slightly by 2035. This is because, although the individual appliances are likely to become more energy efficient, this effect will largely be offset by the higher number of appliances.

Future electricity requirements of household appliances for the scenarios “Business as usual” and “Label class A+++”.



Source: Project "Energy efficiency in households'

For household appliances, it thus follows that in addition to further technical innovations, additional efforts at a behavioural level are also required, for example with a view to more efficient use.

No less important are sufficiency-driven approaches such as sharing, using things over a longer period and purchasing second-hand products. What all three approaches have in common is that they do not primarily save end energy, but rather chiefly serve to reduce grey energy. After all, it is highly unlikely that a borrowed drilling machine will be used less solely because it belongs to somebody else.

In the project "Sustainable lifestyles and energy consumption"[2], the extended use of mobile phones until they ceased to function was investigated as an example for the "longer use" approach. Here, it was shown that around half of the respondents first purchase a new mobile phone when their old device stops working in any case, while approximately a quarter replace their mobile phone well before the end of its service life.[3] Here too, individual room for manoeuvre, personal values and emotions are the key drivers in bringing about more environmentally friendly consumer behaviour.

Notes and References

1 Project "Energy efficiency in households"
2 Project "Sustainable lifestyles and energy consumption"
3 Ohnmacht T., Thao V. T., Schaffner D., Weibel Ch. 2018; How to postpone purchases of a new mobile phone? Pointers for interventions based on socio-psychological factors and a phase model. Journal of Cleaner Production 200, Elsevier Ltd

Digitalisation   # Behaviour

3.3.5. Save energy intelligently

The digitalisation of buildings, which creates so-called smart homes, can contribute to energy savings. Here, it is not only about ensuring that lights are turned off in your apartment by using a GPS-based app to recognise that you have left the building. The project “Behavioural mechanisms of household electricity consumption”[1] looked at the question of what impact the installation of smart meters has on the electricity consumption of private households. Around 1,000 private households were given a mobile app. They were divided into five groups which received different information on their electricity consumption as well as different advice and incentives to save. The following findings were identified:

- Private households that received detailed information about the key energy consumers such as their cooking stove, refrigerator and washing machine saved considerably more electricity than users who only knew the energy consumption of their household.
- The provision of individual advice on saving electricity in specific households had a major impact on reducing electricity consumption.
- Short-term incentives do not have any major impact.

The study shows that the use of smart meters in private households leads to electricity savings of between 5 % and 10 % – provided that electricity consumption is communicated according to the individual appliances and lighting devices and the users are informed on a situation-specific basis about the purpose and potential of electricity savings. This savings potential is significantly above the savings of 2 % to 3 % that can be demonstrated through the use of a conventional meter with a display of the aggregate power consumption.

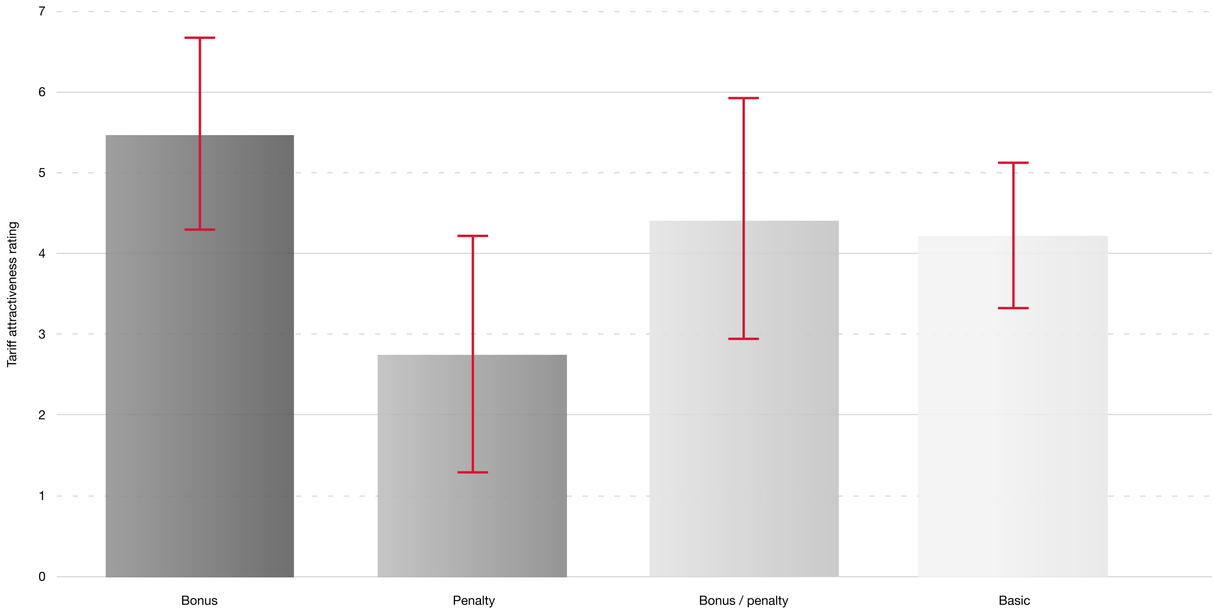
If the revision of the Electricity Supply Ordinance (ESO), which has already been initiated at a political level, comes into force as planned, the pressure on energy suppliers and building owners to introduce smart meters across the board will increase greatly – according to Art. 31e of the ESO, 80 % of measurement points must be covered by the distribution system operators with smart meters by the end of 2027.

Notes and References

1 Project "Behavioural mechanisms of household electricity consumption"

Tariff # Incentives

3.3.6. Those who save are rewarded



Reduction of heating requirements for new buildings (heating and warm water) in the last 40 years. *Source: Project "Energy efficiency in households'*

Incentive systems have a long tradition in Switzerland: subsidies and tax breaks are in place, for example, for agriculture, the SBB, hydropower plants and building renovations. The benefits, costs and possible disadvantages of new incentive systems need to be weighed up carefully within this jungle.

The project "Energy efficiency in households"[1] investigated two tariff models for the procurement of electricity in households:

- Tariff bonuses upon achieving an electricity-saving objective
- Progressive electricity tariffs in the form of a penalty system

It was shown that both tariff models lead to substantial electricity savings. The disincentives were slightly more effective than the positive incentives. A survey revealed, however, that bonus solutions are more popular than progressive tariff models which punish high electricity consumption.

The dilemma between the effectiveness and acceptance of new tariff models could be resolved with a combined bonus/penalty tariff, at least in the case of certain consumer groups. Of key importance to the success of such consumption-steering tariff models is that consumers have certain choices. The studies also show that the introduction of new tariff models is a very demanding process and is linked to a great deal of uncertainty; they must therefore be planned and communicated carefully.

Notes and References

1 Project "Energy efficiency in households"

Bonus / penalty   # Sustainability

3.3.7. Higher energy efficiency thanks to behavioural changes: drivers

- **Bonus/penalty energy tariffs**: An intelligent combination of incentives and disincentives for energy tariffs has a major impact on the energy-saving behaviour of building users who are usually charged directly for their individual energy consumption.[1]
- **Knowledge and understanding**: If building users know and understand the energy system as well as their personal options, potential influences and the economic consequences of their actions, they tend to be prepared to make efforts to save energy – even if this is tied to a certain loss of comfort and additional costs.[2]
- **Enhancing awareness of sustainability**: Subjects such as resource scarcity, global warming and air pollution are currently very present. The growing awareness of sustainability, particularly among young people, is increasing willingness to implement measures.[3]

Notes and References

1 Project “Energy efficiency in households”
2 Project “Energy efficiency in households”
3 Rivas, J, Schmid, B & Seidl, I 2018, Energiegenossenschaften in der Schweiz. Ergebnisse einer Befragung. WSL-Berichte, Heft 71, WSL Birmensdorf

Costs / benefits   # Population

3.3.8. Higher energy efficiency thanks to behavioural changes: obstacles

- **Building users ≠ Building owners**: Very few building users own the properties they use, irrespective of whether this is living space or work areas. This limits their willingness and opportunities to implement greater energy efficiency.[1]
- **Uncertain economic viability**: It is difficult to quantify how economically viable energy-saving measures are – and this is an obstacle to their widespread implementation. The hope of lower prices due to future economies of scale means many would prefer to wait.[2]
- **Ageing population**: The share of the overall population accounted for by the elderly is growing quickly, a development that is having a rather dampening effect on the speed of social development. The implementation of energy-saving measures in private households and business is tending to slow.[3]

Notes and References

1 Project “Energy efficiency in households”
2 Project “Energy efficiency in households”
3 Project “Energy reduction potentials of elderly people’s households”

Digitalisation # Tariff

3.3.9. The behaviour of building users: need for action

The research work conducted as part of the NRP Energy on the "behaviour of building users" revealed the following areas where action is needed:

- **New tariff models**: For the procurement of energy – electricity, heating and cooling, gas, etc. – new tariff models are required that differ from traditional, volume-independent uniform tariffs: they must reward building users financially for saving energy and make energy wastage more expensive.[1]
- **Knowledge transfer**: More and, above all, easier-to-understand information is required to ensure that all current and future building users understand the energy system and know what the relevant energy-saving levers are both at home and at the workplace.[2, 3]
- **Smart metering**: The comprehensive installation of smart meters must be promoted and accelerated. Building users need to know when and why they are using how much of which energy.[4] Only this knowledge allows them to identify potential for savings and to plan and implement the relevant and financially affordable measures for saving energy in their personal environment. The initiative for the installation of smart meters can come from the building owner or the energy supplier.

Notes and References

1 Project "Energy efficiency in households"
2 Project "Energy efficiency in households"
3 Project "Behavioural mechanisms of household electricity consumption"

4 Project "Behavioural mechanisms of household electricity consumption"

4. Nine recommendations for the future

The subject of “buildings and settlements” affects a wide range of stakeholders – these actually include everyone involved in the energy system, namely the overall population, all businesses, energy providers, professional associations, public administrative bodies and politicians.

However, the following recommendations are aimed at those stakeholders who could exert a direct influence on the future shaping of energy provision and the energy consumption of Switzerland’s building stock. In particular, these include the following:

- Building users (private households and businesses)
- Building owners
- Energy suppliers
- Politicians (federal government, cantons, municipalities)
- Associations

Furthermore, recommendations have primarily been formulated that can be derived from the research work conducted in the NRP Energy as well as the areas identified in which action is required. The recommendations are also relevant with respect to the transformation of our energy system.

Behaviour # Households # Businesses

4.1. Building users control their own energy use!

Building users know their energy consumption and use existing opportunities to save energy.

The members of private households and the employees of businesses know the energy requirements of individual energy consumers – they know, for example, how much energy is used for heating, warm water, household appliances, IT, consumer electronics and lighting. In new buildings, they utilise the more commonly available options for managing and controlling their energy use. These include central on/off switches, the maximum utilisation of daylight, individually controllable shading devices, the thermal storage capacity of walls and floors, the room-specific regulation of the ambient temperature, options for night cooling, the installation of smart meters and the sacrificing of a fireplace. When moving property, the building users look to see if these conditions are met at the new location. In addition to this, the building users exclusively use energy-saving household, audio-visual, communication and IT appliances. Overall, the systematically implemented individual measures make a significant contribution to reducing energy consumption and thus occupancy costs.

Investment   # Building owners

4.2. Strategically position the optimisation of energy efficiency!

Building owners integrate the energy optimisation of their property portfolio as a central pillar of the real estate strategy. All building maintenance measures are also assessed with a view to energy efficiency and CO_2 emissions.

Building owners develop a long-term strategy for optimising the energy efficiency of the building stock. The objectives of the strategy include achieving a substantial improvement in terms of energy efficiency, eliminating CO_2 emissions, ensuring cost-effective operations and preserving the value of the building stock. For the financing of the investments derived on this basis, a long-term financial plan is drawn up and the supply of funds for the maintenance fund is adjusted. The implementation of this strategy is monitored on an ongoing basis, with the strategy itself being reviewed and updated periodically.

Participation # Investment # Building owners

4.3. Involve users in renovation projects at an early stage!

If users are informed in good time about upcoming renovation projects, they tend to be willing to accept the associated inconveniences. Building owners thus save time and money.

Building renovation projects lead to temporary restrictions for building users and, in some cases, also give rise to additional costs. Nevertheless, in order to create understanding among users with respect to energy optimisation measures and motivate them accordingly, they have to be informed about the planning and preparations at an early stage. Often, renovation stages can be divided up spatially and in terms of time in a way that allows for the legitimate concerns of users to be taken into account in a cost-neutral manner. It is therefore advisable to form a special working group for such renovation plans already during the strategic planning stage.

Digitalisation   # Tariff   # Energy suppliers

4.4. Save energy with attractive tariff models and reduce costs!

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Dynamic tariff models with attractive incentives contribute to reducing energy consumption and energy costs.

Today's tariffs for electricity consumption with a set high and low tariff and fixed grid usage fees are not in line with the current and future energy world. The situation is slightly better for gas prices, which in many areas have a consumption-dependent, progressive basic fee but a fixed subscription fee. In future, attractive tariff models for the various energy sources are required that are stimulated by cost-neutral incentives, for example in the form of progressive tariffs or a combined bonus/penalty system. The target value and the bonus or penalty are agreed between the local energy supplier and the energy consumers. Supply-dependent tariffs represent a further approach: low tariffs when there is a high energy supply and high tariffs when there are shortages. To enable energy consumers to make maximum use of the benefits offered by such supply-dependent tariff models, load management must be automated. This requires the use of smart meters.

Digitalisation # Tariff # Energy suppliers

4.5. Initiate decentralised multi-energy hub systems!

Decentralised multi-energy hub systems support local energy provision, the interplay between various energy sources and the assumption of individual responsibility by energy buyers. Here, a key role is played by the local energy supplier.

On their own initiative, energy suppliers identify perimeters within their sphere of influence that are suitable for the use of decentralised multi-energy hub systems (DMES) and produce for each of them a DMES concept as well as a technical, environmental and financial feasibility study. In the case of a positive result, the energy supplier notifies the local municipal authorities as well as the building owners and initiates the next steps: it informs the population, establishes an energy cooperative and initiates the required approval processes. The energy supplier remains co-owner of the DMES and takes on responsibility for its operation.

Associations and NGOs

4.6. Coordinate specialist further training!

The know-how of the energy, construction and real estate experts with respect to the future energy system needs to be improved. This will not require any new instruments, but rather the focussing and coordination of the current programmes for further training.

In Switzerland, there is already an enormous range of energy-relevant further training opportunities. These are mostly offered by professional organisations and specialist associations but differ in terms of their quality and are poorly coordinated. Pressing further training topics include new energy-relevant materials, products and technologies, especially in connection with decentralised multi-energy hub systems and building-integrated photovoltaics. A professional organisation, for example the Swiss Society of Engineers and Architects (SIA), should take the initiative to streamline the uncontrolled development of further training. They should coordinate, and ensure the transparency of, individual programmes, training goals, course content, conditions of participation and final certificates. The federal government should assume patronage and cover the costs of this coordination.

Regulation # Politics (federal government, canton, municipality)

4.7. Create reliable framework conditions!

In order to calculate investments in energy efficiency and new renewable energy sources, all stakeholders are reliant on predictable and reliable framework conditions.

The Federal Council and the Federal Assembly can go some way towards bringing about reliable framework conditions, for example through the clarification of the relationship between Switzerland and Europe and the associated continuation of bilateral agreements, the quick conclusion of an electricity agreement, the introduction of attractive steering measures, the dynamic handling of water rates, the clarification of imputed rental value taxation and the associated tax breaks, or a partial relaxation of the Federal Act on Spatial Planning and so on. As long as there are serious uncertainties in these areas, energy providers and building owners will be very reluctant to invest in new renewable energies or energy efficiency; this raises the question of whether the objectives of Energy Strategy 2050 can be achieved. In this critical situation, the Federal Council should show greater leadership and both chambers should put managing Switzerland's future over individual interests.

Regulation # Politics (federal government, canton, municipality)

4.8. Focus and simplify regulation!

Regulation with laws, ordinances and standards provides a strong lever for achieving the objectives of Energy Strategy 2050. It is not more rules that are required, but rather more effective and easier-to-understand regulations.

The energy-relevant regulations that were formulated in a different context are no longer adequate for the current requirements and opportunities. The cantons therefore need to focus their planning, construction and energy-related legislation on the quick and economic implementation of Energy Strategy 2050 and to simplify the authorisation and approval procedures. The next revision of the model provisions of the cantons in the energy sector (MuKEn) and their systematic implementation is of particular significance. The MuKEn should focus on a few clearly defined and understandable target values.

Public administration # Politics (federal government, canton, municipality)

4.9. Inform and inspire the next generation!

If the phasing out of nuclear and fossil energy is to succeed, the next generation needs to be informed and inspired.

Young people are demonstrating around the world for a liveable world without global warming. They are often accused of doing so without in-depth knowledge of the causes and related factors. They therefore need to be provided with this knowledge. To this end, cantons and municipalities should provide an attractive teaching block on energy and climate issues for school pupils.