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Federal Energy Research Commission CORE

Federal Energy Research Masterplan 2013–2016

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Vision

The Federal Energy Research Masterplan is based on the following vision developed by the Federal Energy Research Commission (CORE) and shared by the research community in Switzerland:

Swiss energy research plays an important role in achieving efficient and low-emission energy conversion, storage, generation and use. It helps to ensure that energy supply is economical, ecological and secure, both nationally and internationally. It also contributes to an effective energy policy.

Research to support energy policy

The Federal Energy Research Masterplan is both a vision shared within the Swiss research community and a planning tool for federal funding bodies. It is also intended as a guide for cantonal and communal authorities who are familiar with implementing energy policy requirements or have their own funding tools for energy research.

CORE
The Commission fédérale pour la recherche énergétique (CORE) was set up by the Federal Council in 1986 as an advisory body for energy research. It develops the Federal Energy Research Masterplan every four years, monitors and supports Swiss energy research programmes, comments on other public energy research activities by the federal government and provides appropriate information concerning findings and developments in the area of energy research. CORE has 15 members, representing the fields of industry, science and politics. A list of the current members can be found at www.energieforschung.ch.

This Energy Research Masterplan applies to the period 2013–2016. It was developed by CORE in consultation with major stakeholders in Swiss energy research and is based on up-to-date international scientific findings.

Background to energy policy
In 2008, Swiss **climate policy** set the goal of reducing domestic carbon emissions to 80 % of 1990 levels by 2020. The Federal Council's "New Energy Policy" also envisages phasing out nuclear power once existing nuclear power stations reach the end of their lifespan. Federal energy policy is based on the following four key areas:

Energy efficiency: The most important measure in ensuring energy supply in future is to reduce energy use.

Renewable energy: Hydropower should continue to be the main source of domestic renewable energy, and should be moderately expanded. The proportion of other renewable energies in the energy mix should be increased.

Large power stations: From 2020 some major power stations will be disconnected from the grid. In order to cover energy requirements after this date, Switzerland needs either to build new conventional large power stations, import more power or install a large number of smaller combined heat and power (CHP) installations.

Foreign energy policy: One of the key focuses of the energy strategy is to improve international cooperation, in particular with the EU.

The Federal Council's **new energy strategy** defines five fields of action in which energy research can be improved: efficiency technologies; energy systems; grids and electricity transmission; energy storage; electricity provision; socio-economic and legal aspects. The Federal Energy Research Masterplan covers these fields of action, but goes beyond the field of electricity alone. CORE stresses that increased funding for research in these fields of action should not be to the detriment of energy research in areas which are not directly related to the new energy policy, such as research into combustion techniques or areas such as Living and Working or Mobility. The objectives set out in the Federal Energy Research Masterplan therefore also retain their validity in the Federal Council's new energy policy.

In addition, the **Swiss Cleantech Masterplan**[1] formulates objectives, action areas and measures to increase Switzerland's competitiveness in resource efficiency and renewable energies.

Until 2020, the **European Union** will be pursuing the so-called **20/20/20 strategy:** 20 % carbon reduction, 20 % renewables as a proportion of total EU energy requirements, and a 20 % reduction in consumption compared to 1990.

[1] *www.cleantech.admin.ch*

Scientific Background

The **IPCC (Intergovernmental Panel on Climate Change)** is calling for a 50 to 85 % reduction in carbon emissions compared with 2000-levels by 2050, if global warming is to be limited to 2–2.4 °C.[1]

The International Energy Agency IEA has drawn up a range of scenarios for how CO_2 emissions may develop.[2] The baseline scenario assumes that no new measures will be introduced by the state. In such a case, primary energy use would rise by 83 % between 2011 and 2050 and CO_2 emissions would double.

The **BLUE Map scenario** envisages a 50 % reduction in CO_2 emissions compared with 2005 levels. Diagram 1 shows existing and new low-carbon technologies which could contribute to achieving this goal.

CORE already formulated guideline objectives for 2050 in the Energy Research Project 2008–2011:

- Eliminate use of fossil fuels to heat buildings (old and new buildings)
- Reduce energy consumption in buildings. Current primary energy use: 500 PJ
- At least treble the use of biomass as an energy source. Current use: 37 PJ
- Reduce average fossil fuel consumption of cars to 3 l per 100 km. Current consumption: 7.6 l per 100 km.

In drawing up these guidelines, CORE assumed that there could still be a 60 % rise in energy requirements by 2050 – for example in distances travelled, living space and goods production.

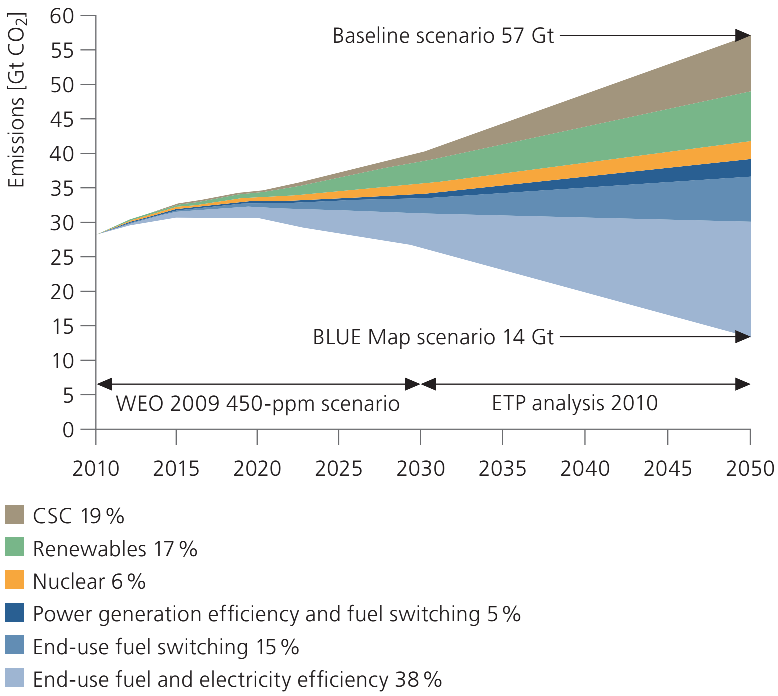


Diagram 1: Key technologies for reducing carbon emissions under the IEA BLUE Map scenario.
(IEA Energy Technology Perspectives 2010)

[1] *WEO: World Energy Outlook, www.iea.org*
[2] *ETP: Energy Technology Perspectives 2010, www.iea.org*

In Switzerland, two rather different visions occupy centre stage in the discussions, although they were both developed in the ETH Domain.[1] The main focus of the *2000-Watt Society* is energy efficiency. This concept calls for global primary energy use to be reduced to a level equivalent to a continuous consumption of 2000 watts per person by 2100. In 2010, average energy consumption in Switzerland was 6500 watts per person. The second idea, the *One-Tonne-CO_2 Society,* tolerates greater energy demand so long as this is met by renewables. The main aim is to keep long-term carbon emissions per capita and year below one tonne.

A comparison between these two visions in diagram 2 shows that both scenarios would lead to comparable reduction patterns in coming years.

Based on these two scenarios, the ETH Board has proposed the following goals for the second half of the century:

- Primary energy requirements for Switzerland are cut by a factor of two to three.
- CO_2 emissions are reduced to one tonne per person and year.
- Pollutant emissions and waste do not cause damage to humans and the environment.
- Energy generation material flows are considerably smaller than today, and in particular, material cycles are closed.

In order to reduce energy consumption in this way, the field of energy research wants to adopt two different approaches in the near future. Firstly, energy must be used more efficiently to reduce primary energy requirements, and secondly, the use of finite supplies of fossil fuels must be supplanted by renewable energy or other carbon-free energy sources in order to reduce greenhouse gas emissions (decarbonisation).

In the long-term, the two visions – 2000-Watt and One-Tonne-CO_2 – are very different. Each may lead to specific technologies being accepted or rejected.

Diagram 2: Different ways of reducing primary energy requirements and CO_2 emissions: the vision of a 2000-Watt Society (PSI, CCEM, Novatlantis) and of a One-Tonne-CO_2 Society (ETH Zurich).

Reduction patterns in these two models will be similar in the immediate future. By 2050 the differences will become clear: The efficiency strategy will lead to carbon emissions of about 2 t and energy requirements of 3 kW, whilst the decarbonisation strategy will lead to a reduction in carbon emissions of 3 to 4 t with primary energy requirements of 4 to 5.5 kW.

At the end of the century both strategies will lead to emissions of one tonne CO_2, albeit with different energy requirements.

[1] *ETH Board factsheet April 2009: "Auf dem Weg zu Energiesystemen von morgen"*

The decarbonisation strategy, for example, involves technologies such as carbon caputre and storage or recycling. It should become clear by the middle of this century which of these paths will be most effective.

Knowledge and technology transfer

Knowledge and technology transfer from higher education institutions to industry is of particular importance, as it allows research findings to be translated directly into added value in the market. Switzerland has considerable potential in this field compared with other countries, as diagram 3 shows.

Pilot and demonstration (P+D) installations should be planned early on in conjunction with industry. These can demonstrate if an innovation is technically viable and if it can be feasibly applied on a large scale. Without this type of support, private investors cannot be found, as the risks involved would otherwise be too great.

Knowledge also has to be passed on and applied. The training of **specialists in science and technology** plays a major role here. In particular, the state must ensure that enough specialists capable of setting up such P+D installations are available.

Social science

Socio-economic research has three important tasks in this seventh Energy Research Masterplan. Firstly, it should investigate human behaviour and the way markets function for each of the research focus areas. This will create a better understanding of what motivates the different players and what influence specific energy policy instruments have. Secondly, socio-economic research can establish the relationship between the different research focus areas and establish their relative potential and cost. The focus areas share both economic and social aspects. In the long term, efficient solutions must be applied across sectors. Thirdly, socio-economic research has the task of analysing general political, economic and social conditions and their effects, independent of the individual research focus areas. Research which gives us a better understanding of how market players behave and how different markets interact is essential. For example, general economic models are an important tool in assessing the economic effects of possible energy scenarios. In carrying out these three tasks, socio-economic research can play an important role in achieving the energy vision. By posing specific questions, we can increase our understanding of how models, experiment design, estimation methods and data can be improved.

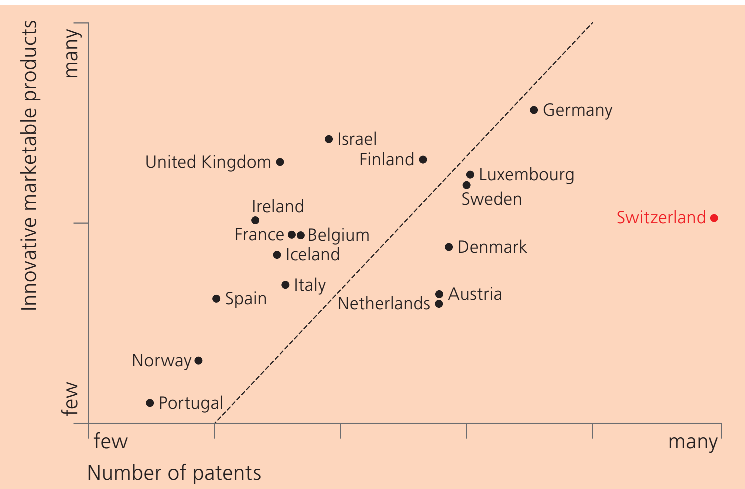


Diagram 3: Switzerland issues a lot of patents but too few are translated into marketable products (Swiss American Chamber of Commerce, European Innovation Scoreboard 2007).

International cooperation

International cooperation leads to a more efficient use of research funding. Successful cooperation depends on Switzerland actively participating in international programmes and making recognised, high-quality contributions to international research. International cooperation needs to extend beyond the borders of the industrialised nations to include developing countries.

Cooperation between Switzerland and the International Energy Agency (IEA) and EU research programmes (framework programmes, SET plan[1]), joint programming etc.) must be firmly established and improved by the federal offices responsible, such as the State Secretariat for Education and Research (SER), the Swiss Federal Office of Energy (SFOE), the Federal Office of the Environment (FOEN) and the Federal Office for Professional Education and Technology (OPET).

1) SET: Strategic Energy Technology, www.setis.org

Goals

We need to adopt a holistic approach to energy research based on the principles of sustainable development. The Federal Energy Research Masterplan considers the entire research-innovation-market value creation chain and addresses it at various levels.

Publically funded energy research should provide results of the highest quality.

Technology
In all activities involving energy generation, conversion and storage, we must attempt to produce state-of-the-art technology with the greatest possible technical potential, yet which at the same time remains economic viable.

Economy
The Energy Research Masterplan aims to improve security of supply in Switzerland long term, to generate added value for the country in the form of jobs, know-how and new marketable products, and to improve Switzerland's competitiveness on the international stage.

Low resource use
CORE regards improvements in energy and resource efficiency, increased use of renewable energies and the consequent reduction in emissions to be key elements in energy research.

Society
Last but not least, energy research should help us to realise that global climate goals cannot be achieved by means of technical measures alone, but that changes in behaviour are also necessary. We therefore need to ask questions about how acceptable new technologies are and how to create incentives so that they can soon become widespread on the market. This involves investigating the economic, sociological, psychological and political aspects of energy conversion, distribution and use.

Four thematic focus areas
CORE has defined four focus areas which essentially cover all aspects of energy research. They reflect everyday life and our everyday energy requirements. The four focus areas are also recognised in other countries as the main ways of improving efficiency and reducing emissions.

By establishing these focus areas we are able to derive key topics for research "top down" and to encourage systemic thinking. This structure makes it easier to communicate the ideas contained in the Masterplan and encourages cross-disciplinary research.

Living and Working in the future
Energy-efficient buildings and near emissions-free housing stock: This focus area includes technologies and models for energy requirements and energy conversion in buildings. It also involves the distributed generation of renewable energy in the buildings sector.

Mobility of the future
Reducing fuel consumption by increasing efficiency of means of transport and improving engines: Mobility of the future looks at efficiency, environment and energy supply in transport systems. This includes the availability and use of fuel in private, public and freight transport.

Energy systems of the future
Intelligently networked energy systems ensure that our energy supply is secure and sustainable: This focus area involves research and development of technologies for energy supply through to the end-user.

Processes of the future
In processes of the future, resource use and environmental damage are to be reduced by 50 %, minimising energy and material consumption over the whole product lifecycle, from production through use to disposal or recycling.

There are close overlaps between the four focus areas in terms of technology, economics and society. **Socio-economic considerations** play an important role in all four focus areas; the role of human behaviour, translating research findings into marketable products and understanding the way markets function all contribute to achieving the goals. Socio-economic research has three important tasks. Firstly, it can investigate human behaviour and the effects of energy policy instruments within each focus area. Secondly, it can help to identify the relationship between the different focus areas and establish the potentials and costs involved. Finally, it can provide an analysis of political, economic and social conditions. Sustainable and efficient solutions which apply to all focus areas need to be found. Furthermore, it should be possible to apply a single system to assess and weight measures and technologies, so that priorities can be set.

Timescale for achieving goals
The following chapters define the priorities and aims for the individual focus areas, according to two different timescales:
- Medium to long-term research priorities for the timescale 2020–2050;
- Short-term goals for the period to which this Energy Research Masterplan applies, 2013 to 2016.

Living and working in the future

Towards an energy-efficient and near emissions-free way of living and working: In the future the larger part of our building stock should no longer produce pollutants and greenhouse gas. Buildings should be an important contributor to distributed energy generation and produce approximately the amount of energy required to meet heating and electricity needs in our daily lives.

In order to achieve this vision, the "Living and Working in the future" focus area researches technologies and concepts involving energy requirements, energy conversion, energy use and the local generation of renewable energy in individual buildings, building complexes, residential areas, towns and cities.

Because cost-benefit analyses highlight the need for different solutions where old and new buildings are concerned, we are faced with a number of different challenges:

In **existing buildings,** we need to considerably reduce energy demand (energy supplied) and convert buildings to be carbon-neutral.

New buildings should not generate any polluting emissions. In future, emissions generated in building construction and the subsequent disposal of construction materials should be considerably less than is currently the case.

To achieve this, research scientists need to develop **technologies and concepts** with which we can generate, convert and use energy intelligently in buildings. This includes both **technological** and **socio-economic research.** Findings must then be translated into products, planning and implementing instruments and subsequently transferred to the market.

At the same time, interfaces with the other focus areas should be taken into account, such as the influence of construction planning and spatial planning on the way we travel.

Background
Buildings account for about 45 % of primary energy consumption and 40 % of all carbon emissions in Switzerland. There is therefore huge room for improvement in this area. Various national and international strategies are calling for our housing stock to undergo a thorough makeover according to sustainable development criteria. At national level, these strategies are based on the scenarios described in the Introduction, the *2000-Watt Society* and *One-Tonne-CO_2 Society.* Furthermore, the Swiss Society of Engineers and Architects' information leaflet entitled "SIA 2040 Effizienzpfad Energie" (energy efficiency path), produced in conjunction with the Confederation, ETH Domain institutes and the City of Zurich, sets a midway target for the year 2050, taking account of both these scenarios. The target is to produce not more than 2000 watts of total non-renewable primary energy and two tonnes of CO_2 equivalent per person per year. The buildings sector is to account for half of this; this includes not only the energy needed to run a building, but also the grey energy contained in the construction materials and the amount of energy consumed due the degree to which its users travel, as dictated by the building's location.

The SIA energy efficiency path intermediate target up to 2050 was set taking into account current technical and economic feasibility as well as considering architectural and town planning limits. For an individual object it therefore represents the minimum requirement for a pilot and demonstration project (P + D project).

Future research efforts in the "Living and Working" focus area should go far beyond this intermediate target and aim to reduce the SIA target values by about half.

Renovation of an apartment block with prefabricated elements. The International Energy Agency's (IEA) "Prefabricated Systems for Low Energy Renovation of Residential Buildings" project (ECBCS Annex 50), headed by Switzerland, aims to find innovative solutions for the efficient renovation of apartment blocks. A three-dimensional plan is made of the buildings by means of laser scanning and bird's-eye view images. This means a new building shell can be made in a factory efficiently and to the exact measurements, considerably reducing construction time. (Empa)

Medium- to long-term priorities

Existing buildings

In order to reduce energy consumption and carbon emissions, existing buildings need to be renovated economically. When a building is renovated to improve its energy consumption, the costs rise considerably for each unit of energy saved from a certain level upwards. If energy efficiency can be improved or the associated carbon emissions reduced by other eco-friendly means, for instance by the use of renewable energy, it makes more economic sense to invest in the cheaper option. We do not currently have the methodological bases or the application tools to assess the benefits of measures to improve energy efficiency or to reduce carbon emissions; the research community is called on to develop these.

For **residential buildings,** research needs to provide solutions for minimising energy use and greenhouse gas emissions in existing buildings, for example with new, highly efficient insulating materials which meet renovation requirements or with innovative integrated planning and operating instruments. At the same time, buildings need to be brought up to the latest standards of comfort and spaciousness. In **non-residential buildings** such as offices, schools and public buildings, waste heat from computers, lighting and also people should be recovered and factored into any renovation of the building shell.

For **historic buildings,** renovation techniques are required that affect as little as possible the architecture of the façade, windows and other parts of a building.

In order to encourage this transformation of the existing building stock, we need to increase incentives to renovate buildings. This entails certain economic and political preconditions. The research community is called on to develop suitable instruments and socio-economic concepts to achieve this.

Finally, a further task of research is to consider not only individual buildings but to find solutions for developing whole districts and towns sustainably.

New buildings

With regard to new buildings, research needs to focus on looking at energy consumption and pollutant and carbon emissions over a building's entire lifecycle. In order to **reduce the amount of energy required** to operate buildings, we need to develop technologies which substantially reduce energy losses and increase energy absorption via the building shell. At the same time, the range of architectural styles should remain varied.

Another key aim in new buildings is to **minimise the amount of grey energy and grey emissions,** for example by developing new materials and planning instruments.

Building technologies

Zero energy buildings and energy plus houses present opportunities for producing more energy in future. There needs to be more research into innovative technologies which can generate energy in and on existing buildings and use energy efficiently in the buildings.

We also need to improve existing technologies and develop new ones for generating renewable energy on buildings and using waste heat. It is important that these technologies are architecturally well integrated into a the building. There also needs to be a high degree of **standardisation and reliability.**

A central issue in the field of building technologies is the **storage of heat and cold.** Besides their technical feasibility, the economic viability of such solutions is a key consideration.

Integrated intelligence systems in **electrical appliances** and other power-consuming devices help to increase efficiency and minimise stand-by losses.

Finally, innovative solutions are needed to **network buildings** so that energy generation and load management in buildings, sites and residential areas can be optimised.

Integrated Living and Working

So that we can **live and work sustainably** in energy-optimised buildings, we need to develop **new models** for the way in which our daily and working lives are organised. **Consumer behaviour** can also be influenced by technologies and concepts which cater for specific user-types or different age groups.

Research topics 2013–2016

The following is a list of selected research topics to be addressed between 2013 and 2016. Concrete target values are given where appropriate and possible.

Existing buildings

Economically viable renovation of existing buildings

- Innovative calculation methods and planning instruments to reduce energy consumption and carbon emissions in building renovation with the best possible cost-benefit ratio. The building's entire lifecycle should be taken into account
- Highly efficient insulating materials for building renovations with thermal conductivity (λ) of maximum 20 mW/(m · K) and which meet on-site processing requirements
- Methods and tools to optimise energy losses via the shell of non-residential buildings in relation to internal heat generation
- Demonstrate how historical buildings worthy of protection can be renovated to be more energy-efficient
- Establish optimum mix of energy policy tools and economic conditions (incl. regulations) to make existing building stock sustainable within a short time
- Analyse costs, benefits, acceptance of and barriers to different renovation strategies
- Demonstrate concepts and strategies for sustainable development of individual sites, residential districts, towns and cities ("smart cities")

New buildings

Minimise energy consumption, pollutants and emissions over the complete lifecycle

- Demonstrate prototypes of innovative construction materials for building shells (vacuum-insulated panels, dynamic building elements, vacuum windows, switchable glass)
- Develop concepts, technologies and new materials to minimise grey energy and grey emissions (e.g. replacing metals with range of functions such as supporting structure, building shell, utilities etc.)
- Socio-psychological aspects: investigate acceptance of advances in technology in energy-efficient buildings

Building technologies

Technologies to meet energy requirements in buildings

- Develop innovative solar components and testing procedures, in particular for hybrid panels producing hot water and electricity
- Solar-powered air conditioning in buildings
- Investigate and document standard configurations for solar thermal heat pump systems
- Improve efficiency of thermodynamic machines (heat pumps, cooling systems). Aim to improve efficiency from current 45 to 65–70 % of theoretical efficiency (quality grade)
- Optimise economies of depth of ground source heat pumps in connection with solar regeneration and (partial) seasonal storage

- Develop exergy-optimised[1] solutions for cooling buildings
- Introduce innovative cooling agents with ozone depletion potential ODP = 0 and global warming potential GWP < 5
- Develop more attractive solar façade elements (PV, solar thermal) of flexible shape and size for better integration into buildings
- CHP for building applications: focus on renewable/CO_2-free energy (biomass, hydrogen), CHP optimisation, aim: $\eta_{tot} > 95\,\%$, $\eta_{el} > 50\,\%$
- Establish criteria for assessing when CHP is better than a centralised CCGT solution
- Develop new materials and innovative concepts for heat and cold storage (seasonal storage for buildings and entire sites, technical heat and cold storage with high storage density etc.)
- Develop innovative renovation solutions for ventilation and air conditioning systems (extent, cost, required ventilation)
- Introduce electrical appliances, converters and loads with high efficiency and minimum stand-by losses (e.g. fridges, LED retrofit lamps etc.)
- Introduce information and communication technologies (ICT) solutions to meet consumer needs such as smart-user interface, smart metering, smart grids; self-learning measurement and control technology; research influence of these technologies on heat and electricity consumption in appliances and buildings
- Develop professional service and operating models for distributed building technologies
- Research thermal electrical storage possibilities in private homes
- Research daily and weekly heat and cold storage facilities
- Develop load and production management in buildings in interaction with electricity grid and possible technical internal storage methods (including electric vehicles)

[1] Exergy expresses the quality of an energy source and quantifies the useful work that may be done by a certain quantity of energy

Integrated Living and Working

Living and working in energy- and greenhouse-gas-optimised buildings

- Impact of where we live and how we choose to travel, acceptance of new living and working models; develop models to reduce traffic resulting from building location
- Rebound effects in living and working (number and efficiency of electronic appliances in conjuction with energy-efficient living); eco-sufficiency strategies to avoid these effects
- Consumer-segment-specific strategies and models to improve consumer behaviour, taking into account user needs
- Socio-economic analyses of homeowners' role as electricity producers
- Quantify impact of global climate developments and of microclimate of residential areas and towns/cities on heating and cooling in buildings; implement results in planning tools
- Models for new space- and resource-saving living
- Analyse reasons for discrepancy between planned and measured energy consumption of a building and derive recommendations

Mobility of the Future

Reduced motor fuel consumption thanks to greater efficiency of transport and advanced propulsion solutions: Efficient, flexible transport systems are an important factor in the health of the economy and how it develops. Despite growth, in future we must substantially reduce total energy use and greenhouse gas and pollutant emissions. We therefore need to concentrate on research and development in the field of highly efficient transport technologies, introduce them on a much wider scale and encourage people to adopt a more sensible approach to how we move around.

In order to achieve the goals in the mobility focus area, a number of different approaches are taken. These include efficiency and ecology, energy supply and fuel availability, as well as the use of private and public transport by road, rail, water and air. The particular challenges facing Switzerland are in the following areas:

If we are to reduce energy consumption, we need more **efficient vehicle systems.** This means engines with low fuel consumption and low emissions, and advanced propulsion systems with innovative energy storage systems.

Efficiency can be increased and damage to the environment reduced by making the **transport system** as a whole **more efficient.** This requires attractive public transport models and combined mobility models, and innovative ways of using information and communication systems (ICS).

If we are to find **substitutes for fossil fuels,** we need a supply of biogenic fuels or other renewable fuels from economically viable sources. We also require suitable infrastructure and engines that can run efficiently on the new forms of energy.

Consumer behaviour also plays a major role in reducing fuel consumption. An understanding needs to be developed of which is the most appropriate form of transport for a journey and how different modes of transport can be combined. In order to achieve this, we need comprehensive information (e.g. about environmental impact) and a better understanding of how instruments, technologies and business models are accepted by the public.

If we are to develop sustainable transport services and use them appropriately, we first need to take a holistic view of the transportation system. This includes considering energy supply, how we live and work and spatial planning.

Background

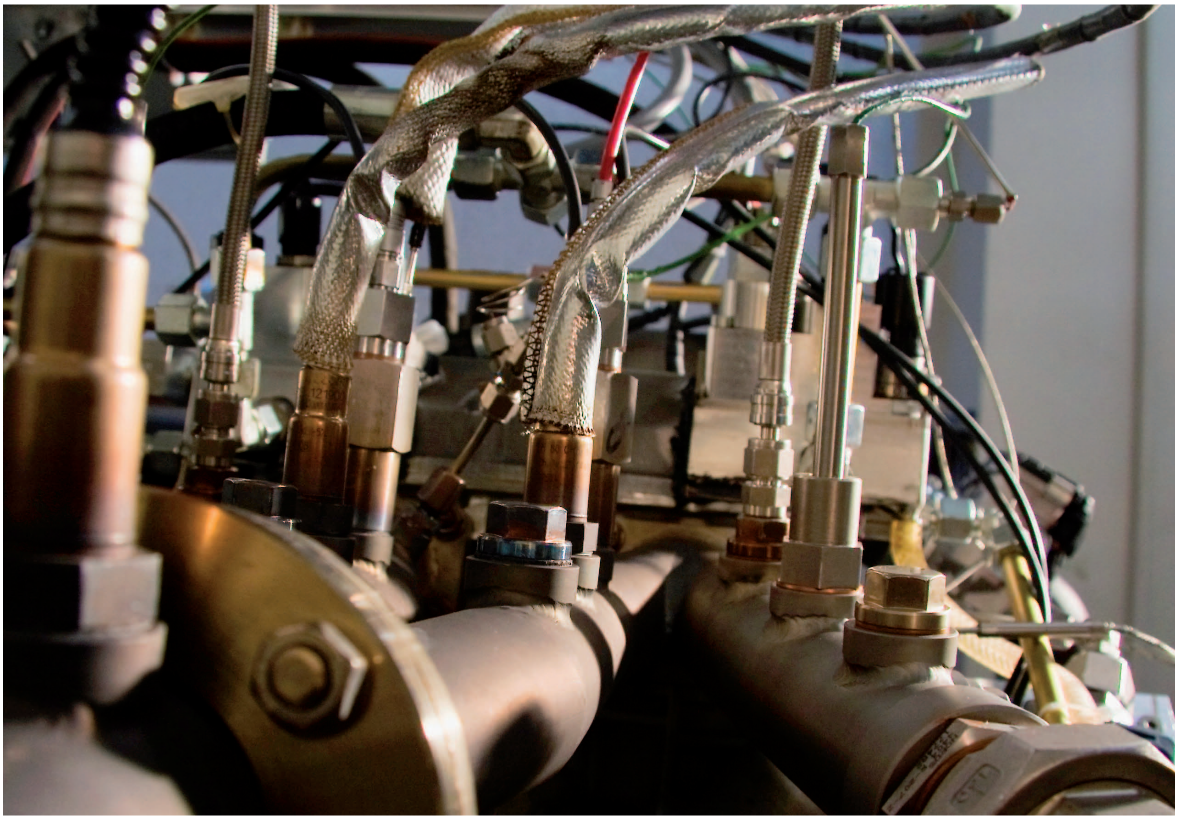
Our means of transport mainly depend on fossil fuels, and in Switzerland these account for about 40 % of all CO_2 emissions. Both in Switzerland and abroad, a range of future scenarios and concepts has been drawn up for the mobility sector, e.g. by the International Energy Agency, the European Climate Foundation, the Energy Science Center (ESC) at the ETH Zurich, Swiss government departments and the Energy Trialog Switzerland. These concepts are aligned to a certain degree and in some cases they are tailored to the individual requirements of the country concerned. The following concrete aims for action in the period up to 2050 are based on estimates by Swiss experts:

It is aimed to **halve** the use of **fossil fuels** for public and freight transport by improving energy conversion, components, controlling mechanisms and vehicle systems.

In motorised private transport, we need to reduce **fuel consumption in new vehicles by a third.**

Short- and medium-distance transport must be **decarbonised** to a large extent, e.g. by using electric vehicles and efficient storage technologies.

In **long-range transport,** energy efficiency needs to be improved, fossil fuels substituted and the most efficient means of transport used. Combined with an innovative management approach, this will greatly reduce energy consumption and carbon emissions.



*Scientists at the ETH Zurich have developed a **petrol-pneumatic hybrid** which uses 30% less fuel than conventional engines and which costs only 20% more. Current hybrid engines save around 35% energy, but cost about 200% more than petrol engines with the same output. The project has attracted huge international attention. Scientists are now working with the automobile industry to apply the concept.*

Medium- to long-term priorities

Replacing fossil fuels
In order to reduce greenhouse gas emissions, we not only need more efficient engines but also energy sources and fuels without carbon emissions. The aim is to **decarbonise** transport. Short-distance private journeys should be made without any use of fossil fuels. Fossil fuels should also be gradually phased out and replaced by alternative energy sources in medium- to long-distance transport and freight transport.

One research focus area is the development of manufacturing processes for **alternative energy sources and fuels.** This includes second and third generation biofuels whose production does not compete with food production, e.g. fuels from wood, straw, waste biomass or algae. Solar-generated hydrogen is a further possible energy source. Fuel production, in particular hydrogen, is looked at further in the section on "Processes of the future".

We are faced with the challenge of constructing infrastructure for new energy sources such as electricity and hydrogen, and of creating payment systems. This requires user-friendly, marketable solutions which can be applied on a large scale, for example, refuelling systems for electricity with rapid recharging and appropriate business models.

In order to make electric engines economically viable, **mobile storage technologies** such as batteries and ultra- and supercapacitors are essential.

A further way of substituting fossil fuels involves systems in which a range of different energy sources, such as biogas and natural gas, or different propulsion systems can be flexibly combined without increasing consumption or carbon emissions. We also need to develop products and business models which allow us to meet our range of travel needs with the most appropriate type of engine or vehicle.

Efficiency of transport systems
Fuel consumption can also be reduced by improving the efficiency of our transport systems. **Information and communication technologies** can play an important role in this, as they help us to fully exploit transport capacity and coordinate the use of rail and road for goods and passenger transport. ICT also provides the basis for active safety systems in vehicles, a particularly important requirement in non-robust, lightweight vehicles if they are to be safe enough to become widespread.

A further priority lies in integrating new types of transport into existing **distribution networks and communication systems.** For example, plug-in hybrids can be connected to an intelligent electricity grid.

We also need to make public transport more attractive, which means finding viable alternatives to **short-haul flights** and making sure that users can combine different forms of mobility more easily, both at local level and in national and international transport.

Efficiency of vehicle systems
The main theme of the Mobility focus area is the need to cut down on the use of fossil fuels. Potential lies in increasing efficiency by downsizing, optimising combustion processes (including turbocharging) and optimising all aspects of propulsion systems, for example by developing hybrids and improving waste heat use. Lightweight construction methods which reduce the total weight of a vehicle can also contribute considerably to lowering fuel consumption.

Pollutants and noise emissions also need to be reduced, the ultimate aim being to create a **near emissions-free vehicle.** Improved catalytic converters, particle filters and new silencer technologies are examples of possible research areas.

Socio-scientific aspects
If we are to create an efficient framework for transport services, we need to have a thorough understanding of why, when and how we travel and what affects our behaviour, and to provide comprehensive information to transport service users. This involves making a **thorough assessement** of mobility and transport services, for example considering total lifecycles and complete systems, environmental impact, technology assessments etc.

Underlying this is the need to improve our understanding of the transport choices we make, our behaviour when purchasing cars and the effects of demographic change on the behaviour and needs of transport-users.

We also need to find new ways and technologies to encourage people to avoid the use of transport services, and establish new business and working models to reduce mobility and increase efficiency. Finally, we need to raise our understanding of how new mobility concepts and technologies function and under what conditions they find acceptance among the general public. This includes new instruments such as a transport incentive tax, technologies and business models in electric mobility, the design of incentives and price systems, and traffic management concepts such as mobility pricing.

If we are to substantially reduce energy consumption in our transport system, we need to consider people and human behaviour: How does the need to travel arise and how is it changed by new technologies, business models, demographic change and political intervention? (Image: NZZ, 5. 01. 2010)

Research topics 2013–2016

The following is a list of selected research topics to be addressed between 2013 and 2016. Concrete target values are given where appropriate and possible.

Decarbonisation

- Vehicle components and systems which use alternative fuels (incl. electricity) and energy sources (incl. hydrogen and biofuels) more efficiently
- Second generation biofuel production processes, bioethanol from lignocellulose raw materials: cost reductions of up to 50 %
- Demonstrate highly efficient non-motorised vehicles to effectively reduce private motorised transport, especially locally
- Improve rechargeable batteries for mobile applications from currently approx. 120 Wh/kg (battery pack weight) to energy density of at least 150 Wh/kg and life of at least 1500 cycles
- Demonstration projects on widespread, rapid recharging infrastructure for car batteries incl. research into and minimisation of impacts on battery life
- Demonstration projects and research into potential of recharging in towns and cities, also in conjunction with directly renewable energy generation (photovoltaic)

Transport systems

- Measures and services to improve attractiveness of public transport and combined transport systems in order to transfer motorised private transport and aviation to public transport
- Measures, models, components and initial applications to improve energy efficiency in public transport by up to 10 % (e.g. exploit capacity to a greater extent, optimise engines used)
- Develop and implement models for more fluid operation of public transport network (e.g. dynamic driving directions)
- Effects of market introduction of plug-in hybrid and electric vehicles on electricity supply and of other measures
- Opportunites and potential of substantially influencing electricity load profile with plug-in hybrid and electric vehicles, or via smart grid additional use of vehicle batteries and stochastic energy generation

Vehicle systems

- Information and sensor technologies as the basis for active vehicle security systems to make construction of lightweight vehicles easier
- Combination of lightweight, aerodynamic form, light tyres and highly efficient engine to reduce consumption in family cars to up to 2.5 l/100 km
- Pilot vehicles and demonstration projects for rechargeable/hybrid models with fuel savings of at least 35 % compared to similar vehicles, yet at only slightly additional cost
- Improve efficiency of combustion engines by 3 % in driving cycle for heavy diesel vehicles, as demonstrated in tests

Socio-economic/socio-technological

- Develop understanding – taking account of rebound effect – of technologies, instruments and incentives to encourage people to avoid work-related travel and transport (e.g. teleworking) and help reduce leisure traffic (e.g. by creating attractions and facilities locally)
- Investigate and run field trials on opportunities and limitations of desynchronising work and leisure-related traffic to achieve more evenly distributed use of transport networks
- Identify sustainable transport infrastructure and business models for work and leisure (e.g. teleconferencing) and user-friendly, standardised use. Establish bases for corresponding energy policy
- Implement nationwide, large-scale pilot projects with new mobility concepts and forms to promote implementation of new technologies and business models; raise acceptance among general public and create bases for future energy policy
- Reduce uncertainties in environmental impact and life-cycle assessments by improving data and methodology in order to gain comprehensive overview of mobility. Further develop available tools and current status of knowledge for more extensive application and communication measures

Energy systems of the future

"Intelligently" networked energy systems ensure safe and sustainable energy supply. The supply of energy for electricity, heating and cooling as well as heating and motor fuels should in future be acceptable to society, as efficient as possible, free of adverse greenhouse gas emissions and safe. Security of supply for Switzerland must be guaranteed. Research and development must provide innovative solutions to ensure that Swiss energy requirements can be met over the coming decades according to the "new energy policy", which envisages abandoning nuclear power.

With new technologies and the clever use of system solutions, Switzerland should be able to reduce its dependence on fossil fuels. However, this will lead to a greater demand for electricity (e.g. electromobility, heat pumps). According to the ETH Zurich's energy strategy, electricity consumption may double to 50 % of final energy use by 2050. This **"second electrification"** increases the need for greater efficiency throughout the energy system.

Initially, additional demand will be met by increasing efficiency in electricity generation from fossil fuels. Carbon sequestration should form a part of these processes. Renewable energy sources such as biomass, geothermal, solar, water and wind must also be used to a greater extent.

The Energy Trialog Switzerland estimates that the country could produce around 20 TWh of electricity (currently 1.3 TWh) and 36 TWh of heat (currently 12 TWh) from renewables (not including hydropower) by 2050; this would mean that 55 % of energy demand could be met by renewables.

Theses changes affect all areas of primary energy conversion into electricity, heat and cold, as well as transmission and storage, the integration of sub-systems and safety aspects right the way through to the end-user. The focus lies on creating optimum lifecycles in existing installations and electricity technologies, biogenic and fossil fuel energy systems, intelligent grids and selected areas of nuclear technology.

In all of these areas, account is taken of total system lifecycles, from construction to dismantling. Progress must be made whilst maintaining a balanced approach to the three dimensions of sustainable development – economy, environment and society.

The **interplay between business and society,** tolerance and acceptance of technology are highly relevant issues for energy systems, an essential part of the infrastructure of modern society. Federal energy research is application-oriented, focusing on active knowledge and technology transfer management.

Costs, risks, acceptance, resource use, economic effects and environmental damage can be assessed using transparent energy system modelling. This takes account of the entire range of production methods, transmission, storage, import, exports and consumption, allowing us to draw up and analyse different development scenarios for Switzerland and compare these with possible developments in other countries.

In all scenarios, it is assumed that Switzerland will be a fully integrated and equal trading partner **in European energy markets,** thus ensuring security of supply and better access to imports of renewable energy from wind, geothermal and solar sources. Energy system components must be assessed in context and on a comparative basis so that priorities can be set according to the needs of the stakeholders. With greater liberalisation of the energy markets, investment, business models and the choice of technologies will increase. At the same time, new challenges will emerge in terms of investment, incentives for investment and long-lived infrastructure assets.

The sun irradiates Switzerland with 220 times more energy annually than the country consumes in the same period. But less than 0.1 % of electricity demand and 0.4 % of heat demand is met by solar energy – the costs are still too high. However, thanks to new developments, the price of solar modules is continuously coming down. To test the market viability of solar modules, at SUPSI in Ticino mechanical load tests are being carried out. Scientists are also working on solar thermal concepts that concentrate the sun's energy using mirrors, heat water and generate electricity with conventional turbines. Pictured: In the Gams solar park various state-of-the-art photovoltaic technologies – monocrystalline and multicrystalline and amorphous silicon solar cells - mounted on the roof and facades of a new office building combine to form a plant of 60 kW and produce in the course of a year significantly more power than the building uses. (Heizplan AG).

Medium- to long-term priorities

Existing and future facilities
Existing power plants, district heat and cooling facilities should be operated more ecologically and managed sustainably on the basis of lifecycle analyses. Efficiency can be increased by creating integrated energy conversion systems for electricity, heat and cold. Improvements need to be made in resource use and environmental impact over the total lifecycle of generation, operation and decommissioning.

Carbon-based energy systems
Generally, the competitiveness of biomass use for electricity, heat and fuel needs to be improved. This applies to both distributed and decentralised systems.

If we continue to meet electricity and heat demand by burning fossil fuels, it is essential that we decarbonise. We must therefore significantly increase power plant efficiency, develop carbon capture processes from flue gases and demonstrate these technologies in the market place.

In combined cycle gas turbine (CCGT) power plants we can aim to achieve conversion efficiency levels of 62–63 %, while reducing emissions at the same time.

Multidisciplinary research into **carbon catpure and storage (CCS)** needs to address combined power plants and their components as well as energy systems used in industrial processes (construction materials manufacture, oil and gas refining and chemical and metal industry processes). In complementary geological research, potential underground carbon storage sites are being explored; Switzerland has a theoretical storage potential of 2700 million tonnes.

Pilot and demonstration projects in carbon capture and storage and CO_2 tests to determine how CO_2 behaves in possible storage sites should display the sustainable potential of CCS technologies.

Renewable energy

Long-term, we must meet the growing demand for energy with sustainable renewable energy, improving the technologies involved to make it a more competitive option.

By expanding **hydropower** over the coming decades we may be able to generate an additional 5 to 10 TWh of electricity annually. Solutions need to be found which are compatible with nature and landscape conservation and water protection. We also require new technologies to renovate and maintain safety levels in existing dams and reservoirs.

In the field of **photovoltaics,** a local source of energy and a technology with major export potential, research needs to be carried out into improving efficiency and reducing costs, both in terms of cell and system technology and in the field of building-integrated solar cells.

Wind farms in Switzerland are often found in locations which are subject to very specific conditions: cold and snow, low wind speeds or gustiness result in the need for special measures to increase availability and energy yield. This means that new installation components need to be developed. Furthermore, it is important to increase the public acceptance of wind power so that projects can be realised more rapidly.

The greatest potential for generating enough electricity to meet baseload demand (heat and electricity) in Switzerland is provided by **geothermal energy.** A concerted effort over many years is required to increase success rates in detecting and developing underground heat and hot water reservoirs, and to construct, operate and subsequently decommission geothermal plants safely and cost-effectively.

Intelligent, high-performance grids

Renewable energy generation is often distributed, and supply can fluctuate greatly. The energy system therefore needs to be considered as a whole when renewables are integrated into the power grid. This involves large and small, centralised and distributed power plants with fluctuating or baseload electricity generation. Intelligent networks for transporting fuels and electricity which regulate production and consumption and match energy supply with demand are also required. These "smart grids" involve technologies that optimise the management and regulation of energy flows.

If the future energy mix is to include a greater share of renewables, **energy storage devices** are required in the power grid. Research is necessary into large storage power plants and efficient localised technologies such as batteries and supercapacitors, heat accumulators, water, compressed air and gas reservoirs and thermal and thermo-chemical storage equipment for solar energy.

Nuclear technologies

Independent regulatory safety research needs to be continued so that we can learn further lessons from the nuclear disaster in Fukushima.

We must continue to conduct research into the disposal and reduction of nuclear waste (e.g. transmutation).

Social and ethical issues need to be addessed if the three-stage site-selection process for a deep geological depository in Switzerland is to be carried out successfully.

Switzerland needs to contribute to the development of nuclear technologies, from safer and more efficient reactors through to nuclear fusion, so as to maintain the levels of expertise required to assess new technologies.

New fourth generation **reactor technologies** should be continually assessed in terms of safety, waste disposal and storage.

Research into fusion should be continued as long as it can be financed in multilateral research projects, and not at the expense of research funding for other energy technologies.

In this laboratory, PSI researchers produce energy-rich gas from wood, a natural raw material. The process converts wood into synthetic natural gas, which is fed into public gas pipelines. The energy is thus made available for power generation in gas power plants or car engines. At the same time, wood is a very environmentally friendly energy source, as the gasification process is carbon-neutral.
(Scanderbeg Sauer Photography)

Research topics 2013 – 2016

The following is a list of selected research topics to be addressed between 2013 and 2016 if long-term objectives are to be achieved. Concrete target values are given where appropriate and possible. Suitable pilot and demonstration projects could also be set up.

Existing installations

Optimum and environmental use of resources

- System optimisation to increase energy conversion efficiency
- Lifecycle analyses as sustainable management tool
- Electricity technologies for products (thermo-electric generators) and applications with increased efficiency (superconducting cables, generators and distribution transformers)

Carbon-based energy systems

Combined Cycle Gas Turbines CCGT

- Increase electrical conversion from 60 % to over 62 %
- Increase efficiency of components
- Reduce need for cooling, increase process parameters
- Increase overall efficiency and optimise cogeneration of heat and electricity at range of temperatures
- Low-carbon fuel use (biomass, hydrogen from renewable generation)
- Carbon capture technologies with minimal energy penalty
- Fast cycle CCGT technology and rapid grid stabilisation (capacity ramp rates of more than 3 % per second)

Carbon storage

- Determine practical underground carbon storage capacity in Switzerland
- Carbon capture technologies with minimum additional energy requirements
- Risks and long-term behaviour of carbon storage sites and long-term monitoring

Use of biomass

- Improved gas purification methods
- Improved substrate digestion of input materials leading to higher gas yields in fermentation processes
- Safety aspects
- System optimisation and integration to increase efficiency; complete evaluation of value chain
- Standardisation and principles of quality control; efficient communication to raise awareness and so increase acceptance of technology

Renewable energy

Hydropower

- Ways of defusing conflicts between hydropower and water ecology/landscape protection in combination with environmental research, by offering solutions to problem of hydropeaking and fish migration
- Impact of climate change (glacier retreat, sediment input, hydrological changes)
- Adjustment of pumped storage power plants to changing operational requirements in the European combined grid
- Achievable potential and standard solutions for small hydropower plants and low pressure systems
- Ageing of dam concrete (alkali-aggregate reaction) with a view to increasing dam safety
- Extreme flood event assessment; large-scale air surveillance
- Measurement of strong earthquakes with modern strong motion networks; long-term measurements for predicting dam behaviour

Wind

- Develop and optimise installation components, measuring instruments and utilisation concepts for situation in Switzerland
- Raise acceptance for wind power and reduce length of planning and approval process

Geothermal and energy-related use of deep subsurface

- Three-dimensional geological mapping of the deep subsurface
- Revolutionary drilling technologies to explore and develop reservoirs
- Stimulation of wells and subsurface to increase permeability
- Sustainable reservoir management
- Efficient energy conversion
- Integrated systems to reduce costs; safety processes and methods

Photovoltaics

- New materials for thin-film solar cells
- Improvements in solar cells and infrastructure for large-scale processes and pilot production lines
- Production technologies for thin-film solar cells and crystalline silicon
- Grid integration of solar power and intelligent grid monitoring
- Quality assurance of solar modules and electrical system technology

Solar thermal power

- Reactor technology for syngas as preliminary stage in production of liquid fuels
- Increase efficiency in conversion of solar energy into chemical energy

Concentrating solar power (CSP)

- Increase efficiency and reduce costs of power plants and their components (reflectors, absorbers, control systems)

Intelligent, high-performance grids

Harmonisation of energy supply and energy demand

- Combined grids and multicarrier grids (electricity, heat, gas)
- Grid-stabilising charging infrastructure for vehicles
- Transmission grid architecture: planning tools and concepts to address issue of underground cables v. overhead powerlines
- Transmission grid operation: cross-border grid monitoring and coordination, safety criteria and system services
- Integration of renewables in low-voltage grids and medium-voltage grids
- Integration and management of energy storage devices; integration of electric vehicles
- Monitoring and control of low-voltage grids; data collection, transmission and analysis in medium voltage networks
- Protection of critical infrastructure
- Demand-side participation taking into account user needs

Energy storage devices

- Local, efficient storage technologies such as batteries and supercapacitors, heat storage devices, compressed air and gas reservoirs, thermal and thermo-chemical storage devices for solar energy

Nuclear energy: safety and use

Regulatory safety research

- Fuels and materials, external events, human factors, system behaviour, incidents and radiological protection. Participation in international databases on accidents and internal events

Radioactive waste

- Research into clays, design and inventory of a repository including pilot storage facilities (gas development and behaviour in the near and far field of a repository)
- Research into ethical and social aspects of successful site selection process for deep geological repositories
- Transmutation as waste recovery process

Reactor technologies

- Evaluation of new reactor technologies and fuels (thorium), their safety, waste disposal and storage

Fusion

- Scientific bases with focus on plasma physics and materials

Integrated assessments

Energy system

- Modelling of entire energy system including resource security, storage, consumption and impact on society (costs, resources, environmental damage, potential and resilience, risks and vulnerability)

General public

- Scenarios regarding use of living space which accord with aims for energy consumption and carbon emissions
- Scenarios of institutional, economic and structural changes required to accelerate or minimize obstacles to transformation of energy sector
- Scenarios of Switzerland as an improved business environment
- Modelling of optimum resource use over whole value creation chain, from innovation via pilot projects and implementation to end-user; observations of pilot project impact
- Scenarios regarding consumer behaviour in response to policies and measures

Test regions

- Actual behaviour of individuals and groups in test areas in which individual scenarios are implemented

Processes of the future

We must aim to halve resource use and the environmental impact of products over their total lifecycle; industry, services and agriculture in Switzerland account for 36 % of total energy consumption and 61 % of total electricity consumption. This does not include the energy required for transporting workers and goods. Businesses must play their part if we are to achieve climate objectives and reduce electricity consumption.

Processes of the future should be able to manufacture products using **minimal energy and materials,** and with as little impact on the environment as possible. This impact is measured over the whole of the value creation chain. It takes account of all technical processes and the material and substance flows involved in raw material extraction, material production, the manufacture of semi-finished and finished products as well as product distribution, use and disposal.

The use of renewable energy resources and **recycling** at the end of product lifecycle are important factors in improving energy and material balance. If **production facilities** are appropriately sited, this can help to reduce energy consumption. Renewables can be used more effectively and greater amounts of waste energy recovered.

There are currently numerous ways of reducing the amount of energy and materials used in industrial operations. However, they are only partially implemented as it is frequently not cost-effective to do so. There needs to be research into reducing the cost of these processes and **incentives** to reduce barriers to implementing them.

Background

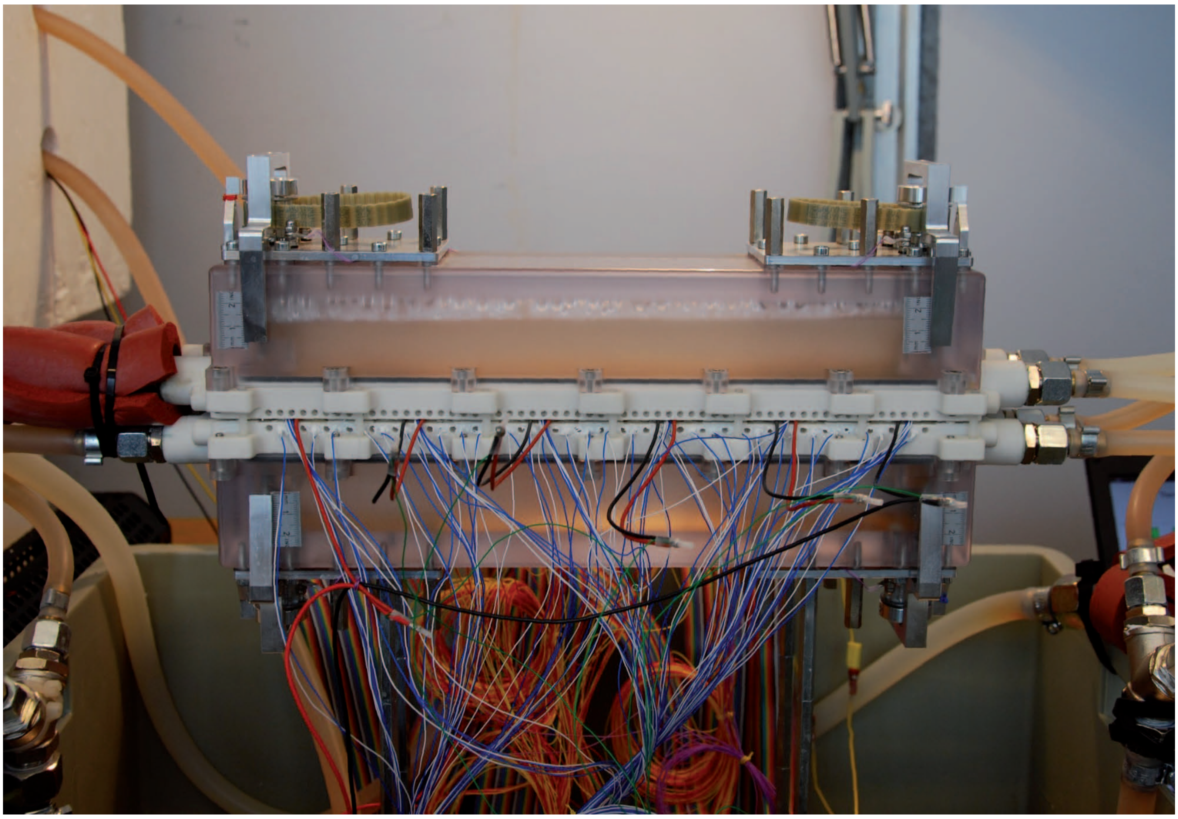
There are thousands of different technologies involved in industrial processes and processes in services and agricultural sectors. Despite the large amount of energy these processes require, the relevant energy strategies do not prescribe upper limit values, as is the case for buildings and vehicles. The Energy Agency for the Economy (EnAW), which has helped numerous businesses to implement energy saving measures under carbon-reduction legislation, suggests that **potential savings** can be made of **up to 30 %,** and some processes can be optimised to reduce energy consumption by up to 80 %.

In reducing energy consumption we need to consider the **quality of an energy source.** Priority must be given to reducing energy consumption and process temperatures, which typically lie between 180 °C and 400 °C. The main focus should be on reducing exergy requirements. Lower process temperatures are also more appropriate for the use of **solar heat.**

Besides making improvements to individual components, we can also make greater savings by adapting processes. As raw materials become scarcer, we need to optimise the energy and material balance. Where possible, waste materials should be **recovered** rather than used to produce energy.

Focusing efforts on improving processes and products in **energy-intensive sectors** only does not go far enough. Measures must be applied across the board, including by the huge number of small and medium-sized energy-consumers in industry, the service sector and agriculture.

Experts see great potential for reducing energy consumption by improving processes and products. By 2020, energy input, exergy use and greenhouse gas emissions can be **reduced by 20 %** per unit of added value. This figure rises to **50 % by 2050.** Similar estimates have been made for material consumption. Publically financed research must therefore prioritise projects which display considerable potential for saving resources.



Waste heat from waste water can be converted into electricity by thermoelectric generators. Waste heat is created in many processes in business and industry, including in energy conversion. At the ETH Zurich, a one-kW demonstrator is used to assess basic feasibility and evaluate efficiency. By applying this process in concrete situations, scientists want to demonstrate that is is possible to use waste heat from data centres and heat from geothermal sources.

Medium- to long-term priorities

Product development
In product development, resource use and environmental impact over the total product lifecycle should be considered. The aim when designing products is to optimise the use of resources over their complete lifecycle. The resulting product concept includes functions and materialisation, appropriate manufacturing processes, energy-related and environmental characteristics during the product use phase as well as disposal processes with a high recovery rate.

Material use should be minimised by concentrating on the functional characteristics of products only. The availability of raw materials and opportunities for material recovery should also be taken into account.

Product manufacture
More efficient or new manufacturing processes can also reduce energy and material requirements, for example membrane technologies instead of thermal separation processes, mechanical instead of thermal drying facilities, cold instead of hot pressing and continuous instead of interrupted processes. Furthermore, we need to develop new materials which require fewer resources in production processes, use and disposal, such as bioplastics. The challenge in doing so is to retain the functional characteristics of the resulting materials.

Material intensity can be reduced by employing different or new processes, e.g. pressing instead of machining. We can also develop new materials which require fewer resources in their production and use.

Renewables can be used directly in solar chemical or solar thermal processes. In processes involving fossil fuels, carbon can be sequestered. We can increase the efficiency of **production facilities** by increasing the efficiency of individual components such as engines and cooling and conveying systems, or by using hybrid engines.

Production networks can be better coordinated as total systems; interruptions in material flows, downtime losses and discard products should be avoided.

We also require concepts for retrofitting existing large facilities with energy-saving compenents and operating systems. Energy use should be reduced to meet the physical requirements of processes as far as possible, and use for peripheral components minimised.

Energy sources should be used in production processes according to their quality. **Energy flows** should produce the greatest amount of exergy (useful work) possible. Unused energy should be recovered, process temperatures reduced and exergy recovered from waste heat flows (Organic Rankine Cycle, thermoelectric).

Energy storage is particularly important in order to balance out time differences between supply and demand in discontinuous processes. Innovative energy storage devices for kinetic, electrical and thermal energy need to be developed and integrated.

Information and communication technologies require increasing amounts of energy. The specific energy input in IT systems (kWh/byte) needs to be reduced. Processors with low electricity requirements, improved cooling systems involving heat recovery or ways of optimising the use of ICT systems are options to be explored.

Product use
Energy consumption and environmental impact during product use are already determined in the product development phase. The relationship between grey energy and the useful life of products needs to be improved. Retrofitting during use is a way of reducing energy consumption and increasing technical useful life. The energy consumed by a product should be minimised according to its designed use.

Product disposal
When products are disposed of, the resources involved should be recovered as far as possible. Energy use should be kept to a minimum and the maximum amount of materials recovered. Material recovery concepts need to be drawn up at the product development stage.

Behaviour
The behaviour of manufacturers and consumers determines the type of products on offer and demand for them. Research must be carried out into ways of increasing the market share of resource-optimised products. This would also involve socio-economic analyses on how to avoid rebound effects.

Finally, education and training programmes need to address at an early stage what processes of the future involve and the methods to develop them.

Research topics 2013–2016

There are huge demands placed by industry and the service sector on power consumption in Switzerland, and greater efforts are required to understand and implement sustainable ways of reducing these levels of consumption. In addition to proposing gradual improvements in individual components in manufacturing processes, federal energy research needs to develop new or alternative methods to substantially reduce energy and material consumption. Showcase projects in the period 2013–2016 should demonstrate the possibilities and potential of different methods in different industries. Manufacturing processes are often developed to meet the needs of a particular company. Public research focuses on improving basic procedures or versatile plant components. This includes developing and improving data and simulation tools. To reduce the actual amount of exergy required, we need to launch projects to reduce process temperatures, ideally involving the use of solar energy. This should be backed up by research into how best to implement results (incentive labels, incentive taxes, quotas or standards), taking into account the socio-economic context of industry and the service sector. The requirements posed by processes of the future should also become a component of education and training programmes.

The following is a list of selected research topics to be addressed between 2013 and 2016 if long-term objectives are to be achieved. Concrete target values are given where appropriate and possible.

Product development

- Determine cumulative exergy need in product manufacture from raw material extraction through manufacture and use to optimised waste recovery, according to material type
- Demonstrate product models with minimum input of energy and materials, toxic and polluting substances; product life and recycling to be taken into account
- Data and simulation models to determine efficient technology chains to reduce energy and material use in manufacturing
- Improve data on grey energy in raw materials, semi-finished products and finished products; consider useful life
- Data on recyclable materials as factor in decision-making in product development

Product manufacture: processes

- Demonstrate temperature-reduced thermal manufacturing processes
- Further develop bioplastics, taking into account manufacture of biogenic raw materials
- Develop biochemical processes to replace conventional thermal processes
- Analyse multiphase transport systems to optimise material flows
- Evaluate solar-chemical processes for direct production of chemical substances
- Demonstrate concepts for recyclable products with maximum material recovery, taking account of energy requirements, costs and material quality after recovery

Product manufacture: facilities

- Develop robust data and develop numerical simulation models to illustrate energy consumption in manufacturing processes
- Further develop instruments to accurately determine energy flows in process chains, taking into account new energy-storage components
- Improve combined generation and use of heat and cold in industrial plant
- Increase efficiency of high-temperature solar heat processes (up to 250 °C) in industrial applications to over 60 % by improving materials and system design (optical losses, degree of reflection, heat loss); reduce costs
- Develop demonstrator of solar heat generation up to 400 °C and integrate in technical processes
- Models and monitoring tools to optimise energy use in continuous and discontinuous chemical processes
- Reduce electricity consumption of electrolysis apparatus by 20 % by recovering energy and using hydrogen to generate electricity (demonstrator)
- Further develop nanotechnology surface coatings to reduce deposits in material separation or heat transfer
- Demonstrate reduction of energy consumption in machine tools by 25 % by means of systematic improvements and integration of peripheral components
- Develop innovative stepper motors to increase energy efficiency of motors by 10 % compared with current state-of-the-art
- Demonstrate thermo-electric generators to recover exergy from heat flows at low-temperatures, e.g. in datacentres

Product use

– Demonstrate tools for web-based monitoring of nominal operating conditions of products with high energy consumption

Product disposal

– Determine material and energy balance in disposal chain as basis for simulation models
– Improve energy recovery in waste recovery processes, e.g. in cement industry, and demonstrate carbon sequestration

Research policy recommendations

CORE recommends that this Energy Research Masterplan provide a basis for public funding activities. This will ensure that public funding is used effectively.

Funding principles

The main focus should be on **application-oriented energy research.** Technology transfer should be encouraged via competence centres primarily engaged in applied research and in continuous contact with industry. Priority should be given to areas of research in which skilled research groups are employed, areas which are expected to be of particular benefit to Switzerland and which will greatly promote sustainability, both nationally and globally. In order to ensure continuity in high-priority research areas, research groups should be well trained, well remunerated and have sufficient staff, funds and equipment at their disposal.

CORE believes that more public money should be invested in **networking** research and teaching institutes which form **internationally recognised competence centres,** as well as in innovative topics which are not currently addressed by the private sector. Intellectual property (patents, licences etc.) which has enjoyed public funding must be put to greater economic use.

Research in the ETH Domain and at universities

The new Federal Council Energy Policy proposes the following four ways of encouraging energy research:

- Extend research capabilities and research infrastructure in the ETH Domain, at universities of applied sciences (UAS) and at cantonal universities
- Establish new competence centres
- Replenish competitive funding for research projects
- Use SNSF funding activities (NRP, NCCR, professorships)

CORE supports these four areas of funding. Universities of applied sciences in particular should be given access to funding, in order to ensure that findings from energy research can be transferred to the market as quickly as possible.

Public sector research at federal level

An important factor in Swiss energy research is public sector research, which is primarily the responsibility of the Swiss Federal Office of Energy SFOE. This office plays a key coordinating role and despite employing relatively modest financial means, has considerable influence on the direction taken in energy research in the ETH Domain, the universities of applied sciences, cantonal universities and even in private institutions. It is also active in involving Swiss researchers in the international programmes of the IEA and the EU. CORE therefore recommends expanding public sector research into energy and in particular it recommends that funding for pilot and demonstration projects should be increased. It should be ensured that public sector research activities are appropriately coordinated.

CTI and SNSF

Suitable funding strategies should ensure that the activities of the Commission for Technology and Innovation (CTI) focus to a greater extent on energy research. When selecting its National Research Programmes and National Centres of Competence in Research, the Swiss National Science Foundation (SNSF) should also give its support to energy-related project proposals.

Knowledge and technology transfer

Switzerland has further potential in the area of technology transfer, especially in terms of cooperation between SMEs and research institutes. Activities in knowledge and technology transfer are currently mainly supply-side. We need to find new ways to identify demand and increase the transfer rate. The latter can be improved by establishing new competence centres.

Specialist training

In order to prevent a further escalation in the shortage of skilled workers in technical fields, the federal government needs to take measures to improve training at both secondary and tertiary level.