Focus on energy research
Contribution of the ETH Domain to the restructuring of the energy system
The following task force produced the ETH Domain’s basic report entitled “Energy Research: Assessment of Technology Fields and Proposals for Additional Research Activities”, 31 December 2011, on which the present publication is based:

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Dear Readers

With its decision in principle to gradually phase out nuclear energy by 2050 while reducing electricity consumption to below the 2010 level, and to do so under conditions that will enable our economy to be competitive, the Swiss Federal Council formulated the core of a new energy policy, a policy with significant consequences for our society.

Energy consumption is being decoupled from growth, and a paradigm shift in the supply and utilization of energy is imminent. Low-\(\text{CO}_2\) production of electricity from nuclear energy must be replaced by a correspondingly high percentage of new renewable energies if specified climate goals are to be met. Enormous expansion of renewable energies will be required in order to achieve this. The new energy strategy demands no less than a fundamental restructuring of the entire system for supplying, producing and utilizing energy, especially electricity.

Federal policy is based on the expectation that energy research will play a key role in this transformation process. Research and development can indeed contribute to technical solutions in the next ten years and demonstrate the existing potential in pilot projects in collaboration with industry and business. Industry and business must ensure – with the support of appropriate political conditions – that these solutions will reach the market and be implemented in a timely manner.

The ETH Domain is forward-looking and has focused in recent years on specific areas of energy research in order to help secure a sustainable energy supply for Switzerland. The emphasis has been on reducing \(\text{CO}_2\) emissions and developing energy-efficient processes. However, the Federal Council’s energy strategy demands completely new dimensions in the next few years and will lead to special new challenges. In order to meet these challenges, the performance mandate awarded to the ETH Domain must be expanded, and at the same time its budget appropriation must also be increased.

This document explains where the ETH Domain intends to build up additional capacities and what additional funding it will need in order to support the new energy policy effectively through sustainable contributions.

Fritz Schiesser
President of the ETH Board
The Swiss Federal Council's Energy Strategy 2050

The Swiss Federal Council has resolved to gradually phase out nuclear energy, and Parliament has basically endorsed this policy. Existing nuclear power plants will produce power until the end of their safe operational lifespan, but will then be decommissioned and not replaced. To implement this goal, the Federal Council has submitted its Energy Strategy 2050. Successful restructuring of the energy system according to this strategy will require very great efforts and changes – in the economy, in individual households, by consumers, in research and development, and in public policy and administration. The Swiss Federal Council’s targets are extremely ambitious because Switzerland is part of the global economy and society, and must remain competitive in order to ensure continued prosperity within its borders.

Electricity production in Switzerland in 2010

In 2010 a total of 66 TWh of electricity was produced based on a mix of 56% hydroelectric power (generating and storage facilities as well as hydraulic production) and 38% nuclear energy. The remainder stems from conventional thermal production and from waste incineration and co-generation plants. The renewable portion (not including hydropower) totals 1.3 TWh (2%). Photovoltaics and wind power each account for only about 0.1% of electricity production.

Rising power consumption

Final domestic consumption in 2010 totalled 60 TWh. After a slight increase in power demand in coming years, this figure will be reduced to 56 TWh per year by 2050 based on the Federal Council’s strategy (including expansion of pump storage to 62 TWh per year). In contrast to the “continue as before” (“weiter wie bisher”) scenario described by the Swiss Federal Office of Energy (SFOE), which foresees domestic demand reaching 83 TWh by 2050, this strategy represents a reduction through savings of 27 TWh or about 30% and replacement of nuclear energy totalling at least 20 TWh, while also retaining climate goals. This substitution is a
The Swiss Federal Council’s Energy Strategy 2050

big challenge, not only due to its absolute magnitude but also because it involves replacing largely CO₂-free electricity and base load supply. Variations between savings and replacement are possible, of course.

Overall, the final demand for electricity will be limited to 56 TWh per year (or 62 TWh per year including pump storage) through increases in energy efficiency, and in the final stage of development it will be met by about 40 TWh per year from hydro-power plus about 22 TWh per year from the other renewable energies – even if population growth to 9 million residents and economic growth of 50% until 2050 are assumed. Those are enormous changes.

The Swiss nuclear power plants can be operated until the end of their safe operational lifespan. Since they have been continuously upgraded in recent years and since safety upgrades are also planned for the coming years, a 50-year lifespan can be expected for the oldest plants. Thus the older plants (which produce one third of the total nuclear power) will go off line beginning in about 2020 and the newer plants by 2045 at the latest. The gradual replacement of these plants and the necessary increases in efficiency must therefore be achieved for the most part between 2020 and 2045. However, since the final targets can hardly be reached before 2050 and perhaps not at all to this degree, additional imports of electricity (of a quality still to be defined) and/or the construction and use of gas-fired combined-cycle plants will be necessary for a transitional period. These power plants, due to their amortisation period and their 20 to 25-year service life, will bring security and flexibility to the power supply for a lengthy transitional phase. This will mean an increase in CO₂ emissions, however, and it will be necessary to minimize this effect through separation and storage or to compensate for it appropriately.

Energy strategy: Priorities of the Swiss Federal Council (decision of 25 May 2011)

- Savings through increases in energy efficiency
- Expansion of hydroelectric power (from 37 TWh in 2010 to 40 TWh by 2050, an increase of 3–4 TWh, including expansion of pump storage by about 10 TWh by 2050).
- Development of other renewable forms of electricity generation (from 13 TWh in 2009) until the potential of 22 TWh is exhausted by 2050.
- If renewable electricity fails to meet demand, then the remaining requirement would be met by additional fossil power production – primarily through cogeneration (from 0.8 TWh in 2010 to 8.2 TWh by 2050), and secondarily through gas-fired combined-cycle plants and imports.
Fundamental restructuring of the energy system

Given Switzerland’s climate goals, the new energy strategy means that the focus must now be not only on heat and fuels but also on electricity. The partial replacement of fossil energy sources by electricity in buildings (heat pumps) and in the transport sector (electric mobility) must be considered.

The pillars of the energy strategy
- Efficiency goal
- Replacement goal
- Grids and storage
- Climate goal

Efficiency goal
The scope of the targeted savings requires a massive reduction in the final available energy per unit of the gross domestic product (kWh per GDP unit in Swiss francs). It also requires a 2 % per year reduction in energy intensity across the entire economy from 2012 to 2050 (compared with the historical figure of 0.5 % or 1 % per year in the reference scenario), which must be achieved through increases in efficiency.

This means that energy demand must be largely decoupled from economic and population growth. Such a dramatic trend reversal can only be successful if an effective reorientation of energy policy is combined with advances in the development and use of new technologies. Pre-requisites include additional efforts in the area of energy research in order to improve the energy efficiency of industrial processes, for example, and to increase efficiency in the supply of all types of energy services to end customers. In some of these segments the focus is already on development and market launches. Market penetration requires support through appropriate political measures. The decoupling goal described above must also involve consideration of “grey energy”. In other words, it cannot be achieved by simply relocating energy- or power-intensive manufacturing processes abroad (for example to China). We must prevent greater impacts on nature and the environment globally.

The goal of achieving savings through efficiency must be supplemented by careful management of the national and global energy services that are in demand. This concept of technically reasonable energy utilization must be communicated throughout Switzerland as a goal for all generations through education and training.

Challenges with the enormous expansion of renewable energies
In 2010 the installed photovoltaic capacity in Switzerland totalled around 110 MW. In order to replace the annual production of approximately 8 TWh of power by a 1 GW-capacity nuclear power plant, photovoltaic installations having a peak capacity of 8 GW are required. The manufacture of such equipment produces some 5–8 million tons of CO₂ emissions (one-time only), depending on the technology. The photovoltaic modules used to produce this output must have a total area of around 50 million or 6 m² per resident. If this capacity were to be installed within 40 years, this would mean installing every working week 25,000 m² or 400 large roof installations generating 10 kW each. This example illustrates the need to develop the related infrastructure and the installation industry.

If the 8 TWh per year were to be provided by gas-fired combined-cycle power plants as an intermediate solution, then the additional domestic CO₂ emissions would total 2.7 million tons per year. If climate goals are retained, it would be necessary to reduce these emissions through separation and storage or to compensate for them in some other way. A complete replacement of the 25 TWh nuclear generating capacity by gas-fired power plants is not contemplated.
Replacement goal
Meeting climate goals while reducing energy consumption represents a major challenge. The new policy envisions partial replacement of fossil-based energy sources by electricity in the building and transport sectors. This is coupled with the need to replace the gradually diminishing electricity-generating capacity of nuclear power plants with hydropower expansion, traditional and new renewable energies, and low-CO₂ electricity imports.

Nuclear plants generated 25 TWh of electricity in 2010, which accounted for 38% of the country’s total production. In addition to efficiency improvements, around 20 TWh of electric power still needs to be replaced by 2050. This requires an increase in the percentage of renewable energies (excluding hydropower) from around 2% to 40% – or, in absolute terms, from 1.3 TWh to almost the potential maximum of 22 TWh per year. Renewable energies must therefore be developed on a massive scale – a twenty-fold increase when regenerative electricity from waste and wood is included and several orders of magnitude when wind and photovoltaics are considered (see box on p. 6).

Experience in recent years, such as with the planned use of biomass to generate electricity (in wood-fired power plants), has shown that greater reservations and resistance to such plants also exist among the affected population. This is due to the low energy densities and the high material and mass flows that are then needed to generate large amounts of electricity. In addition, local emission levels are still too high to achieve the wide acceptance that would be required. There is therefore a greater need for research and development in the various areas of renewable energy production, but there is also a greater need for investments.

Grids and storage
A major problem of the new strategy involves replacing the energy produced by nuclear power plants, which provide a continuous supply. Energy distribution under the new concept is much different from the current concept. It will be much more decentralized and will vary sharply depending on time of day and season. The networks and storage systems will need to have fundamentally different characteristics, but they will be absolutely essential for the functionality and stability of the new system. Optimal linkage of the transmission system to the European grid is a top priority in terms of timeframes due to the potential need to import electricity as well as the interest in exporting it. The distribution grids must be expanded and modified into “smart grids” at several voltage levels in order to manage the control engineering requirements of decentralized infeed of renewable energies. The entire Swiss electric power industry is being put to the test and must play a key role in this process. Greater research efforts and associated advances in the areas of systems and storage are also of key importance. In this respect the ETH Domain faces a real challenge, but it is also well positioned.

Climate goal
The climate goal confirmed by the EU requires industrialized countries to reduce CO₂ emissions by 80% by the year 2050. In Switzerland the necessary reductions will affect the transport sector, the entire building services engineering area and industrial process heat. Efficiency-enhancing measures in these areas may involve an increased need for electricity.
Gas-fired combined-cycle power plants and utilization of natural gas will probably be unavoidable as a transitional solution for medium-term electricity supply until at least 2050. Some fossil-fuel combined heat and power plants are also part of the strategy for the period up to 2050. Because of the available gas line capacity, the limited use of natural gas seems feasible over the short term.

The goal is ultimately to restructure the economy and society with regard to energy management.

Gas-fired combined-cycle power plants and the utilization of natural gas will probably be essential as a transitional solution.

System solution necessary
The change in energy policy cannot be made in one big step. There is no measure that will solve all problems at a time. A basic reshaping of the entire system of energy provision, supply and utilization is required. Coordinated and complementary efforts throughout the entire energy system are necessary. This mutual dependence makes strategy planning and implementation, on the one hand, and the interaction between research, the business community and the policy sector, on the other, even more difficult and fraught with risk. What is needed is not simply a definite trend reversal but ultimately a restructuring of the economy and the society with regard to energy management – not just in Switzerland but internationally. The interactions between science, technology, the global economy and society must be analysed and shaped in this transformation process. The ETH Domain has the necessary expertise in the analysis of systems of this high level of complexity and can also support the management of the transformation process. It is well integrated internationally with the scientific and technological communities.
The Federal Council’s energy strategy: the expansion of hydroelectric power, including pump storage, is one of the main priorities.
Areas of action in energy research

The foregoing discussion presents definite challenges and expectations for energy research in relation to energy policy and the energy industry. Research and development can contribute to technical solutions within five to fifteen years and demonstrate these solutions in pilot and beacon projects so that they can be successfully launched within the relevant time periods – by 2035 or 2050. With respect to the five focus areas of the Swiss Federal Council’s energy strategy, research topics are listed that are considered to have great potential for helping to achieve the overall goal (cf. box p. 11) based on assessment by numerous experts from the ETH Domain (as documented in the Assessment of Technology Fields and in the basic report of the ETH Domain, cf. p. 2). Work on these topics should be supported by additional resources and stepped-up efforts. It is also important that teaching in all these areas be strengthened.

The five areas of action in energy research

- Energy efficiency
- Smart grids and interconnected energy systems
- Energy storage
- Energy provision
- Economy, ecology and society
### Areas of action and research topics with particular potential for contributing to the new energy policy and are therefore proposed for additional funding

<table>
<thead>
<tr>
<th>Energy efficiency</th>
<th>Smart grids and interconnected energy systems</th>
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<tbody>
<tr>
<td>– More efficient building services engineering</td>
<td>– Grids and their stability</td>
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<tr>
<td>– Energy-efficient industrial processes; catalyst for</td>
<td>– Injection of renewable energy into the power grid</td>
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<td>efficient process technology</td>
<td>– Urban energy systems, integration of renewable</td>
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<td>– Energy-efficient information and communications</td>
<td>energy into buildings and districts</td>
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<td>technology</td>
<td>– Integrated design of energy systems</td>
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<td>– Nanomaterials for energy technology</td>
<td>– Life cycle assessment of energy systems</td>
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<td>– Transport: lightweight composites for mobility</td>
<td>– Semi-electric mobility as a bridge to storage</td>
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<th>Energy storage</th>
<th>Energy provision</th>
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<tr>
<td>– Centralized storage technologies; pump storage</td>
<td>– Geo-energy: drilling technology, reservoir connection development</td>
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<td>or hydroelectricity, compressed air storage facilities</td>
<td>and management, flexible production of electricity and heat</td>
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<td>– Electromechanical storage; flywheels</td>
<td>– Carbon cycle (storage and utilization of CO₂)</td>
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<td>– Electric storage, supercapacitors</td>
<td>– Photovoltaics – new, efficient cell generations</td>
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<td>– Electrochemical decentralized energy storage</td>
<td>– Bioenergy – raw material basis, principles and process engineering</td>
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<td>– Efficient chemical processes for storage</td>
<td>– Wind energy</td>
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<td>– Solar energy storage in solar fuels</td>
<td>– Cogeneration of power and heat, especially using</td>
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<td>– Electrolysis for hydrogen production with photo-</td>
<td>biomass energy sources</td>
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<td>voltaic and wind power</td>
<td>– Hydropower</td>
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<th>Economy, ecology and society</th>
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<td>– Economy and management of the energy sector</td>
<td>– Careful management of requested energy services (sufficiency)</td>
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<td>including regional aspects such as smart cities</td>
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<td>– Energy policy</td>
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<td>– Impact of new energy systems</td>
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<td>– Attitude of players under alternative regulation</td>
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<td>systems and acceptance issues</td>
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<td>– International interlinking of energy systems and</td>
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<td>their effects</td>
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<td>– Careful management of requested energy services</td>
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Areas of action in energy research

Nuclear energy research
Research in the area of nuclear fission must be continued in view of the need to preserve and develop the necessary expertise in nuclear technology. This involves research on issues such as the safety of nuclear power plants and the treatment and storage of radioactive waste. It is especially important to train qualified young scientists and engineers to safely operate and later dismantle nuclear power plants. The field of nuclear energy research also involves other applications such as medical technology.

Contribution by nuclear fusion to production of electricity in line with Switzerland’s Energy Strategy 2050 is improbable.

Switzerland’s research in the area of nuclear fusion is now integrated into international research efforts and plays a key role in this global programme. In response to a request from the State Secretariat for Education and Research, the ETH Board on 2–3 March 2011 decided on its strategy for fusion research for 2013–2016. This involves participation by the ETH Domain on a scientific basis in European programmes. For this purpose, however, the appropriate funding must be made available.

Internationally, investments are being made in research on fusion as a potential option for large-scale electricity production. On the other hand, it is considered improbable that nuclear fusion will make a key contribution to electricity production before 2050. The challenge of remaining competitive given the decreasing costs of renewable energies is growing. As a result, we can assume that fusion will not be included in the planning framework for Switzerland’s Energy Strategy 2050.

Development of additional research capacities
In order for energy research to be able to make contributions in these areas over the long term, it must be gradually strengthened with an eye to sustainability. It must build on the existing expertise at academic and scientific institutions. The synergies between the research institutions that have already been active in energy research in recent years should be exploited in order to achieve the greatest possible leverage.

The existing link of research and teaching should be given special consideration. This is why it is proposed to create additional new research teams as well as new chairs and to strengthen the required academic and research-oriented infrastructure. The plan is to form and develop four new research teams every year, including infrastructure, in the defined areas (cf. box p. 13). The new chairs and teams of researchers will collaborate with industry so that the research results can be effectively integrated into industrial operations and the energy sector, and hence be implemented in practice.
### Areas of action in energy research

#### Energy efficiency

**2013–2016**
- Exploitation of nanotechnology for energy-relevant materials
- Low-energy and low-emission buildings and districts
- Catalysis centre for efficient industrial processes
- Networked, multimodal mobility with ultra-low emissions

**2017–2020**
- Industrial efficiency
- Lightweight materials for automotive engineering

#### Smart grids and interconnected energy systems

**2013–2016**
- Complex energy systems: models, scenarios and management
- New urban concepts
- High-power electronics for smart grids

**2017–2020**
- Advanced concepts for urban regions
- Integration of decentralized production into the system
- Power-autonomous districts and communities
- Efficient resource use
- Electromobility

#### Energy storage

**2013–2016**
- Thermal energy storage
- Electrical energy storage; batteries
- Electrolysis and electrochemistry
- Highly dynamic pump storage

**2017–2020**
- Solar thermochemistry
- Utilization and storage of waste heat such as through thermoelectricity

#### Energy provision

**2013–2016**
- Geothermal energy and carbon capture and storage (CCS)
- Geo-engineering
- Thin-film photovoltaics, especially manufacturing technologies
- Production of biogenic fuels
- Decentralized generation of electricity, heat or cold using biomass

**2017–2020**
- Photovoltaics
- Solar fuels
- Thermal exploitation of biogenic fuels in the decentralized generation of electricity and heat

#### Economy, ecology and society

**2013–2016**
- Energy economy and energy policy
- Resource management and socio-economic research

**2017–2020**
- Innovation and energy policy
- Society and public policy
- Resource economy
- Socio-economic research
In anticipation of the importance of the energy issue, the ETH Domain created a special focus in energy research early on (cf. Strategic planning 2012–2016 of the ETH Board for the ETH Domain as well as earlier strategic planning). In recent years reallocations have been made in favor of energy research, and high-quality projects in this area have been expanded. Approximately 140 million CHF in public funding was invested in activities related to energy research in 2009, including 115 million CHF from budgeted funds.

As one example, ETH Zurich – working in some cases jointly with other research institutions – reallocated regular funds internally to create nine chairs in the areas of electric energy research, energy storage, sustainable building and energy efficiency. In some cases, this process was accelerated by outside funding. Long-term financing is being provided by ETH Zurich and to some extent by the research institutes (in the areas of electrochemistry and catalysis, for example).

EPFL also implemented significant restructuring in the period from 2009 to 2011 that benefited energy research, such as in the School of Architecture, Civil and Environmental Engineering (ENAC). With the support of industry, a centre for energy storage and renewable energies was established as well as a chair for distributed electrical systems. Since 2011 the EcoCloud Programme has brought together a dozen EPFL institutes to pool their specialist expertise and tackle the rising energy consumption of IT systems. In January 2012, EPFL (in a joint effort with the Canton of Valais) announced the creation of 11 new chairs, including several in the area of energy research.

PSI has already carried out important reorientation campaigns in recent years. In 2011, for example, the decision was made to decommission Proteus, the last and only zero-power research reactor. Important research infrastructures were created for the Competence Center Energy and Mobility (CCEM), which was initiated by the ETH Domain. The activities of the Bioenergy and Catalysis Laboratory were refocused from material cycling to the utilization of bioenergy and catalysis. The newly created Catalysis and Sustainable Chemistry Laboratory has established advanced methods for characterizing catalysts by using the Synchrotron Light Source (SLS).

Given the high expectations of federal government policies, energy research efforts will have to be stepped up in the coming years.

Empa has also created an efficient new infrastructure for energy research using institutional funds, which includes an engine bench dynamometer and a wind tunnel for building research. The staff of the Energy and Environment area has been increased, and a new department called Hydrogen and Energy has been created. Many of the material research activities are related in important ways to energy.
The ETH Domain has therefore already committed considerable resources from basic funding to energy research in recent years and is continuing to do so with the aim of maintaining this high level in coming years. However, the Swiss Federal Council’s decision in principle on 25 May 2011 and the high expectations of federal government policies demand that these efforts assume totally new dimensions in the coming years. In order for research on the topics listed above to be expanded and intensified, additional funds are vital. The development of a team of researchers at one Federal Institute of Technology or one research institute will cost an average of 2 million CHF per team per year.

This leads to the following year-by-year breakdown of the additional funding requested for the ETH Domain relative to the legislative period 2013-2016 (cf. fig. 3). Continuation of this build-up process is proposed for the subsequent period 2017–2020.

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<td>New teams</td>
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<tr>
<td>Operating teams</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
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<tr>
<td>Cost/year for all operating teams in million CHF</td>
<td>8</td>
<td>16</td>
<td>24</td>
<td>32</td>
<td>80</td>
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Proposals for a financing model involving balanced contributions through basic financing and competitive funding are being developed in conjunction with the action plan “Coordinated Energy Research Switzerland”. The decision regarding the allocation of approved funds from the additional basic financing that has been requested will be made by the ETH Board. It will base its decision on scientific research plans and curricula with the goal of supporting implementation of the energy strategy. The team selection process and quality control will follow established procedures.

The magnitude of the challenge and the complexity of the systems require research networks and nationwide collaborations. The magnitude of the challenges and the complexity of the systems require research networks and nationwide collaboration between the ETH Domain, universities, universities of applied sciences and industry. For this reason, competence centres are to be created or existing successful centres given an expanded mandate to pursue these objectives based on participation by all the aforementioned educational and research institutions; these will focus on collaborative projects that address the major challenges facing the energy system. These thematic networks will be financed through public private partnerships, funding from the global budget and also with competitive second- and third-party funding.

The strategic use of these additional resources will be necessary until 2020 so that the required
Areas of action in energy research

Technologies will have a chance, through project implementation and market launches, to help achieve the energy policy goals for 2035 or 2050 (cf. conclusion p. 18). Interaction with industry, as described in the following sections, will be essential for developing research results into innovations that can be launched as marketable products.

Investments in infrastructure and in pilot and demonstration facilities

Two steps are necessary for taking innovative technologies from the laboratory scale to the point where industry is willing to take over development. Scaling up technologies to laboratory pilot plants at the research institutions that test technology on an industrial scale requires investments in infrastructure. Based on this infrastructure, actual pilot and demonstration (P&D) facilities can be built "in the field" and, as non-commercial prototypes, require co-financing by public and private (industrial) funding. Public funds should be used where the risks as well as the opportunities are great. The financing volume of the proposed projects is based on estimates by experts who are directly involved.

The recommended investments in infrastructure are necessary for the work of the newly created research teams and cover areas with major potential for contributing to the energy turnaround. Since they are the prerequisite for subsequent implementation, the focus is on the 2013–2016 budget period. The proposed allocation to the two budget periods is a way to set time priorities. The financing for these investments is not integrated into the budget appropriation for the ETH Domain based on the ERI Dispatch for 2013–2016 and cannot be covered. The investments can therefore not be made without additional resources for basic financing.

At both Federal Institutes of Technology, implementation of the new infrastructures is closely tied to the selection of the chairs that are due to be created. Part of the associated expenses is included in the development costs for the teams. In the areas of advanced energy concepts and industrial efficiency, investments for the laboratory infrastructure are required for the period from 2013 to 2020. The construction and operation of large infrastructure facilities are one of the key responsibilities of the research institutes, in particular.

Some of the suggestions for the realization of research and technology transfer platforms (RTTP) are listed below as examples. The total funding, which consists of institutions’ own contributions, investments, and research achievements made through the action plan "Coordinated Energy Research Switzerland" is likely to run into the double-digit million range for almost all of the projects, which have different time frames.

- NEST research and technology platform for sustainable and energy-efficient building technology (Empa)
- Smart Campus – role model function of the sites (ETH Zurich, EPFL, PSI and Empa/Eawag)
- Utilization of deep geothermal energy (ETH Zurich)
- Carbon capture, storage and utilization (CCS) (Consortium from the ETH Domain)
- Use of hydroelectric power (flexible pump turbines and small hydropower plants) (EPFL)
- Solar energy use (photovoltaics, thermal solar energy, integration) (EPFL)
- Conversion of biomass into methane (PSI)
- Conversion, chemical storage and exploitation of new renewable energies (PSI, Empa)
- Experimentation equipment for nuclear safety research (PSI)

Public funds should be used where the risks as well as the opportunities are great.
Areas of action in energy research

P&D facilities will serve as “flagship projects”, demonstrating tangibly – and on an appropriate scale – the potential of new solutions to society, government and the energy industry. They will be put out to tender and planned by the Swiss Federal Office of Energy (SFOE) in consultation with industry. The plants will generally be built by industry, which then has the opportunity to test new processes developed by the research community on a larger scale. The Swiss government will participate appropriately in the financing of the P&D facilities through SFOE.

ETH Domain researchers will participate in formulating proposals for P&D facilities, provide support during construction, and then personally carry out measurements and tests at the installations in the field.

Some ideas from the research community for P&D projects, along with estimated total cost, are listed below. More specific project proposals need to be developed later in close consultation with SFOE.

- Innovative building services engineering (20 million CHF)
- Demonstration of smart grids with integrated decentralized storage (costs depend on the size of the pilot region)
- Test drillings for geothermal projects (five boreholes at 40 million CHF each)
- Demonstration plant for the production of methane from wood (28 million CHF)
- Implementation of a swarm of decentralized combined heat and power plants using biogenic fuels (15 million CHF)
- Chemical looping combustion (CLC) as a method for CO₂ separation in gas turbines (11 million CHF)
- Demonstration of the production of liquid fuel from lignin (14 million CHF)

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- Innovative building services engineering (20 million CHF)
- Demonstration of smart grids with integrated decentralized storage (costs depend on the size of the pilot region)
- Test drillings for geothermal projects (five boreholes at 40 million CHF each)
- Demonstration plant for the production of methane from wood (28 million CHF)
- Implementation of a swarm of decentralized combined heat and power plants using biogenic fuels (15 million CHF)
- Chemical looping combustion (CLC) as a method for CO₂ separation in gas turbines (11 million CHF)
- Demonstration of the production of liquid fuel from lignin (14 million CHF)

Building services engineering, which is part of the energy efficiency focus area, is a high priority field. It is therefore important to demonstrate innovative approaches and thus create incentives for wide-scale implementation. Decentralized energy storage in smart grids is also a key element of energy strategy.

The production of electricity from geothermal resources is a production technology with high technical potential. In order to develop it, expensive test drillings are indispensable. Universities of applied sciences and traditional universities should also be involved in these projects.

There are synergies between the geological investigations required for geothermal electricity production and those concerned with possible deposition of CO₂ in formations below Switzerland’s Central Plateau and in the Canton of Valais. In the case of the latter application, Swiss researchers must take advantage of the technical and social experience acquired in European pilot projects. In this context, chemical looping combustion is one of the technologies that can be applied when CO₂ from gas-fired combined-cycle power plants is to be isolated (captured) and then stored in repositories.

The production of methane from wood and of liquid fuel from lignin is an immediate priority since both processes utilize biomass, a domestic renewable resource, and convert it into high-quality, storable and transportable chemical energy sources.

It is important to note that P&D plants will also be necessary beyond 2020.
Conclusion: increased funding and coherent policies

Additional funding is essential for the proposed research contributions by the ETH Domain. Special efforts require special resources. Helping to strengthen energy research by allocating funds within the ETH Domain from the 2013–2016 budget appropriation would necessitate considerable financial cuts in other specialized areas. This would undoubtedly provoke sharp and swift political responses from the respective scientific communities in government and society. The ETH Domain has already changed its focus substantially in recent years, which has also benefited the energy area. Unless additional federal funding is provided, the ETH Board will be forced to reject additional responsibilities of the financial magnitude demanded by the Swiss Federal Council’s energy strategy. Performance cannot be significantly increased solely through efficiency enhancement measures, shifting of resources and setting of new priorities. Given the Swiss Federal Council’s decisions regarding implementation of its energy strategy, the performance mandate to the ETH Domain must be expanded and the budget appropriation increased accordingly so that the ETH Domain will be able carry out the additional tasks.

A coherent long-term energy policy is necessary

Successful contributions to energy research require the effective support of a coherent long-term energy policy. Energy research creates the foundations required for widespread implementation in order to achieve the Swiss Federal Council’s goals. In this area the ETH Domain strives to work closely with the universities and the universities of applied sciences. Research and development (R&D) can make a substantial contribution if complementary measures in energy policy are taken. Implementation aspects and stakeholders must be integrated into R&D at an early stage. The entire innovation value chain must be included. The need for newly developed solutions, as well as their suitability, must also be confirmed by the market, the investors and the users.

Socio-economic research must begin at the interface between technologies and public policy, and must also play a role. Research and development projects in many different disciplines open up new ways to solve energy problems. They identify causal relationships, new solution approaches and potential benefits. The opportunities that are opened up as a result must also be effectively exploited and widely implemented, for otherwise they will have no effect. They must be accepted, adopted and put into practice by a large number of companies and households. And that is where government must also meet very challenging responsibilities. It must create effective and success-
Conclusion: increased funding and coherent policies

Indispensable prerequisite: close alliance between government, industry, society and research
The research community develops solutions and – through teaching – imparts the necessary specialized knowledge to future experts, whereas the government defines the basic conditions and legal framework. However, the actual implementation of these solutions lies in the hands of industry and the business community. That is why it is extremely important for industry to be included at an early stage in the definition of research projects. It is also why P&D projects – the preliminary stage before implementation – are of great significance. Feedback from the practical sphere to the research sphere based on experiences that can only be acquired during application is a crucial element in this. Research and development can only contribute effectively to meeting the goals of a very ambitious energy strategy when supported by companies’ investment decisions and households’ consumer decisions. Technological development, application and dissemination of new energy concepts, and the shaping and implementation of a well-designed system of incentives must go hand in hand.

The magnitude of the challenge represented by the reshaping of our energy system could be likened to the Marshall Plan for Europe. The initiation of urgently needed and effective steps requires a drastic speeding-up of implementation. Only if additional capacities are made available will the ETH Domain be able to develop the portfolio of specific concepts described in this report by 2020, demonstrating them in beacon projects so that their implementation in the energy system by business and government can meet the goals set for 2035 and 2050.
ETH Domain publications on energy research
– ETH Board, Strategic planning 2012–2016 of the ETH Board for the ETH Domain, Zurich 2011

Basic documents

Cover
Zurich Oerlikon by night: with the population and economy constantly growing, demand for electricity continues to rise.

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