Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy SFOE

Public Energy Research in Switzerland

Summary

Editorial

Dear readers

Energy research is a central element of future-oriented climate and energy polices. High quality research must point the way to a dependable, efficient, environmentally benign and economically viable energy supply system for the future. The benefits from well-executed energy research are quite evident: Technical innovation leads to increased energy efficiency, and more effective use of renewable energy conserves our natural resources. As a result of these efforts new jobs are also created. Export of such innovative energy and environmental technologies strengthens the Switzerland's position as a research and knowledge leader and contributes to reducing the threat of global climate problems.

The development of new energy technologies often spans decades. Good research simply requires time, is expensive and may include high risks. Exactly for these reasons public financing is essential. Thus financial risks for an institution engaged in innovative research can be reduced and a long-term impulse provided. In this manner achieving a future-oriented energy supply can be effectively pursued and activities can be carried out which are essential to preserve Switzerland's technological position.

Energy research is much debated and written about, but how it is organized, which fields are pursued and the achivements of the researchers are less well known. This brochure serves to illuminate the main areas and activities of Swiss energy research.

Walter Steinmann
Director of the Swiss Federal Office of Energy

Impressum

Brochure on energy research in Switzerland. Spring 2011. Available in German, French, Italian and English.

Editorial and production

Swiss Federal Office of Energy SFOE, 3003 Bern, Switzerland.
Phone 031 322 56 11, Fax 031 323 25 00
contact@bfe.admin.ch
www.bfe.admin.ch

Editorial team

Swiss Federal Office of Energy SFOE;
Almut Bonhage, Bonhage PR; Philippe Gagnebin;
Jürg Wellstein, Wellstein Kommunikation.

Translation

Suter Consulting

Layout and design

Agence Symbol, 1763 Granges-Paccot

Sources of illustrations

Cover SFOE

p. 2 SFOE; p. 3 Alstom Schweiz AG; p. 5-7 SFOE; p. 9 Encontrol GmbH, Niederrohrdorf; p.10-11 Mark Zimmermann, Empa; p. 12 ETH Zürich; p. 13 Mes Dea; p. 14 Lonza AG; p. 15 ETH Zürich; p. 17 Liebherr, Bulle; p. 18 Wärtsilä Schweiz AG; p. 19 Alstom Schweiz AG; p. 20 PSI; p. 21 Hochschule für Technik Rapperswil; p. 22-23 VHF-Technologies SA, Yverdon-les-Bains; p. 24 Airlight Energy SA; p. 25 EMPA; p. 26 Jürg Wellstein; p. 27 Blue-Water-Power AG, Schafisheim; p. 28 Holzverstromung Nidwalden Korporation Stans; p. 29 PSI; p. 30 Geopower Basel AG; p. 31 Meteoswiss; p. 33 ETHZ/PSI; p. 34 www.iter.org; p. 36-37 SFOE; p. 38 Institut de Microtechnique, Neuchâtel; p. 40 SFOE.

”We need a vision in order to correctly set goals”

According to Tony Kaiser, president of the Federal Energy Research Commission (CORE), Swiss energy research is high quality. Increasingly energy and climate polices, that is the reduction of greenhouse gases shape energy research activities. The challenges are great; in demand are a long-term oriented energy polices and commensurate budget.

Tony Kaiser

Tony Kaiser holds a PHD in physical chemistry from the University of Zurich. Today he is employed by Alstom, Switzerland (AG). As director of ”Future Technologies”, he is responsible for long term research in the area of power. Since 2002 he has been a member of the Federal Energy Research Commission, CORE and he has been president since the beginning of 2004.

Tony Kaiser, why is energy research important for Switzerland?

There are two reasons why energy research is important for Switzerland: First, energy research should deliver the necessary technologies to meet our own energy demand in a sustainable manner and be based on the broadest possible energy mix. Second, the export potential and jobs are a particularly important factor for our economy. With our broad basis of technical competencies we can successfully bring products onto the world market. Such economic development of sustainable technologies is a driving force behind Swiss energy research.

What is the purpose of CORE?

The CORE's main function is to advise the Federal Council (the federal executive branch) and the Swiss Federal Department for Environment, Transportation, Energy and Communications (DETEC) in areas of energy research. This assignment was defined as the mandate of the CORE at its founding in the year 1986 by the Federal Council. The 15 members of CORE represent industry, energy businesses, technical universities as well as different authorities committed to promoting Swiss energy research. Together with the Swiss Federal Office of Energy (SFOE), every four years the CORE defines and updates the Swiss Federal Energy Research Master Plan. This document formulates recommendations for Swiss energy research. Input is given by experts, including the leaders of the research programmes of the SFOE.

As president of the CORE how do you see Swiss energy research polices?

Swiss energy polices are oriented towards revising the CO_2 law aiming at and fulfilling goals being discussed in Europe and worldwide. These goals are based on knowledge in the area of climate research and aim to stabilize global temperature increases to between +2 to +2.5 K by 2100. This recognizes that Switzerland must also drastically reduce global greenhouse gas emissions, in particular CO_2. To achieve drastic reductions, substantial increase in the efficiencies of all energy conversion processes and services are necessary. Essential are major reductions in the consumption of fossil fuel based energy production as well as the full realisation of the potential of renewable energy and low CO_2 technologies in general. In the long term visionary concepts, such as the ”2000 Watt Society” or the ”1 ton CO_2 per person and year” are important to emphasize that strong and not just cosmetic corrections are essential.

What can the CORE contribute?

Already in the Master Plan 2008 - 2011, developed about three years ago, we established four interim goals to be achieved by the year 2050 in the true sense of energy politics:

- no more fossil fuels to heat buildings and produce hot water,
- halving the energy demand of all buildings in Switzerland,
- realizing the fullest potential of biomass, and
- achieving a fleet average of 3 litres per 100 km for all private automobiles.

CORE

In 1986 the Swiss federal executive branch established the CORE (Commission fédérale pour la recherche énergétique) as its consulting body and also to advise the Deparment of Environment, Transportation, Energy and Communications (DETEC). Every four years the CORE prepares the Swiss Federal Energy Research Master Plan. This concept guides the planning of publically funded energy research and the amount of funding necessary to help achieve policy defined energy goals. The CORE, with its 15 members, examines and accompanies Swiss energy research programmes.

www.energy-research.ch

We have set clear priorities and focus on the two main areas: buildings and mobility. The goals were deliberately chosen to be very pragmatic and visible. Achieving them by 2050 would result in halving our emissions and bringing us very close to the CO_2 goals we discuss today.

Buildings require a lot of energy resulted in clear successes but at the same time energy research. How is this going to continue?

In fact, much has been achieved in this sector and the research continues with ambitious goals, including: houses with zero-energy emissions, CO_2 neutral buildings and even buildings which produce more electricity than they consume. Researchers are working today on architectural concepts with solar use combined with highly efficient thermal insulation and glazing systems with defined light transmission properties. I am thinking also about innovative heating and cooling systems, concepts for standardizing the renovation of buildings to reduce energy demand, and so forth. And, when we think about building-integrated photovoltaic panels, it is only a small step to consider ″smart grids″. Such clever electric grids already have taken form in research laboratories.

What is the significance of the next energy research Master Plan for the period 2013 to 2016, with respect to comments by some, that global warming, though now irreversible, may be stabilized albeit with drastic measures?

Certainly, the latest insights from climate research will influence our next Master Plan. We wish to emphasize the fact that new energy technologies have to offer efficient and low CO_2 energy services. To this end we will try to be even more explicit than before in formulating thematic research topics, such as the project: ″living and working in the Future″ or ″Mobility in the Future″. We will strive to facilitate application oriented clusters of individual programmes. Researchers should be motivated to cooperate more than in the past. This new structure and context will also help in judging projects in the sense of overall goal setting, and will enable some concentration of available funding on high-priority topics.

Is it not difficult to come to an agreement on a single energy research Master Plan, given that the CORE consists of 15 individual members with very different backgrounds?

On the one hand, the CORE members are recognized specialists in the energy field. They are constantly in search of first class arguments but are not politically motivated. On the other hand, discussions within the CORE take place in a very constructive manner. In this way, it is possible for us to develop an energy research Master Plan which considers all stakeholders. Finally, the Energy Research Conferences provide an ideal discussion platform with participation of a broad range of interest groups to present our Master Plans.

Publicly funded energy research: a contribution to sustainable development

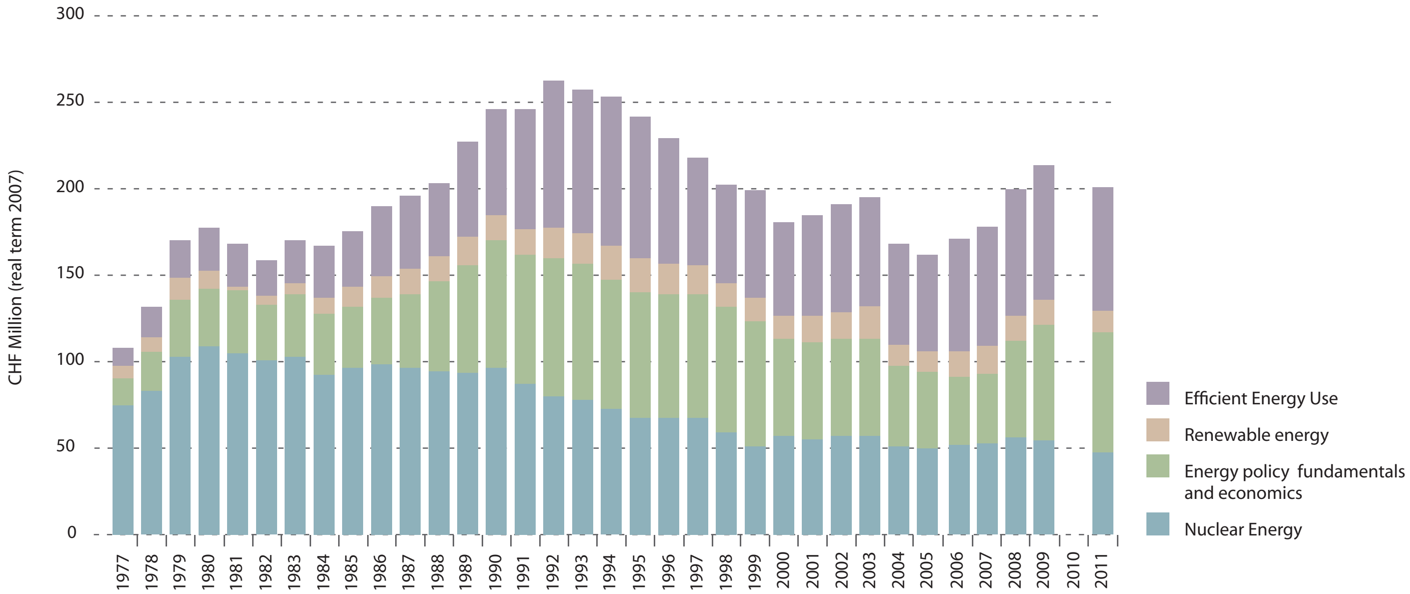
Energy research is the foundation for our future energy supply, for innovation and for economic growth. Thereby, publicly funded energy research is of central importance. It provides an impulse, helps establish research networks and builds bridges to the economy. It has the very important objective of contributing towards meeting future energy demands in an efficient, economical, clean and safe way.

Generally, research is carried out at the beginning of a process with culminates in the successful introduction of a new product into the market. In the field of energy the time span between research and market entry often requires several decades. Private enterprises, with pressure for a fast return on investment, are often is to risk investing in such long-term research projects. Publicly funded research, in contrast to privately funded research, looks beyond day-to-day operations.

Although quite modest in magnitude, public investment in energy research is, however, effectively applied. Today, public funding amounts to about CHF 175 million annually. This is less than at the beginning of the 1990's when totals were up to CHF 200 million per year. Still, today's public research funding represents about 0.3‰ of GDP, placing the nation in the same league as leading countries like Finland, Sweden or the Netherlands.

Given the need to advance technologies that support sustainable development and given the threat of energy supply shortages and climate change, must additional public resources be made available for energy research.

Public expenditures for energy research since the beginning of data collection in 1977. The values given for 2011 are as proposed by the CORE.

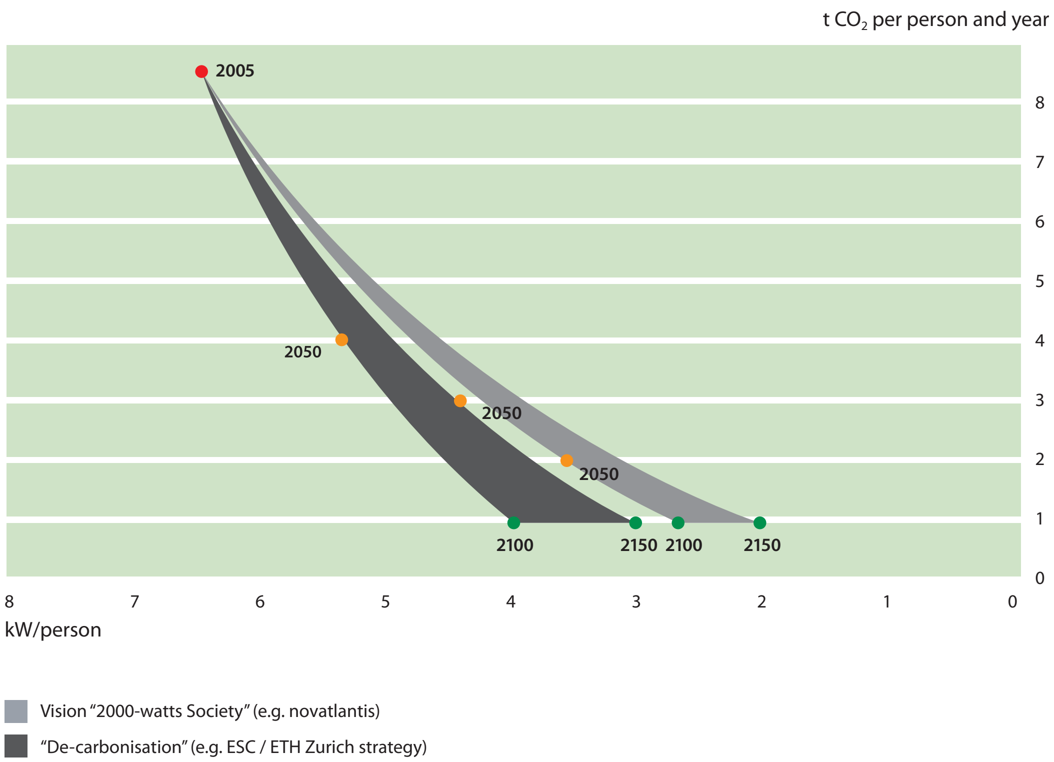


A new approach: the vision of a "2000 Watt Society"

Swiss energy research is guided by the Swiss Federal Energy Research Master Plan, which is updated every four years by the Swiss Federal Energy Research Commission (CORE) (see page. 3). The Swiss Federal Office of Energy (SFOE), aided by the CORE, is responsible for the implementation of the master plan.

The goals for energy research are based on the energy and climate policy goals of the federal government. Switzerland requires 6,500 watts of primary energy per person, which results in around nine tons of CO_2 emissions per person annually. In order to achieve sustainable energy consumption, the vision: "2000 Watt Society" was formulated. In the meantime, considering the strong climate change and necessity to de-carbonisation existing energy systems, the ETH-Zurich defined the vision "1 ton CO_2 per person and year". While both concepts strive to achieve a marked reduction of greenhouse gas emissions, the 2000-Watt Society also pursues a major reduction of the overall energy consumption. Both visions serve as a foundation to define national research programmes and their individual projects.

Swiss energy research has a clear direction. Research projects are considered to be of central importance when they strive to improve energy efficiency and increase renewable energy use. The ultimate objective, as formulated in a constitutional article on energy, is sustainable development. This is reflected in the Master Plan by a commitment to a long-term vision for an ideal energy and environmental state. This vision has been titled: "The 2000 Watt Society" (see page 4). In this society energy consumption per capita has been reduced to one third of its current level, and annual CO_2 emissions have been substantially reduced by a factor six to about one ton per person. The Master Plan also defines concrete, short-term goals which can be put into effect towards reaching the long-term goal. These are updated every four years with each adjustment of the Master Plan.



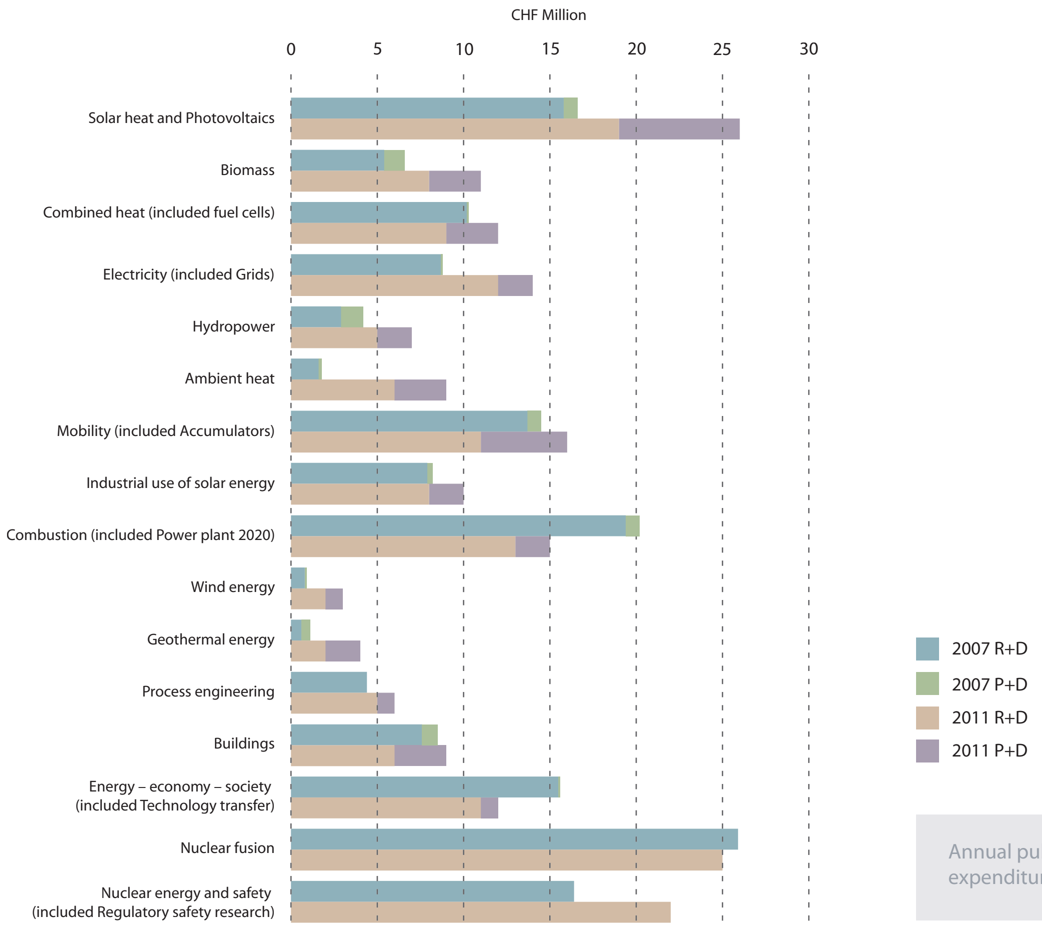
The SFOE, with its 25 research programmes, is a main player in the Swiss energy research scene (see page 41). It continuously supports 250 to 300 research projects with supplementary funding and accompanies the scientific and technical work. It also serves as the gateway to Swiss research for other national or international funding agencies and organizations like the European Union and the International Energy Agency.

Hand in hand with industry

Supporting energy research is not the prerogative of the government alone. Swiss businesses also show a strong interest in investing in the energy future. In fact, the investment in energy research by industry is nearly four times greater than the investment from public sources.

The combined investment of public and private sources totals roughly CHF 1 billion. However, a substantial part of industry-sponsored research is devoted to product development. Hence, for energy research per se, the public and private sector investment is nearly equal.

Public funds are also available for private research. Companies willing to invest in risky projects are given special consideration. This has lead to increasingly close research collaboration among industry and public bodies since the end of the 1980's. One speaks today of close public-private partnerships and indeed today industry has a say in the definition of government energy research directions.



Annual public expenditures for 2007

65% of the resources for applied research

The ultimate goal of energy research is market compatibility and practical application. Hence, research covers almost the whole spectrum from fundamental research to market introduction of the product. Applied research is emphasized, receiving about 65% of the total budget. Research must result in products, installations, materials and processes. Fundamental research accounts for about 31% of the total. It is sponsored under the condition that at least potential uses for energy technologies are identified.

Pilot and demonstration plants currently account for a mere 4% of the total funding, though they are absolutely essential as a bridge between research and market.

Ensuring a transfer of publicly funded research results to the market place is a responsibility of public institutions disbursing research funds. Accordingly, close collaboration with the private sector is not only advantageous, it is absolutely essential.

A stakeholders network

The Swiss Federal Office of Energy (SFOE) coordinates energy research in close collaboration with other public institutions that support research. Specific examples are the Board of the Swiss Federal Institutes of Technology, the State Secretariat for Education and Research (seco), the Federal Office for Professional Education and Technology (OPET) through the Innovation Promotion Agency, the Swiss National Fund for Scientific Research (SNSF), the universities and universities of applied science, and private grant-giving foundations of the energy industry.

A large proportion of the research projects are conducted by public scientific institutions. The main federal institutions are the Swiss Federal Institutes of Technology in Zurich (ETHZ) and Lausanne (EPFL), the Paul Scherrer Institute (PSI) and the Swiss Federal Laboratories for Materials Testing and Research (EMPA). At the cantonal level, universities and universities of applied sciences are involved. Apart from this, public bodies often grant financial aid to industry, to engineering consultancies and to private individuals. Such projects are operated, when possible, in partnership with public research establishments. An underlying principle of the Swiss Federal Office of Energy is subsidiarity; public funding should primarily serve to trigger new projects and top-off project budgets if needed.

International collaboration is a must!

Switzerland's energy research is not isolated from the rest of the world; international co-operation is a must, as it provides advantages to all participants. In particular it makes use of synergies, avoiding duplication. Thereby overall research efficiency increases. International projects are a tradition, in particular within the framework of the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA). Moreover, Swiss participation has increased in framework programmes of the European Union.

Energy research strives to be a corner stone to achieve a sustainable energy system in Switzerland. To accomplish this, researchers cannot remain in an ivory tower; they must interact with other disciplines and with practitioners. In this process economic, political, social and ecological factors must be considered. By adopting an active communication policy, public bodies, among others, are tasked to inform the wider public about results achieved in energy research.

Thinking of everything when designing processes

Good practice in process engineering can lead to up to 20 percent energy savings in industrial applications. Mathematical analysis of processes and simulations can identify the economic, ecological and energy saving impacts of different process designs. In addition to increasing energy efficiency, research is also striving to increase the use of renewable energy in industry.

Priority is, however, given to improving thermal processes. Example applications include drying, production of speciality chemicals, the food industry and agriculture.

Bringing together the key knowledge parties

Through applied research, energy use can be optimised and the ecological impact of processes minimised. A project typically begins with an industry partner expressing a need. A research activity is then initiated. This may be in the form of engineering a needed measurement technique or modelling a process. Success depends on bringing together the right specialists, process engineers, energy experts and researchers.

In practice it can be observed that a good technical solution considering all aspects is only applied when there is an economic gain in the end. Production processes, above all, must deliver the required quality and productivity. Energy use and ecological impact are also important, but secondary. An impediment to change is the certification of production and safety.

Improving complex production processes

A basic principle, particularly in the case of complex thermal processes is: first analyse and then optimise. In one example, the process chain of a clay masonry manufacturer was studied in order to develop a computer-supported optimisation tool. This tool was to enable processes to be carried out with a lower energy consumption but maintaining the same product quality. This goal was unfortunately not achieved because measuring the firing process proved more complex than anticipated.

Better results were achieved for a chemical manufacturer. The ETH Zurich developed a computer programme "ecosolvent" which was instrumental in improving the use of energy and resources by this company. It was possible to assess the recycling processes for waste solvents by means of distillation or alternatively, burning the waste solvents to produce useful heat. The analysis showed that recovery of solvent is not always the best ecological solution.

Sought: energy conscious industry partners

Energy-intensive industry branches are a target for further advances in energetic process engineering. Their processes can be made more energy efficient and CO_2 emission reduced through process engineering research and development.

Keywords

Waste heat use
Waste heat up to 200 °C from processes can be utilized. This, too, is an essential part of economic and ecological optimisation.

Process heat and cold
Process heat is normally generated by oil or gas fired plants. Cold is produced by electrically powered machines. Decision-makers often do not trust the quality or dependability of alternative energy systems to produce heat or cold. Hence alternative energy use is seldom considered in engineering a process. Convincing evidence to encourage such use can be supplied from feasibility studies, laboratory investigations and from monitoring plants.

Greenhouses in Steinmaur are now heated by burning wood instead of oil. The challenge for the process engineer was to guarantee the supply of heat quickly enough from normally rather slow responding wood combustion, in order to respond to the drastic changes in solar radiation and cloud cover that would otherwise lead to greatly varying greenhouse temperatures. The solution lay in calling on hourly weather forecasts from Zurich-Kloten as input to automatically determine the control strategy. This system has been in operation and proven effective since the beginning of 2006. It is a first in Switzerland.

Energy consumption: down – Comfort: up!

Buildings require approximately half of the primary energy in Switzerland. Of this about 30 percent is consumed for space heating and cooling, and water heating; 14 percent for electricity use; and 6 percent for construction and maintenance. Residences amount to 27 percent of this total national energy consumption. Fossil fuels such as petroleum and natural gas dominate the energy supply. Buildings therefore represent a substantial burden of climate. Building research in Switzerland is targeted towards developing technologies to reduce this burden and pave the way towards a 2000-Watt Society. In the foreground is the optimisation of the whole building as a system and research into new materials and components.

Renovation is affordable

A wide choice of technologies is available to substantially reduce energy consumption in new buildings at reasonable additional costs. In a building designed to the Minergie-P Standard (see key words) heating energy consumption is reduced to such an extent, that it is hardly worth mentioning. Also in structures constructed to the normal "Minergie Standard" (see key words) or the target values of the "SIA-Standard 380/1" heating consumption can be reduced to only slightly more than half of that used by conventional buildings.

Applying ecological building standards only to new building construction is, however, insufficient. An important opportunity to save energy lies in the renovation of existing buildings. Parliament recognized this and implemented a subsidy through a national building renovation programme. Due to this support, but also due to rising heating oil prices, a strong incentive to renovate buildings is expected. Accordingly, the research programme should develop concepts, technologies and planning tools for renovating buildings considering the specific situation of existing buildings (see the example).

Today, the knowledge and proven technologies required to meet many of the goals of the 2000-Watt Society are available. To show how buildings can contribute to their part of this vision, the Swiss Professional Society of Engineers and Architects (SIA) has developed an instrument, the "Energy Path". It includes target values for individual energy end uses of space heating, ventilation and cooling; hot water production; lighting; and appliances. Starting in 2010, gray energy and location induced mobility are included in the Energy Path.

Light and heat transmission in conflict

In the area of lighting the building research programme is concerned with the building as a comprehensive system, for example lighting concepts in combination with optimal daylighting. Appliances and lighting fixtures are addressed under the subject of electricity research.

A principal topic of the programme is the development of glazing systems with optimal energy and light transmission properties for a given situation. Nevertheless, a transparent façade continues to be a weak element of the building envelope. Even the best glass today is suboptimal regarding its ability to admit daylight but hold back thermal radiation. At the University of Basel new optical coatings are being investigated and at the EMPA vacuum glazing is being further developed. The latter offers the potential of halving the thermal conductivity compared to the best glass currently available.

Building renovation with prefabricated construction elements
A Minergie-P renovation of a multi-family building in Zug. Prefabricated, highly insulating façade elements make it possible today to efficiently renew and add a floor to an existing building. The heat losses can thereby be reduced to 10 to 20% of the original losses. (Photo: Mark Zimmermann)

Room climate comfort and energy savings

Energy efficiency in the conditioning of spaces no longer means simply frowning upon air conditioners. Nobody really wishes to sacrifice the comfort of a cooled room in the heat of summer, particularly inoffices. The key topic today, is "gentle cooling". The key to this is the co-ordination of all factors affecting room temperature. This system optimisation approach allows the optimisation of room climate with minimal energy consumption. In any case, the quality of the building envelope, sun-shading and room geometry remain the main factors influencing summer comfort in a room. In winter energy demand can be dramatically reduced by means of a high level of insulation, optimised mechanical ventilation with heat recovery and the use of passive solar gains.

High performance insulation and new cooling systems

New materials for both high performance insulation and new cooling systems are already in the pipeline. That is, they work in the laboratory, though they are not yet ready to be marketed. For the building envelope impressive progress has been made with vacuum insulation. In order to apply it in construction, solutions must be found to protect it during installation and anchoring.

For cooling a significant breakthrough is expected with magnetic cooling at the University of Applied Science in Yverdon-les-Bains. When they succeed one may see air conditioners in automobiles and offices as well as refrigerators no longer operating with HFC, ammoniac or CO_2 compressors, but rather via direct magnetic cooling.

Distributed energy production

Buildings of the future will not only be the places where energy is consumed, they will also be designed to be the sites of distributed power production. This is thought of with regard to the use of photovoltaic systems and fuel cells.

Keywords

Life cycle analysis
Life cycle analysis serves to evaluate the ecological and economic performance of materials, systems or appliances. In the case of buildings, not only the energy consumption during its useful life is considered, but also "grey energy"

Grey energy
Grey energy is that energy consumed to acquire raw materials, process them, manufacture an item, store, then to transport and install it. This is in contrast to the energy consumed during the useful life of the component once it is installed.

Minergie standard
"Minergie" is the most important energy standard in Switzerland for low energy buildings. The Minergie Association certifies buildings which fulfil its standards in the twelve building categories covered. Currently about 15 percent of new buildings and 1 percent of existing building renovations are certified with the Minergie label.

Minergie-P-house
Minergie-P is a very high energy standard for buildings. A building of this standard affords year-round comfort without the need for a conventional heating system. Housing, office buildings, factories, kindergartens, schools, sports halls and supermarkets are already built to this standard today.

Vehicles should become more efficient, lighter and more intelligent

Transportation accounts for about a third of Switzerland's energy consumption. Of this about 70 percent ower to automobile traffic. In spite of considerable improvements in efficiency for the nation's car fleet, the energy consumption for this segment has remained relatively constant. Increases in the weight of vehicles and power of motors as well as increased traffic capacity have offset higher efficiency. The main thrusts for research and development are improving or creating new drive trains, lighter vehicles, small mobility systems and public transportation.

Fulfilling high ambitions

Modern vehicles possess exceptional performance with regard to minimal exhaust gases, safety and dependability. These qualities must not be compromised by efforts to reduce energy consumption. The average fuel consumption of recently matriculated automobiles in Switzerland is 7.43 litres per 100 km (2007) and the average efficiency of a modern passenger car is less than 20 percent. As a result of researching the power train, the efficiency can be expected to be improved to well over 20 percent. At the same time, vehicles should become substantially lighter, thanks to the strategic use of new materials, without compromising safety. As a long-term goal, future cars should consume less than 3 litres of gasoline equivalent per 100 km.

Efficient power train

Swiss research in the area of power trains pursues a combination of strategies:

- Downsizing the internal combustion motor and further improvements of the motor and gear box;
- Hybrid thermal power trains;
- Natural gas and biogas as a fuel, synthetic or bio-fuels;
- Electric power trains with batteries and/or ultra-capacitors and/or fuel cells.

The order of these approaches reflects their expected market penetration. All of the efforts supported by the SFOE (Swiss Federal Office of Energy) have been able to be, at least partially, applied in Switzerland.

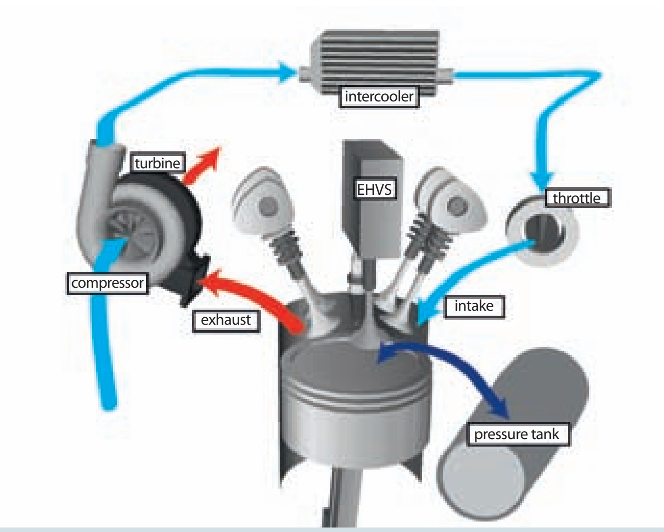
The mass of a vehicle strongly affects its fuel consumption

Light construction of a vehicle rests on using materials of lower density, choosing intelligent constructions and by means of bionic-simulation. Current approaches to light construction will be further pursued. Aspects of safety, comfort, manufacturing time and costs, as well as recycling of materials are all being considered so that the product can be readily industrialized.

In addition to light construction, new small vehicles may provide mobility. These vehicles, such as electric-bikes, achieve a high degree of efficiency and can quickly relieve commuter traffic. Less bulky, more energy efficient and emission free vehicles are a major environmental benefit in urban agglomerations.

Public transportation

Also, energy performance of public transportation systems can be greatly improved. Enhancing comfort can accelerate the shift from private to public transportation. The SFOE is funding development work in buses such as the "Light Tram3 Hybrid" by Carrosserie Hess, Inc. in Bellach, is cut where fuel consumption by approximately 40 percent and air polluting emissions by at least 50 percent. In addition, noise emissions have been reduced, an important benefit as noise is a major stress factor in modern cities.



Sketch of the principle of a pneumatic hybrid vehicle recently developed at ETH-Zurich. One prototype in 2008 demonstrated a fuel savings potential of about 32 percent.

Keywords

Light construction vehicles
Lighter vehicles are possible by means of intelligent constructions, for example copying nature and/or using materials with lower densities.

Efficient power trains
The efficiency (tank to wheels) of contemporary automobiles ranges from 17 percent for common vehicles with Otto engines, to over 20 percent for vehicles with diesel engines, to approximately 25 percent by hybrid vehicles. Modern electric cars achieve a notably higher efficiency, but have a limited range. This is a significant disadvantage. Exactly this point is, however, where a total concept is demanded, including the production of fuels, hydrogen and electricity.

Improving energy storage with accumulators

The research programme "Accumulators" investigates opportunities to improve electro-chemical and electrostatic energy storage. The focus of this work is on secondary batteries for the electro-chemical storage of energy and super or ultra capacitors (s-caps) for electrostatic charge storage. Not included in this work are non-rechargeable primary batteries.

Programme goals

The specific energy output (Wh/kg) from accumulators should be increased in the long term from the current maximum of 200 kWh/kg to 2,000 kWh/kg.

By reducing inner resistance and optimising the storage structure, future storage systems should have an electro-chemical efficiency of at least 80 to 90 percent, a life expectancy of at least 2,000 charging cycles, a lifetime of at least seven years and contain no toxic materials. In addition, they must be safe for handling. Such accumulators could increase considerably the use of renewable energy, because renewable energy production is rarely synchronized with energy demand.

In s-caps, specific energy storage should be increased from currently 10 to 40 kWh/kg. Accumulators may play a considerable role in storing renewable energy and cover demand peaks for electricity.

Approaches

To achieve these goals nano-technology may be applied. In focus are accumulators based on light alkali metals (lithium, sodium) because they yield the highest specific energy levels. Hydrogen, the smallest light chemical element, promises the highest possible specific energy from this point of view.

S-cap improvements should be possible through several means, including increasing the specific surface area and intelligent switching.

Safety

There is a correlation between the high specific energy level of a battery and its tendency to burn out through deflagration. This can be avoided by appropriate storage and shielding solutions and this is also one goal of the research programme.

An example is a zebra-battery based on sodium and nickel chloride. It has a high storage capacity together with a high efficiency and long life expectancy.

Keywords

Accumulators, also called secondary batteries, are electro-chemical energy storage devices which release energy in the form of direct current. In contrast to primary batteries, they can be recharged.

Super or ultra capacitors are physical energy storage devices which store an electrostatic energy charge. Discharging and recharging occur in a manner similar to batteries.

Task: more efficiency and innovative technologies

The importance of electricity has grown and will continue to grow in future. The increase in electricity consumption is not only due to the overall increase in energy consumption; it can also be explained by the substitution of electricity for other energy carriers. An example is the increased use of heat pumps, which increase electricity demand while decreasing demand for other heat sources like combustion of oil or gas.

The goal of the research programme on electricity is to increase the efficiency of the end-use of electricity, and to develop innovative technologies for its production, conversion and storage.

Higher investments to save money in the end

Opportunities to save energy can be found in industry, offices and homes – virtually anywhere where new electrical machines and equipment are purchased and operated. One goal of applied research is to demonstrate manufacturers as well as consumers potential opportunities to save energy, and improvements in energy efficiency. An example of inefficiency is the standby mode for IT or entertainment electronic appliances. During standby, these devices consume energy to no real benefit. Technically, it is no problem to prevent such waste.

In industry special attention is needed for electrically powered devices. Often the investment costs are given all the attention, operational costs over the service life of the motor are not considered adequately. Within the framework of the research programme, tools are developed to calculate costs over an entire life cycle. Thus, motors will be identified which are cost efficient over their lifetime. Buyers of such motors must, however, be motivated and accept that a higher initial investment may be necessary to achieve lower operating costs and hence lifetime costs.

Storing electricity – why not with compressed air

A further important topic in energy research is storing electricity. One may, for example reverse, a hydroelectric plant to serve as a pumping station. A similar principle is the application of so-called compressed air storage. The idea is simple: with an electrical motor air is compressed into a suitable container (for example a pressure tank like those used for industrial gas). In the reverse process, when there is a high demand for electricity, the compressed air is released through the compressor and the electrical motor serves as a generator. The advantage of this concept is that there is practically no energy loss over an extended time. Furthermore, the storage tanks are relatively mobile and can be used practically anywhere and their handling is easy. The challenge is now, together with industry, to increase the efficiency and optimise this approach.

Valuable waste heat

Still at the level of basic research is the work on thermoelectric processes. The search is ongoing for materials which can produce electricity directly from heat, for example waste heat in the temperature range of 80 to 120 °C by means of the Seebeck effect (see key words). Another topic of basic research is the search for materials for high-temperature superconductors. Superconducting materials, when they are below a certain temperature, have the property of being able to conduct electricity with no losses. Thereby, very efficient electrical applications can be possible.

Keywords

Motors
Electrical motors are responsible for 45 percent of the total electricity consumption in Switzerland. Without any loss in comfort it is possible to save 20 percent by simply optimising systematically the drives and their operation.

Seebeck effect
The Seebeck effect describes the production of an electrical current of an electrical voltage by heating the contact point of dissimilar conductors. Thereby electricity is produced directly from heat.

Challenging Energy Consumption at Lonza
The company Lonza, Inc. in Wallis is one of the largest electrical consumers in Switzerland. 94 percent of its consumption is from electrical motors. A study of the efficiency of the plant pointed out that energy consumption could be cut up to 30 percent, with a resulting large cost saving. As a result of this study, Lonza, Inc. created a position "Energy Challenges" to systematically identify opportunities to economise by saving electricity.

Flexible, dependable and economical

At the beginning of the electricity era, electricity was produced at the location where it was consumed. In the course of time such decentralised, small power station based structures have been replaced by large power plants interconnected by a centrally managed grid. Today, there is a reversal back to distributed generation. On the one hand, for ecological reasons small power generation facilities producing electricity from renewable sources are being promoted. On the other hand, the electricity consumer should be able, in an open market, to choose any provider. These new developments impose increasing demands on the electricity grid. The electrical grid of the future must be able to distribute energy from both large central power stations and small decentralised plants with the same degree of dependability.

The consumer is becoming active

A grid which is able to deliver high performance as well as being flexible is the backbone of the energy system of the future. The delivery of electricity runs not only from the producer via the distributor to the consumer, but also in the opposite direction, namely, when the consumer himself is also the producer. This is the case for example, when the consumer has his own photovoltaic or wind energy electrical generation.

Mathematical models and simulations are being used to study the basics and investigate new grid architectures in order to develop grids which are very flexible, extremely dependable and economical. In addition to technical and ecological factors, questions regarding regulation of the electricity market extending beyond national borders must be considered. Only then can supply bottlenecks and grid overloads be avoided.

An intelligent grid in Europe and world-wide

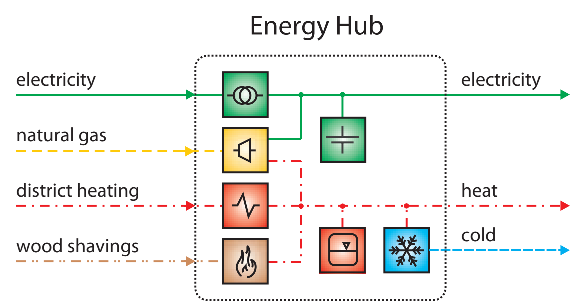
Three programmes are working on developing intelligent grids: the "European Technology Platform SmartGrids", "ERA-Net Smart Grids" of the European Commission and the implementing agreement "ENARD" (Electricity Networks Analysis Research & Development) of the IEA (International Energy Agency). The objective is the development of a future-oriented electricity grid in which the consumer, the producer and the end distributor all work closely together. Key to this is the intelligent configuration of the nodes of the network in a manner that makes an automatic exchange of information possible. Energy and communication nets must be intertwined to make the net operation more efficient and in the end, to save energy. Switzerland is an active participant in all three programmes.

Business interests versus security of supply

The transition from old to new grid structures within the framework of liberalization is a difficult and major effort. During this process maintaining a level of supply security at least equal to today's standards poses a major challenge.

A balance must be found between the criteria of autonomy of supply and independence, and economics. Independent island grids, so called "micro grids" enjoy the advantage of not having to react to far-reaching grid disturbances. On the other hand, large grids benefit from being able to distribute large amounts of electricity with economies of scale and hence at lower prices.

At ETH-Zurich a model for the future energy supply is being developed. The energy network contains so called "energy hubs". These allow the coupling of a specific number of decentralised energy sources. The various energy forms can be converted at the hubs to other forms or stored. The goal thereby is to increase reliability and cost efficiency. The illustration shows the concept of an energy hub with different energy conversion and storage possibilities.



Keywords

Multiple energy source systems
The grids of the future will deliver not only electricity, but also a complex mix of diverse additional energy carriers such as gas and heat for example. At the intercept points between grids, energy will not only be delivered, it will also be converted from one form of energy carrier to another.

Blackout
A short overload of a grid can lead to a wide-reaching break in power supply, as for example happened in Italy on September 28, 2003. To avoid such accidents the grid and its loads must be planned and co-ordinated internationally.

Smart Grids and the IEA Implementing Agreement ENARD
The EU initiated the European Technology Platform, "SmartGrids" in April of 2006. This was followed with the program "ERA-Net Smart Grids" in 2008. In addition the IEA (International Energy Agency) initiated the Implementing Agreement ENARD. One of the goals of these bodies is the international coordination of research between universities, research institutes and industry. Switzerland has been active in all three bodies since their inception.

Production of heat and power go together

When heat production is combined with electricity generation, the result is a much more efficient use of chemical energy. Combined heat and power (CHP) generation couples the production of heat and electricity in a single optimised system. Principally, there is a wide palette of applications, from small systems for single-family houses to large power plants with connected district heating networks. Various factors have, however, have prevented wide spread application of this technology until now. Frequently cited reasons against CHP generation include: low prices of fossil fuels, impediments to feeding power into the utility grid, high investment costs for the district heating network, high maintenance costs and low electrical efficiency.

A multitude of technologies and fuels

To meet heat demand, coupling combined heat and power generation with a heat pump is an optimal way to maximize efficiency and reduce emission of pollutants. From 100 percent energy input in the form of a fuel, 150 to 200 percent useful thermal energy can be produced. Stated another way, only half of the fuel is needed to produce the required heat. The increase in heat pump efficiency achieved through research and development work makes combining a heat pump and CHP generation all the more interesting.

CHP generation systems make use of piston machines (gas and diesel engines), gas and steam turbines, fuel cells and Stirling motors. A multitude of niche applications confirm the increased overall efficiency made possible by these technologies. Whereas previously, oil and natural gas were used, in future many alternatives can be imagined, including renewable energy from biogas, sewage and refuse dump gas, garbage, wood, the Earth (geothermal) and hydrogen.

More efficiency and less pollution

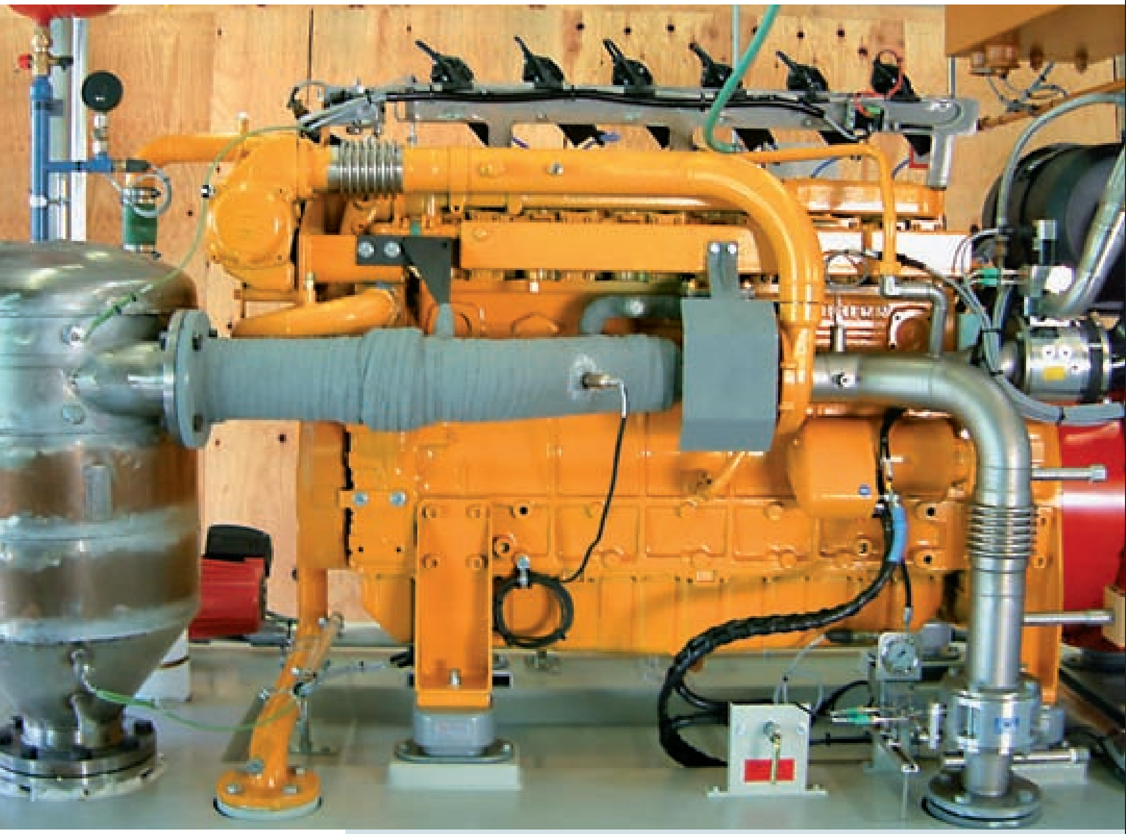
As many technologies exist for the production of heat and of power, research and development in this area extend over a wide range. Accordingly the research and development of plants producing both heat and power

Combining Heat and Power Generation as a Focus of Development

The challenges of the future are known: energy must be efficiently used with less pollution. An important step in this direction is increasing the efficiencies of the individual technologies and apparatuses. A further important step is the combination of power and heat production in a system to efficiently cover our energy demand. This latter approach is called combined heat and power (CHP) generation and has long been known, but is not yet used widely enough.

Research and development efforts are targeted on identifying and expanding possible applications of CHP generation systems in different directions. These applications must be coordinated with changes occurring in other areas. In various research programmes, individual components and apparatuses for energy use and conversion are being improved, processes simplified and emissions reduced. Research in CHP generation brings these single elements together as appropriate and then optimises them for a given application.

Combustion research addresses processes and questions regarding materials for combustion engines. It seeks optimal solutions for specific fuels, considering their properties. The Programme: Power Plants 2020 is oriented towards traditional knowledge on gas and steam turbine technologies. The goal is to promote research to further increase efficiencies while also sinking costs. Swiss research on fuel cell technologies is helping to achieve a break-through in a novel energy conversion system.



The heart of a combined heat and power generation plant is the combustion engine. It must be optimised to maximize efficiency under the constraint of keeping emissions low. The combined heat and power module, consisting of a gas engine with recycled exhaust gas, represents an important development.

is considered a cross-cutting programme, in contrast to other research programmes which address specific questions and solutions. All share a common goal to increase efficiency of components and whole systems, as well as reducing emission of pollutants, i.e. in the case of combustion, particulates, carbon dioxide (CO_2), and nitrogen oxides (NO_x).

The goals are oriented according to the state-of-the-art and so, according to the electrical power of the system, are set to different levels. More ambitious goals for increasing efficiency and reducing pollution emissions have been set for concepts up to 100 kW than for larger systems which have already been optimised.

Expectations are particularly high with regard to improvements resulting from research efforts on fossil fuels systems. Such systems will in future be confronted with price increases, supply shortages and stricter emission requirements. In parallel, emphasis is put on systems using renewable fuels. In the short term, lower efficiencies for electricity production by such systems must be accepted but not higher pollutant emissions. Such plants will likely be compact distributed applications, responding to the distributed resource availability. This raises questions regarding the price of electricity fed into the grid and stability of the grid.

Striving for cost reductions

Research and development is targeted above all to strong market diffusion from plants in the lower power range, which shall be very dependable regarding control and diagnostics. To overcome the high investment hurdle, measures to lower costs will be pursued. This also includes operational and maintenance costs. On the other hand, the success of large heat and power generation plants can only be sustained if they are able to tie into a district heating network or some other large customer for heat.

Keywords

Combined heat and power
Combined heat and power generation plants produce work and heat at the same time, whereby work is mostly converted to electrical energy.

CO_2 emission
The chemical reaction of combustion produces primarily carbon dioxide (CO_2) and water vapour (H_20), but also small amounts of diverse pollutants such as carbon monoxide (CO) and nitrogen oxides (NO_x). As the amount of carbon in the combustion mix increases, so do CO_2 emissions. Hence, burning natural gas produces less CO_2 than heating oil to produce a given amount of useful thermal energy.

Efficiency
Efficiency is defined as the relationship between the amount of useful energy produced compared to the amount of energy in some other form which must be input into a process. Therefore, all processes, which can also transform some form of ambient energy into useful energy, are implicitly more efficient than processes which are dependent on the direct combustion of fuel to produce heat and work. Large diesel and gas engines in stand-alone-operation can produce from 100 percent chemical energy about 40 to 45 percent electrical energy and about the same amount of useful heat for heating buildings. However, if the produced electricity is used to power a heat pump, useful heat amounting to 150 to 200 percent of the electrical energy can be expected.

In search of optimised combustion processes

Combustion processes have always played a central role in energy supply, and they will continue to be essential for numerous related tasks in the future. In the areas of research and development, the focus is therefore on finding solutions to meet increasing requirements on high levels of efficiency, minimum pollutant emissions and improved economic viability. The concept of zero emissions therefore represents the ultimate target for the combustion process. The objective of reducing CO_2 emissions and the higher prices for fossil fuels increase the pressure to optimise combustion systems and improve the chances for the use of renewable fuels.

Growing demands

Continuity in Swiss combustion research has paved the way for the development of a high level of expertise. A sound basis exists for further research activities aimed at meeting the increasing demands to reduce emissions and improve the efficiency of combustion systems. By 2020, for example, the goal is to reduce emissions of nitrogen oxides and particulate matter from diesel engines by a factor of 10. And in order to reduce CO_2 emissions, the degree of efficiency will also have to be increased. As a rule, internal measures in engines aimed at reducing the production of pollutants also tend to lower the level of efficiency, and vice versa. In order to achieve these opposing goals, our understanding of the complex processes that are set in motion during combustion needs to be intensified. For this purpose, a variety of instruments are required, including optical measuring procedures (laser spectroscopy), computer-aided calculation models (modelling) and suitable test facilities in laboratories.

A concentration and continuity of effort in selected areas are essential to assure success. In the past, this has been the case in the collaboration among institutes and laboratories of the ETH and qualified industry partners. Clear evidences of such effective collaborations include the development of sensors for tracking the processes in a combustion chamber, special exhaust-handling processes and the SwissMotor. The latter is a gas motor in the 200 kW power range. Its performance is impressive, with an efficiency of over 42 percent and minimal emissions.

Main points of further combustion research

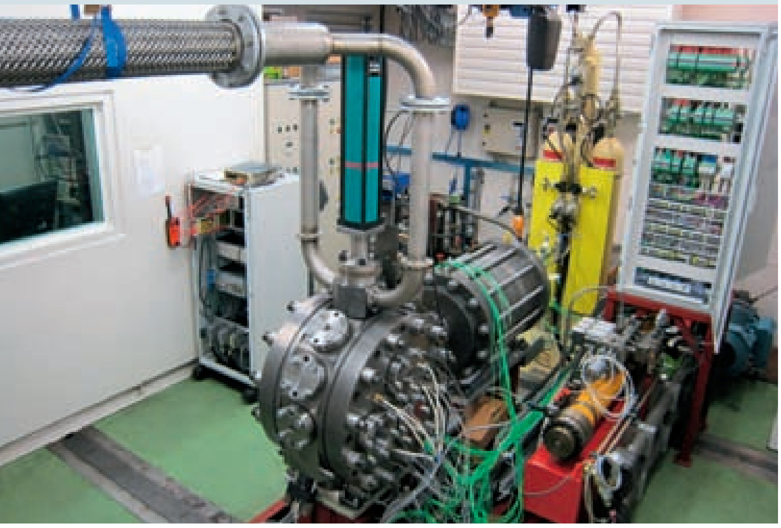
Combustion must be understood as a chemical, thermodynamic and kinetic process. The spectrum extends from feeding the fuel, the mixture and combustion processes, to the production and handling of exhaust gases. Laboratory facilities and equipment are available for testing and implementation. These include the high-pressure, high-temperature cell; the single-cylinder, two-piston engine; and a test cylinder for ship diesel engines. The latter contributed significantly to the Hercules project of the EU research programme. Future ship diesel engines should have reduced gas and particulate emissions as well as increased efficiency and reliability.

Research on soot build-up and analysis, on particulate characterisation and on cooling processes poses further challenges for computation and simulation. A further desire is to better understand turbulent pre-mixing flames and the interaction between turbulences and fuels. Results will serve, in particular, to better dimension and further improve the performance of gas turbines.

New fuels are coming

The increasing use of new fuels, be they new compositions or synthetic fuels, sewage gas, biogas, hydrogen raises new questions. Computations, simulations and testing are necessary to guide research to optimise single and dual-fuel operations.

A test stand for combustion systems of large 2-cycle ship diesel motors; EU-Project Hercules.



Keywords

Soot build-up
Soot consists primarily of carbon particulates with a size from 10 to 300 nanometres (nm). The dispersion of such tiny particulates in the environment poses a health hazard. Research activities aim at limiting their build-up.

Efficiency
Efficiency is the ratio of delivered power relative to supplied power. The term, efficiency, is used in order to describe the efficiency of energy conversion and also of energy transfer.

Synthetic fuel
Customized fuel is a composition precisely designed for the needs of modern motor concepts, so called "designer fuels". For this various processes are applied, such as biomass to liquid (BtL) gas-to-liquid (GtL), etc.

Single and dual-fuel operations
Dual-fuel operation indicates that either of two modes of system operation can be selected, each with a different fuel. An example is an automobile which can run on gasoline or hydrogen. By contrast, a single-fuel system can only operate with one fuel type.

Improving large power plants

It is still possible to improve the efficiency of the well-known combined cycle gas turbine technology. Improvements are also needed in turbines to enable them to use other chemical energy sources like hydrogen or biogas, in addition to fossil fuels. The Swiss industry, in co-operation with research institutes, should continue to be in the position in the year 2020 to plan and build the best possible plants.

Integration of the whole process chain

Basically the goal is to develop targeted technical measures to increase the efficiency of electricity generation from combined cycle, gas-and-steam turbine processes. Included, for example, are improvements in air compressors and turbines, reducing the cooling load by air, and achieving higher process values. For this work, multiple disciplines are needed, including: aerodynamics, high temperature material science, electrical engineering, process-engineering and combustion physics.

The research project "Power Plant 2020" should improve the electrical efficiency of combined cycle gas turbine processes while reducing the output of pollutants. In addition these processes should be adapted to operate using new fuels. Finally, interfacing with the grid should be optimised.

An overriding goal is to reduce CO_2 emissions, be it by process changes in order to facilitate separation and retention of this gas; or by increased use of renewable, CO_2 neutral fuels.

For compensation in the electrical grid

The short reaction time of gas turbine power plants makes them well-suited to offset short term production variations from wind or photovoltaic power plants. For this reason research is also ongoing to improve the stabilisation of the electrical grid by making possible high demand gradients (± 3% demand variation per second) or grid-frequency independent operation.

The work on "Power Plant 2020" is being carried out in co-operation with an EU research framework programme with the initiative "Power Plant 21" in Germany, as well as the "FutureGen" Programme of the USA.

Power shortages soon

Political and economic boundary conditions are as important as scientific and technical aspects, given the strong application-oriented structure of the research. Furthermore, the interface to the gas, electricity and district heating grids poses special challenges for applying the results of this programme.

Research on combined cycle plants with a high efficiency and low pollution levels for power and heat production is not only interesting for the export industry, it is essential work. By the year 2020 shortages in the electrical supply in Switzerland can be expected and additional power generating plants have to be foreseen.

Keywords

Combined cycle gas turbine power plants (CCGT)
In CCGT power plants gas combustion drives a gas turbine. Waste heat from the flue gas is recovered to produce live steam which drives a second turbine. Both turbines together drive a power generator. This combination of two processes, one at high (gas) temperature and one at low (steam) temperature, leads today to an overall efficiency of about 60%.

Swiss developments for a European key technology

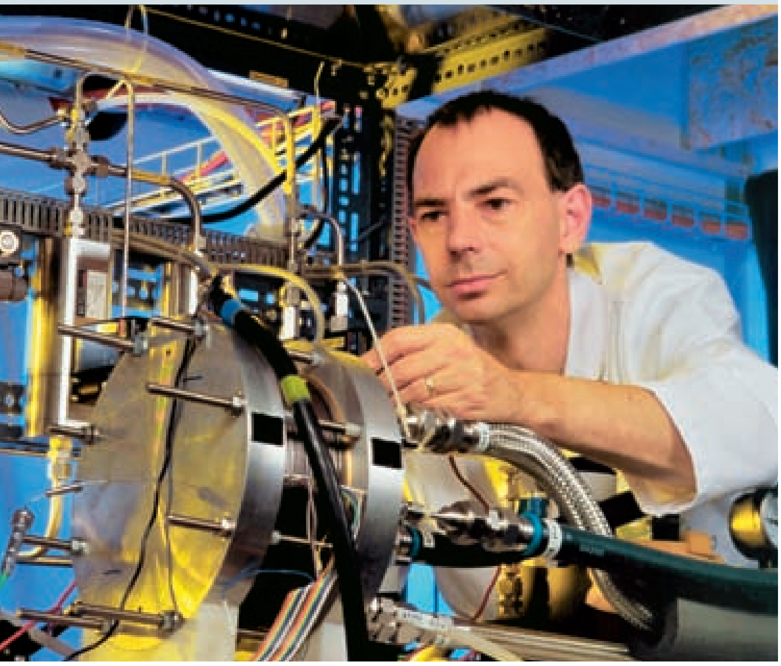
Fuel cells produce electricity directly from a chemical energy source by means of catalytical combustion. They have a great potential because of their minimal emissions and high efficiency. Polymer electrolyte cells (PEFC) produce primarily electricity while solid oxide cells (SOFC) are used for producing both heat and power. The wide range of possible applications of fuel cells is therefore not surprising. The PEFC are especially well suited for mobility applications. SOFC have been primarily used in stationary applications, though today they are also finding uses in portable applications.

The future lies in cell stacks

Basically, three research areas have been given priority to achieve a technology breakthrough, namely, achieving:

- a high degree of dependability from the cell stacks and the whole system to enable uninterrupted operation;
- increased life expectancy of cell stacks through material science and modelling;
- improvements in cell stacks and system technology to reduce investment costs.

Switzerland is strong in basic research, system integration and the development of complete solutions for fuel cells.



In this way such systems will become more competitive with conventional technologies like internal combustion engines, heating furnaces and accumulators.

Pilot and demonstration projects will have to demonstrate the readiness and economics of fuel cells for practical applications. There is growing support of projects addressing system and process technologies to be able to industrially produce cell stacks and fuel cells.

Applications with different time horizons

Given the currently available fuels a step wise introduction of fuel cell technology makes sense. Fuel cells with efficient fossil fuel operation should be introduced first. Later, these will be replaced by systems that operate with biogenic energy sources or hydrogen. As PEFC operation requires hydrogen input, long-term research has to be established in this area. On the other hand, an internal conversion process allows SOFC to operate with natural gas or biogas. A more rapid market introduction of such systems can be expected.

Networked research capabilities

Collaboration between research and private enterprises is very important. For example the Paul Scherrer Institute (PSI), the University of Applied Sciences of Biel and the firms Michelin and CEKA are working together to develop the PEFC. Another example is collaboration among the ETH in Zurich and Lausanne, the EMPA, the University of Applied Sciences of Zurich and the firms Hexis, HTceramix and Fucellco to develop the SOFC.

SFOE emphasizes international networking in this area. Swiss researchers are closely involved in research projects within the framework of the IEA. This high priority that this technology enjoys in Switzerland and international importance are further illustrated by the creation of a so-called "Joint Technology Initiative for Hydrogen and Fuel Cells" of the European Commission. With the united forces of research, business and policy makers, Europe should take the world lead in the development of this technology.

Keywords

PEFC
Polymer electrolyte fuel cells convert hydrogen and oxygen into water and electrical power. A solid polymer membrane serves as electrolyte. The conversion process is operated at low temperatures and has good dynamic properties, making it suitable for mobility applications.

SOFC
Solid oxide fuel cells are operated at high temperature (800 to 1000 °C). In this fuel cell type a ceramic is used as solid electrolyte. With this type of fuel cell not only power generation but also waste heat utilisation is important, especially for space heating purposes.

The EU's Joint Technology Initiative for Hydrogen and Fuel Cells
In a limited number of technological areas of high strategic relevance for the European Union, Joint Technology Initiatives are setting up public private partnerships. Significant investment and research capabilities from both the private and the public sector are being generated to push Europe to become the world leader in research and development of these technologies.

Increasing the use of solar heat

The principle of active solar heating can be summed up as follows: capture, convert, store and deliver energy according to actual demand (see keywords). Active solar applications are as diverse as the temperature ranges covered by these technologies, namely from 25 °C for heating buildings or swimming pools, to more than 2,000 °C for solar ovens. In between these extremes are applications for industrial processes demanding temperatures between 100 and 250 °C.

The research programme Solar Heat concentrates mainly on applications with the largest potential: those producing heat at low temperatures for heating domestic hot water and space heating. These two applications account for about 40% of the total energy consumption in Switzerland. Today, solar collector technologies for domestic water heaters and space heating are technically mature. Thanks to research and development carried out in the 1990's, systems developed in Switzerland are considered among the best in Europe.

Reducing cost

Nevertheless, the cost of solar heat to the consumer is still high compared to the competing fossil fuels. Heat from flat plate collectors typically used for single-family houses costs between 25 and 35 Swiss cents per kWh. Solar heat reduces the amount of conventional energy which has to be purchased, typically costing only 5 to 20 Swiss cents per kWh. For this reason, current research focuses on simplifying installations to reduce the initial investment and improve performance in terms of useful kWh/m^2 of collector area. Scientists are particularly interested in so-called combi-systems for domestic hot water and space heating. Such systems require between 12 and 20 m^2 of collector area for a single-family house. Demand for such systems is growing throughout Europe. They can cover between 30 and 50% of the heat demand in a well designed and insulated single-family house. The longer term goal is to have full coverage by solar only.

Compact combi-systems for domestic water heating and space heating are tested at the University of Applied Sciences in Rapperswil. Promising results indicate that a significant improvement in solar heat delivery at less cost may be achieved, thanks to compact design and system optimisation.

The challenge for the future

Because today, solar thermal systems are often confronted with acceptance problems, research and development are needed in the architectural integration of systems. Accordingly, the solar thermal research programme has given priority to new technologies and components which can be used as building elements.

Another topic is the increasing demand for room air conditioning and the resulting large increase in demand for electricity. Because the greatest cooling demand occurs during sunny weather, solar energy is a logical means to supply the needed energy for cooling. Solar applications for this purpose should be developed which can compete with conventional electrically operated air conditioning.

Improving storage technologies

Heat storage is a major research topic. Seasonal heat storage systems store solar energy collected in the summer for use in winter. Short-term storage systems span shorter intervals, for example bad weather periods of a few days. Heat storage is therefore a key technology to achieve a high solar coverage of the heat demand by buildings.

In Switzerland storage technologies are mainly designed for the single-family housing market. One perfected seasonal system stores low-temperature heat (5 to 30 °C) in the ground, then raises the temperature to useful levels with a heat pump. Such systems, however, are still waiting to find a place in the market. Research is also addressing the efficiency of heat storage in water tanks and the use of new materials. Heat storage via physical-chemical processes promises to achieve high energy storage density and low heat losses. The goal is to achieve the heating autonomy of buildings by covering 100% of the heat demand by a solar technology at reasonable costs.

The main Swiss institutions researching the use of low temperature solar heat are the University of Applied Sciences in Rapperswil with its Institute of Solar Technologies, the University of Applied Sciences of the Canton Vaud in Yverdon and the Federal Institutes of Technology (ETH), in particular in Lausanne.

Keywords

Active use
In the active use of solar energy, solar radiation is converted by collectors to usable heat at an appropriate temperature, typically between 30 and 60 °C. Components (pipes, possibly pumps and heat exchangers) transfer the solar generated heat to the point of use.

Passive use
In the passive use of solar energy, solar energy is collected, distributed and stored by the building itself. Because the building is the key, this technology is presented in the programme Energy and Buildings (see page 10).

Photovoltaic energy enters the industrial phase

Solar radiation is the most important source of energy on earth. Every day it supplies enough energy to satisfy more than 10,000 times the daily energy needs of the whole world. It would therefore be sufficient to convert 0.1‰ of this radiant energy into electricity to cover all of the world's energy current consumption.

The conversion of solar radiation into electrical energy has been possible for some time. In fact the first solar cell prepared from silicon crystal (see keywords) was perfected by American researchers already in 1954. The idea is simple and based on a principle well known by physicists: the photoelectric effect. The fact is that some substances emit electrons when they are exposed to light. This transformation occurs without movement, noise, or any other emission.

Industry of the future

Today, photovoltaic (PV) energy has made its mark in the industrial era. Thanks to the quality of its research, Switzerland has a trump card to play in this new market, which globally is growing annually 30 to 40% and increasing. Based on a survey of the Swiss PV industry, exports from the country were estimated to total about 500 million Swiss francs in the year 2007. If national sales are included, the total sales volume for the Swiss photovoltaic industry rises to at least 600 million Swiss francs.

Furthermore, the sector has a large unexploited potential. Scientists estimate that the price of solar cell installations can still be reduced by a factor of 3 or 4. Only if this is achieved can this technology be truly competitive and large scale applications feasible.

Giving priority to applied research

Given these facts, PV research is focused on improving existing technologies by projects that are directly oriented towards practical applications. Accordingly, 90% of Swiss public research resources allocated for the PV energy sector are assigned to reducing system costs. This includes all components of systems: the photovoltaic modules which are responsible for two-thirds of the system costs, the inverter and the mounting structure. Further, the technical efficiency of the complete system should be improved.

Developing second-generation cells

The main focus of this research is developing thin-film cells made from silicon or semi-conductor compounds (see the glossary). Second-generation cells offer the advantage of needing much less material and energy for their production, compared to the silicon crystal cells of the first generation that still make up the backbone of today's photovoltaic industry. However, the market share of thin-film cells has recently increased. Second-generation solar cells have a greater potential for cost reduction than those of the first generation. In addition, thin-film cells offer greater flexibility to meet the needs of a range of applications and they can be readily combined with building materials. Current research projects aim to further improve the cell efficiency, optimise the manufacturing process and establish the infrastructure necessary to support the industrial partners. Thin-film technologies are nearing industrial maturity. Paradoxically, the success of classical technologies based on crystal silicon has been helpful for the new technology. The production capacity of the first-generation cells cannot keep up with demand, resulting in increased demand for the second-generation cells.

Close collaboration with the industry

Thin-film silicon cell techniques are being developed mainly at the Swiss Federal Institute of Technology in Lausanne (EPFL) with the support of two universities of applied sciences: the Haute Ecole Arc Ingénierie in Le Locle and the Interstate University of Applied Sciences of Technology (NTB) in Buchs (SG). In parallel, the EPFL continues to work on the development of cells with colour dyes (Graetzel cells). The Swiss Federal Institute of Technology in Zurich (ETHZ) is investigating the development of solar cells comprised of semi-conductor compounds. These institutions all collaborate closely with industry and several receive support from the Swiss Innovation Promotion Agency (CTI). They are well integrated into international networks, especially in projects of the European Union.

Other Swiss competence centres for PV research can be found at the University of Applied Sciences of the Italian-speaking region of Switzerland in Lugano (photovoltaic panel technology) and at the University of Applied Sciences in Burgdorf (inverters and electrical systems). Supplementary activities take place at the Universities of Berne (antenna-solar cells) and Geneva (determining the solar radiation on a surface based on Meteosat data), as well as at the Paul Scherrer Institute in Villigen (thermo-photovoltaics).

Imitating nature

It is thought that thin-film cells and crystalline cells would co-exist for a long time. This has indeed been the case because first-generation cells continue to show potential for considerable improvement. This is in particular evident in the areas of materials, cell efficiency and production processes. Such developmental work is principally the job for industry.

It is becoming apparent that three generations of cells will probably coexist. Approximately 10% of public funds (not invested in applied research) benefits fundamental research projects with applications foreseen first after the year 2020. This research aims to develop a new generation of solar cells that are organic or polymer-based, making use of nanophysics. The motivation for this work is the hope for materials with lower costs, using raw materials in unlimited supply and easier to work. The ultimate aim is to imitate nature in order one day to achieve artificial photosynthesis.

From fundamental research to the market: The thin-film cell technology, developed in the laboratories of the Institute of Microtechnics (IMT) of the University of Neuchâtel (today integrated into the EPFL in Lausanne) is being further developed today by a spin-off firm. VHF Technologies in Yverdon is getting the thin-film technology for application on flexible substrates ready r the market. This is proceeding in collaboration with the world's largest solar cell manufacturer, Q-Cells.

Keywords

First-generation cells
First-generation crystalline cells are made of silicon in mono-crystalline or poly-crystalline form. Solid silicon is used because of its semi-conducting properties. It is present in abundant quantities on the Earth, as sand or quartz in an oxygen compound (silicon-oxide, silicates). The use of silicon for solar cell production requires the appropriate processing.

Second-generation cells
Second-generation cells are made up of a thin-film or layer of material which is applied over a substrate material. The goal of thin-film technology development is to reduce the amount of material and energy required by the cell production. The new cells should have similar physical properties, offer more flexibility for different types of applications and cost less. For thin-film photovoltaic cells different materials can be used, namely amorphous silicon and its derivatives (micromorphous silicon), or II-VI compounds of the periodic table of elements. Substrates can be made of glass, metal or plastics.

High Temperature Solar Energy Use

The Program "Solar High Temperature Processes" encompasses the areas of solar thermo-chemistry, solar heat usage in industrial processes and solar thermal power systems (concentrated solar power, CSP). These processes have the use of solar energy at high temperatures in common, approximately 150 °C by industrial processes and up to approximately 2,000 °C for thermo-chemical applications. The systems involved are totally different than solar thermal systems for domestic water heating or space heating.

The third prototype put into operation at the site of AirLight Energy in Biasca. The concentrating collector has a linear construction and it makes use of the very simple, new concept of flexible, pneumatic reflectors. The membrane is attached to a simple frame of prefabricated pre-stressed concrete.

A considerable potential for these three solar application areas exists. The Paul Scherrer Institute (PSI) is investigating thermo-chemistry, specifically the production of zinc by means of the thermo-chemical cycle ZnO/Zn as a main topical area. The goal of the second area (solar industrial processes) is to develop systems which enable the use of solar energy in conventional production processes. Finally, solar thermal power systems have a great potential for generating electricity. A considerable uptake of this technology world-wide can be expected soon.

Research status

At the moment solar thermo-chemistry is at the basic research stage of development, but in coming years this can be expected to shift to applied research. In a first step a prototype with 10 kW is being built. This will be followed by a 100 kW pilot reactor for the decomposition of zinc-oxide.

By contrast the use of solar heat in industrial processes and for CSP are already in the stage of applied research. The goal now is to find innovative solutions which fulfil technical and economic criteria for applications. Private and industry interests play important roles in addition to public support.

Specific applications

The mid-term goal of solar thermo-chemistry is to be in a position to easily store and transport solar energy by means of metallic zinc which can then be directly used for the production of hydrogen.

The use of solar heat in industrial processes is intended to reduce CO_2 emissions resulting from energy consumption in Switzerland. Basically, industrial applications combine solar heat and low temperature waste heat recovered from a process, to make it useful.

Without question, solar thermal power generation is a renewable energy technology for generating electricity which will see strong growth in the near future in the sun-belt. Currently, there exist 420 MWe of electrical production in operation and 400 MWe of new capacity are under construction. Concerning applied research a number of activities remain, in order to improve existing systems and capabilities. Example systems include parabolic troughs, linear Fresnel-lens systems, power tower systems, systems with so-called parabolic "dishes" and Stirling motor systems. Also needed is work on power station components like heliostats, concentrators, heat exchangers, turbines, control devices; and technologies for concentrating solar radiation, engineering, software, etc.

Keywords

Thermo-chemical cycles
The long-term scientific goal is to produce hydrogen by means of the material cycle of zinc and zinc-oxide. Solar energy is to be used for splitting zinc oxide into zinc and oxygen. The metal zinc can then be later converted with water vapour to hydrogen and zinc oxide.

Industrial solar heat
High value process energy can be produced through the combination of concentrated solar radiation and fossil fuels for the purpose of using waste heat or in combination with a continuously running industrial process. In this manner using solar energy can reduce CO2 emissions and energy costs.

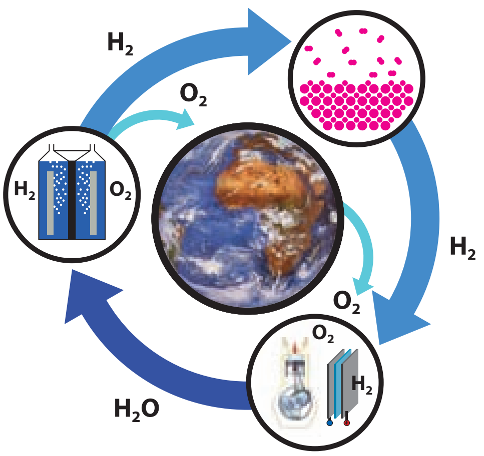
Solar thermal electrical production with concentrators
The most promising of all technologies in this area are the systems with parabolic trough collectors. Solar radiation is concentrated by a parabolic mirror which reflects and concentrates the energy onto a pipe running along the focus line of the parable. A heat carrying medium is heated within the pipe. The resulting steam drives a turbine connected to a generator to produce electricity.

With a vision underway

Hydrogen is an energy source with a future. It seems predestined to help us with our many energy problems, in particular serving as a replacement for fossil fuels. It has the special advantage that it can be produced world-wide, using any number of energy sources. When hydrogen is burned the output is merely water. There are no CO_2 emissions from the process, as long as renewable energy is used to produce the hydrogen. It promises to be a general, diverse energy solution. This is important above all for mobility, because of the urgency of this application. First, however, intensive research and development efforts are needed to find ways to produce, store, transport and distribute hydrogen.

Sustainable production and storage are needed

World-wide more than 68 million tons of hydrogen are produced annually. This is already the equivalent of four percent of current oil production. Today, about 76 percent of hydrogen is produced from natural gas and 23 percent from oil. Only one percent comes from the electrolysis of water. The main consumers of hydrogen are the petrochemical industry and fertiliser manufacturers. If hydrogen is to play a role as an energy carrier and thereby help reduce CO_2 emissions, alternative means of producing it must be developed. Besides using nuclear energy to produce hydrogen, various means using renewable energy are possible. Swiss research has been concentrating for some time on the conversion of water to hydrogen by means of either electricity from hydroelectric plants, direct use of solar energy or a reversible metal oxide produced in a solar oven. Material scientists are hard at work, for example in the area of light-sensitive catalysts with many discoveries still to be made.



Hydrogen cycle with renewable energy use

Storing hydrogen with the largest possible energy density poses a special challenge, given that this should be accomplished with the least possible energy input. A main area of Swiss research with international cooperation is the use of a reversible metal hydride as storage. This feature is in contrast to conventional gas pressure storage or cryogenic liquid-hydrogen storage.

The way to the vision is long

One of the most challenging applications for hydrogen is its use as a substitute for fossil fuels for mobility. This is today's main motivation for this research. Feeding it into an internal combustion engine or a low-temperature fuel cell with an electric motor for mobility purposes is being trialled in many countries in demonstration projects.

Hydrogen has been considered a dependable element in the chemical, pharmaceutical, metallurgy and food industries since over one hundred years. The job to do now is to expand these applications to future applications which use hydrogen as an energy carrier. The hydrogen for this purpose should be produced from a sustainable energy source by a process which has an environmentally benign material cycle.

The national network set up by the Swiss hydrogen business association, Hydropole (www.hydropole.ch) consists of companies and institutions working together on hydrogen production and research. This provides a platform for networking between university research and industry activities.

Keywords

Hydrogen
Hydrogen is the smallest element and lightest of all gasses. It is a component of water and most organic compounds. However, in nature, it seldom occurs in its elementary form. Hydrogen is a secondary energy source because it must first be produced, which requires energy input. This can be done using all energy sources.

Electrolysis
In the electrolysis (splitting) of water, voltage is applied between two electrodes. On the cathode gaseous hydrogen is produced. Water electrolysis equipment has existed world-wide since hundreds of years. The power of such systems can reach several MW.

PEC Tandem Cells
Photo electrical chemical tandem cells (PEC) can split off hydrogen directly from solar radiation at ambient temperatures. Efforts are underway to do this using new, economical light-sensitive thin-film electrode materials like iron-oxide ("rust") with thin film, semi-conducting photovoltaic materials like titanium-oxide (toothpaste whitener).

Reversible metal oxide reactions
Appropriate metal oxide complexes are used as thermo-chemical storage medium. In a cyclic process metal oxide is first thermolytically or carbo-thermically reduced at temperatures above 1,200 °C. Afterwards, according to need it is re-oxidized using water as a source of hydrogen in a low temperature splitting process.

Optimal conversion of energy

Heat pumps are used for space heating and domestic water heating. They use the ambient heat of the outside air, earth, groundwater or waste heat to produce heat at useful temperature levels. Heat pumps are most commonly powered by electricity. This substitution of oil or gas heating and elimination of fossil fuel combustion reduces CO_2 emissions. If a heat pump is powered by electricity generated from renewable sources such as hydroelectric power, wind, photovoltaic panels; or from nuclear energy, then the CO_2 reduction is particularly large. But, also electricity from modern combined cycle gas turbine (CCGT) plants, or combined heat and power (CHP) generation plants can be used to operate heat pumps. Such system combinations can reduce the consumption of fossil fuel energy and accordingly CO_2 production by about 50 percent.

Useful developments at many levels

Research is targeted on improving the efficiency of systems, the so-called coefficient of performance (COP) and its annual average as well as seeking new application areas. Several ideas are being pursued. Components are being continuously improved and test procedures standardized. The latter allows improvements in quality and identifies opportunities for optimisation. For example, a project started in 1994 on compressors with intermediate vapour injection lead to a 15 percent more efficient product which has been marketed since 2004. Still further improvements in efficiency are possible.

Heat pumps serving multiple functions are particularly advantageous. Research and development are concentrated in this area in order to further improve the efficiency and integration of systems in the technical building services. In this picture, a 450 kW heat pump draws its power from a gas-engine-powered combined heat and power generation unit. It is an element in the energy system of a large building complex.

Another important research topic for heat pumps is use of natural substances as the working fluid. Central to this work is how the use of natural instead of synthetic materials affects performance and the limits for applications. By better integrating heat pumps in the complete technical installations of buildings it has been possible to continuously adapt heat pump systems to new developments in building technology, i.e. the drastically reduced heat loads of today's better insulated buildings. Costs have been reduced by introducing several basic schemes for heat pump systems.

Heat and cold in one view

In addition to heat pump heating systems in single-family housing, multifunctional heat pump systems are on the increase. They can combine space heating, domestic water heating, cooling, deep freezing and dehumidification. By such multiple function units the quality of the heat source becomes critical with regard to the intended end-uses and system dynamics must be considered in detail by the planner.

A great potential lies in the cooling of commercial and retail facilities by using a process similar to that of a heat pump. Demand for cooling can be expected to steadily increase. Therefore, research and development leading to improved efficiency for cooling are important. Another essential issue is how to make the best use of the waste heat in such processes. The focus for cooling applications is on improving components and system integration.

Keywords

Heat pump and cooling machinery
Both a heat pump and a cooling machine elevate heat from a lower temperature to a higher temperature. This requires an external input of energy to drive the system, because in nature, the tendency is towards temperature equalisation.

COP (coefficient of performance)
This value describes the proportion of useful energy relative to required input energy. In the case of a heat pump, this is the useful heat in proportion to the energy necessary to drive the system. The COP depends on the technical characteristics of the machinery, the temperature of the available heat source and the temperature of the required heat output.

The annual average COP
The COP of a heat pump depends on the temperature of the heat source and the required output temperature for space heating. Therefore, a heat pump achieves varying levels of efficiency over the course of a winter as the ambient conditions and heat demand change. The annual average coefficient describes the average performance over the heating season, namely, delivered useful heat relative to energy input to drive the system.

Small, decentralised and finally environmentally benign

Small-scale hydro-electric plants are, by common international definition, plants up to 10 megawatts. Such plants were a driving force of industrialization in Switzerland and provided power everywhere on rivers and streams at that time. During their construction environmental issues were not a concern. With the construction of power grids most of these small hydro-electric plants were closed, power being then generated by large plants. Today, the goal is to promote such small plants again, while respecting the environmental issues related to rivers and streams.

The unknown potential of small hydro-electric plants

Since 1992 the federal government has helped operators of small hydro-electric plants (up to one megawatt capacity) with a special tariff for the electricity they feed into the grid. The power contribution of such small plants has continuously increased over the last decade, although old plants gradually closed. Their annual contribution currently amounts to 750 gigawatt hours of electricity.

If the contribution of all plants up to 10 megawatts is considered, it becomes apparent how important their power contribution is towards meeting our power demand today. Approximately one thousand plants up to this size deliver 3,439 gigawatthours per year, or a good five percent of the total power production in Switzerland.

There still remains, however, a large undeveloped potential. How large this potential actually is, is the subject of a research project.

Research to find as simple as possible machines

From a technical perspective, no quantum leap can be expected from researching such small plants. This technology has been the subject of research too long for this to happen. Private firms and the public sector, however, endeavour to optimise such systems to make their operation more economical. In contrast to development work for large hydro-electric power plants, where the goal is to increase their efficiency, the goal for small plants is to simplify systems so that they are less expensive to install and more economical. Particularly promising are innovations in turbine design and closed system designs, as can be found near drinking water and sewage plant power plants (see the example). Also traditional systems are being developed, such as the revival of hydraulic screws.

Environmental protection and financing models

The energy potential of small hydro-electric plants can only be tapped when no adverse environmental consequences result. For this reason, environmental protection measures are being developed. Examples are efforts to optimise fish ladders, renaturation projects, and solutions resolving splash way, sink and residual flow issues. Properly planned small hydro-electric plants can indeed improve the natural habitat.

Last, but not least, feasibility studies are in progress. Financing models are being studied and best practice guidelines being developed for operators of small hydro-electric plants.

Electricity out of drinking water supply
Many drinking water supply facilities have a large, untapped energy resource as a result of their geographic height difference. Currently, excess pressure is adjusted by pressure reduction valves or by pressure breaking shafts. The energy resulting from the pressure reduction is lost as heat. Various research projects are addressing innovative technologies for such pressure reduction. Numerous Swiss firms offer a complete pallet of products for drinking water power production to economically make use of this small energy potential. Examples are Pelton turbines, reverse funning pump turbines; and an original development, the reverse pressure Pelton turbine.

Keywords

Profitability of small and large hydro-electric plants
Producing electricity from water power is not only clean but also economical. This is particularly true for large facilities. Research on such plants is self-financed by private enterprise. The public sector supports research as a basis for regulations to assure safety in large plants. Large hydro-electric plants are ecologically problematic, often resulting in political obstacles for their construction. Small hydro-electric plants, by contrast, must be further simplified and optimised in order to make them economical. They therefore often require the support of public funding.

Drinking water hydro-electric plants
Drinking water power plants have become a hit (see the example). They belong to the category of small hydro-electric plants and are built into the water supply systems. The overall ecological balance of such plants is sensational and their potential impressive.

Combustion, gasification, fermentation

Biomass is an extremely versatile energy source. Raw materials are available at numerous locations from many sources, such as biological refuse or self-regenerating raw materials; and there are already several conversion technologies available. However, picking the appropriate conversion technology for the various kinds of biomass energy carrier (electricity, heat or fuel) is a complex issue. Accordingly, researchers seek not just the most efficient and economical solutions, they also aim to find environmentally benign solutions.

A mid-term goal is to double the current energy production from biomass. Today, wood is the most often used biomass fuel. Wood has considerable potential for heat and electricity production, followed by biomass fuels, refuse and residual raw materials from forestry and agriculture. About one third of this potential is already achieved, though processes and systems need further optimisation.

Clean power production from wood: wood power plant in Nidwalden

By gasifying wood before combustion particulate and NO_x emissions are reduced during the production of heat and power. This project consists of a wood combustion power plant burning wood chips to produce heat and power. It feeds into the district heating network of Rieden/Stans-Oberdorf. The facility produces heat from burning untreated wood and CO_2 neutral electricity by burning old lumber and forest waste. The plant in its full state of completion produces 9.1 GWh of heat and 9 GWh of electricity. The heat is fed into the district heating net and the electricity is fed into the electrical grid as eco-electricity. The maximal heating power is 5.3 MW; the maximal electrical power is 1.36 MW.

Wood

Today, the greatest substitution of fossil fuels can be achieved by burning dry substrates, including wood. Heating oil and natural gas can be practically be 100 percent substituted. The goal is to develop complete combustion plants with high efficiency, complete combustion of the fuel, as low emissions as possible and at low investment and operating costs.

Through gasification, high value energy is produced. This allows flexibility in converting the energy to another carrier (electricity or fuel). In this project existing equipment will be monitored, operating data including costs collected and the technology improved in order to achieve higher efficiency.

Air pollution from room wood stoves

In the next ten to fifteen years the use of wood as a fuel may be doubled, without increasing air pollution. For this reason, a substantial part of the research is dedicated to respirable fine particulates. Open questions regarding the production of such particles include the particle size, numbers and health hazards. Solutions to this problem improve the combustion technique and the use of particle separators. Today, large-scale plants utilize already efficient and cost-effective filters. This approach is, however, difficult to apply in facilities of less than 70 kW, as is the case with domestic wood stoves and fireplaces.

Efficient and quality controlled firing

Systems should be optimised so that highest quality wood stoves can be brought to market. These should be low-cost, clean-burning with low emissions and have a high efficiency. Accordingly, clear directives should be made available to the manufacturers. A quality label should provide clarity on quality for the consumer.

District heating and electricity production from combustion of wood chips

Particularly high efficiencies can be achieved in large installations which produce heat for both district heating and power. Of relevance here are the optimisation of existing systems and finding ways to cut emissions.

Other forms of biomass

Common forms of biomass are used for energy production by means of, e.g., anaerobic fermentation. The goals here are to optimise existing procedures to increase energy efficiency and reduce emissions, and to develop measures to assure quality.

Renewable production of heat and electricity from the farm

In the case of agriculture great potential is still waiting to be tapped. The "energy farmer" who produces both heat and electricity is no longer a visionary concept. One considers, not the cultivation of energy crops on a large scale, but rather fermenting and combusting waste biomass from the harvest as well as manure. These raw materials can be combined and used for the production of both electricity and heat. This is technically possible today, but significant improvements and multiplication potential are still possible.

A still unresolved problem is the large fraction of the energy in the form of heat, typically 50 to 60 percent. In winter it can be used to heat the farm buildings, but how can this heat be put to use in summer? One answer is to find a system which can make use of synergies, for example using the heat in a drying shed or to heat a poultry shed to the required 33 °C.

Closing material cycles

An underlying issue regarding developing biomass energy is always sustainability. It is not enough that a solution be technically feasible and efficient; it must also be ecologically sensible and accepted by the public. This, among other reasons, is why Switzerland holds back on the large scale, intensive cultivation of plants for energy production. A special goal of the research programme is to close the material cycles. Valuable nutrients must not be lost; rather they should be made available again for the production chain. Research into biogas to be fed into the natural gas pipelines is directed at minimizing or eliminating methane losses and reducing ammonia emissions.

Fuel from plants

Even though plants will presumably not be cultivated for energy production on a large scale in Switzerland, biogenic fuels will continue to be an important topic for researchers in the future. Technologies and knowledge in this area can be exported and bio-fuels imported. Research is needed to improve gasification facilities. Also still open questions are feeding of produced biogas into the gas grid and the ecological balance of different fuels from biomass.

The catalytic hydrothermal gasification of biomass is being investigated at the Paul Scherrer Institute in Villigen. Continuous operation is being tested in a laboratory set-up with capacity of 1 kg/h. Typical operating conditions are 400 °C and 30 MPa

Keywords

Particulate and nitrogen oxide emissions
In contrast to oil and natural gas, burning wood results in no additional CO_2 emissions. An environmental burden is, however, the release of nitrogen oxides (NO_x) and particulates. Combustion systems, domestic wood stoves in particular, must be optimised so that negative effects are minimized.

Timber
Eight to ten million cubic meters of wood grow annually in Swiss forests. In 2007 about 6.4 million cubic meters were put to use. Considering the import-export balance, approximately seven million cubic meters are used annually in Switzerland.

Wood used for energy
Wood for energy production comes in various forms: as wood in its natural state from forest, as a waste product from producing lumber and as old lumber at the end of its lifecycle. The annual consumption of wood for energy amounts to about three million cubic meters. It would be possible, without over using the Swiss forests, to increase this to about five million cubic meters per year.

Biogenic waste and residues from agriculture and forestry production
Numerous enterprises produce biomass waste which can serve as an energy source. Example sources include farms (waste after a harvest and manure), forestry, industry in general, food service industry, households, sewage treatment facilities and slaughterhouses.

Renewable raw materials
Good sources of renewable raw materials for energy production in addition to wood include diverse fibrous plants (grass, hemp, flax), oil bearing seeds (raps, sunflowers) as well as grains ("energy grains"), sugar beets and potatoes.

Heat and electricity from depth

With very few exceptions, the temperature of rock increases the deeper it is. In Switzerland, the average increase in temperature is 30 °C per kilometre of depth. Geothermal energy utilises both the relatively low temperature in layers near the surface, as well as higher temperatures deep underground.

Nonetheless, pilot projects aimed at utilising heat from such depths indicate a great deal of potential. If this technology should prove to be economically viable, it would be possible to meet a significant proportion of our electricity demand with this resource over the long term.

Surface heat for heating and cooling purposes

The technology for using this heat – ground source heat pumps – is well developed and can now be implemented at numerous locations. Thousands of these systems are now in use in basements of small to medium-sized buildings where they have replaced oil-fired central heating systems. Competition among commercial suppliers is giving rise to incentives to improve efficiency and cut costs. However, there is still a need for research into the design and operation of complex geothermal energy systems that can also be used for cooling purposes in buildings as well as for heating. And the same applies with respect to the development of new refrigerant fluids as well as quality assurance instruments in the areas of planning and implementation.

Exploration for hydrothermal sources and tunnel water

Hydrothermal sources are important geothermal resources for Switzerland. In the case of tunnel water up to 30 °C and low-temperature hydrothermal sources, the water can be used for heating purposes. And in the case of very hot sources with temperatures between 80° and 130 °C – which can probably be found at the bottom of the molasse basin in the lowlands and central plateau, and in the cantons of Valais and Vaud – the water would be suitable for the production of electricity from low-temperature heat power plants (cf. glossary below). But the exploration of hydrothermal sources is always associated with risks and uncertainties: for example, it is only possible to predict the yield and temperature of hydrothermal sources to a limited extent.

Flow-through heaters at a depth of 5,000 metres

The greatest potential for practically CO_2-free electricity production lies in the exploration of heat reservoirs (with temperatures above 150 °C) at great depths with the aid of enhanced geothermal systems. Ongoing improvements in terms of technology and economic viability will mean that the required minimum temperature will be lower in the future. These reservoirs contain little or no natural hot water, and this means they have to be developed using engineering methods. An enhanced geothermal system comprises at least two wells to a depth of around 5,000 metres and at a distance of several hundred metres from one another. One of the wells is used for pumping water underground, and the other is used for bringing it back to the surface. The water circulates between the two wells in artificially expanded natural rock fissures and is thus heated. Intensive research is required for the creation and management of underground reservoirs – while taking account various risks, including earthquakes – and the conversion of low-temperature heat into electricity. Swiss geothermal researchers are currently actively involved in an international project in Alsace (Soultz-sous-Fôrets), as well as in the required follow-up measurements for the Deep Heat Mining pilot project in Basel, which was halted by the local authorities.

Keywords

Low-temperature heat power plants
Hot water from hydrothermal sources (80° to 100 °C) offers significant potential for CO_2-free electricity production. But in order to optimally utilise these resources, the risks associated with exploration need to be reduced and the conversion technology needs to be optimised. The production of electricity using hot water with a relatively low temperature (around 80 °C) represents a particular challenge.

Deep geothermal energy
Hot dry rock, hot fractured rock, enhanced geothermal system, stimulated geothermal system, petra-thermal technology: these five terms are largely synonymous and refer to methods of producing heat from rock layers deep below the earth's surface (at depths of up to 7,000 metres).

In winter 2009/10, the Zurich electricity supply company EWZ drilled a well to a depth of approximately 2,700 metres beneath the city of Zurich in order to find out whether there are sufficient reserves of hot water for utilisation as an energy source. This project yielded a great deal of geological data, but the exploration did not find any major hot water reserves. The obtained data will now be used for more accurately assessing the geothermal potential in the Zurich region.

Tail wind for Swiss know-how

Today, wind power generation is a mature technology and wind turbines for use under standard conditions have been on the market for many years. With an annual growth rate of 30 percent the branch is enjoying a ongoing boom world-wide. This reflects the great potential of wind energy. During the last years the price of wind power systems has increased by over 20 percent. Because of shortages of raw materials, delivery times exceeding two years are not uncommon.

Well executed research in Switzerland has identified a multitude of suitable locations for generating electricity from wind power. The electrical output can be expected to be in the range as in classical wind energy countries. Swiss wind energy research and development is concentrated on components and systems suitable for Swiss conditions (icing, turbulent gusting, and acceptance). Swiss firms supplying the world market with products like plastics, sensors, electric and machine components, also enjoy a presence in the world wind energy market.

Core competences: wind energy in cold climates and in the mountains

With a multitude of research projects in-depth knowledge in the use of wind energy under specific Swiss conditions is growing, including:

- Development of system components (sensor techniques, nano-technology, electric power techniques) by local industry.
- Increasing the availability and energy output of wind power plants in extreme sites (climate, turbulence, and logistics).
- Increasing the ”value” of wind energy, optimising the integration of wind power plants in the electricity supply (forecasting and levelling power supply).
- Increasing the acceptance of wind energy by engaging social and environmental science competencies and thereby reducing the time needed to complete projects.

This is complimented with pilot and demonstration projects that reduce non-technical barriers and enable a stronger market break-through. Thereby, the gap between research activities and application in the practice is being closed.

International co-operation

On the summit Gütsch near Andermatt the effects of ice and snow on wind generators are studied. The goal is to find ways to prevent the build-up of ice on the rotor blades, so that the energy production can be increased. There is strong international interest in these investigations because numerous sites appropriate for wind power generation are located in cold climate regions.

In addition to very cold temperatures, strong turbulence poses a further challenge to planning and operating wind power generators. For this reason, gaining know-how to evaluate difficult locations is pursued in Switzerland.

Taking into account social factors

Further research issues are societal questions which prevent the spread of wind power generation.

The three federal offices of energy, environment and regional planning in collaboration with the Cantons, environmental organisations and energy industry have developed ”The Swiss Concept for Wind Energy”. It defines criteria for selecting locations for wind parks in Switzerland (see keywords). This concept serves the Cantons today as a basis for their regional development plans and suggests potential wind energy generation sites.

The test site on the Gütsch by Andermatt is used within the framework of national and international programmes for wind power and meteorological measurement research in cold climates. The location allows experience to be gained in the construction and operation of facilities under arctic or mountain conditions. The goals are to find non-icing materials and to be able to forecast when icing weather conditions will occur.

Keywords

Acceptance
Decisive for selecting a wind power site are not only wind conditions, but also the existence of roads and availability of high-voltage electric lines, as well as the visual impact on the landscape. The ”Swiss Concept for Wind Energy” is providing the foundation and criteria for site selection, which now can be applied by the cantons within the planning frameworks.

Now-casting
Wind energy occurs irregularly. An optimal grid operation therefore needs balancing energy. This is energy provided by power plants that have been put on hold to compensate for unexpected mismatch between the load and power generation. Hydropower can serve this purpose. Also important are dependable weather forecasts for the coming hour (so called ”Fore- and now-casting”).

Nano-coatings for rotor blades
Economical means of reducing the negative influence of ice build-up during the operation of wind power systems are being developed. A synthetic coating of the rotor blade surface with a lowered freezing point is used. It is similar to the anti-freeze proteins in nature.

Growing the potential with new reactor concepts

For decades Switzerland has safely used nuclear energy to produce CO_2 free electricity. This technology, together with hydro-electric generation, makes Switzerland one of the few countries which produce electricity with almost no associated CO_2 emission. Considering the present political boundary conditions, nuclear energy is an important option for assuring a safe and economical energy supply in the long term. Accordingly, research focuses not only on existing nuclear power plants, but also on topics consistent with current trends and developments of modern nuclear energy technology.

Continuity in education and research

Swiss research in the area of nuclear fission is carried out almost exclusively at the Paul Scherrer Institute (PSI) in Villigen, AG. Education in this field is offered at the Swiss Federal Institute of Technology (ETH). There are professors at the ETH-Lausanne for reactor physics and system behaviour and at the ETH-Zurich for nuclear energy systems.

The PSI research contributes to assuring the safe and economic operation of nuclear power plants in Switzerland. It assists power plants operators and public safety officials with analysis and, more frequently, experimental investigations using the "hot laboratory". The project "Human Reliability Analysis" investigates human behavioural aspects of safe plant operation. For this work, simulation models are developed and applied. In the future, acquiring a fundamental understanding of the phenomena related to reactor operation will be given priority. An example is the project STARS, in which researchers analyse in detail the transient behaviour of Swiss nuclear power plants during possible disturbances regarding reactivity or cooling medium loss. In the future, investigations about nuclear fuels will be supplemented and confirmed with uranium oxides modelling at a molecular level.

Research reactor prepared for new concepts

The zero-power reactor Proteus of the PSI serves to help validate computer codes for modelling innovative nuclear reactor core configurations and high burned-out nuclear fuels. Such fuels permit a better use of uranium. Whereas in the past, small parts of single, highly burned-out nuclear fuel rods were examined, now complete expended fuel elements are measured. Experimental data are being collected in the framework of the project LIFE@PROTEUS (2008-2012), to confirm the validity of calculation results of key reactor physics parameters. For this the Proteus facility will be modified so that highly radioactive fuel can be handled safely. In parallel, safety will be increased by digitising the control system and strengthening the building. This developmental work will assure that work on new reactor concepts can be carried out in an optimal manner for a long time into the future.

Collaboration for tomorrow's nuclear reactors

Topics addressing long-term development of nuclear energy are the subject of the Generation IV International Forum, a platform in which Switzerland participates. The PSI has appropriate infrastructure and test facilities available for investigating of various reactor concepts and the required cooling media as well as for the development of scientific fundamentals. An example is

Nuclear Energy

Swiss nuclear energy research covers a wide spectrum of topics ranging from the safety of existing nuclear power plants (e.g. analysis of the ageing of materials), the final storage of spent fuel, and future concepts for reactors to nuclear fission and fusion technologies.

The work is carried out in international networks such as the "Generation IV International Forum" and the ITER of the Euratom Programme, and other EU research programmes as well as the Nuclear Energy Agency (NEA) of OECD and the International Atomic Energy Agency (IAEA). Work is also done within various industry research programmes.

In view of the world-wide efforts to reduce CO_2 emissions (i.e. the Kyoto Protocol) and the growing importance of electricity as a flexible energy source, advanced nuclear fission as well as future fusion power generation should have important roles in the future energy supply mix. Beside conventional electricity production by steam turbines, other forms of energy use or, in particular, of heat use are being discussed.

Already today the production of hydrogen by means of nuclear power is being examined. But only through intensive and continuous research can the necessary materials and processes be further developed and the education and advancement of the future generation of scientists be assured.

Research of nuclear fission and nuclear fusion is, however, also shaped by public acceptance. Providing safety and above all solving the final storage of radioactive waste are permanent themes in the debate over nuclear energy. The availability of nuclear fuel in the future is increasingly a topic in discussions. Most likely the growing demand for nuclear fuel should lead to the reintroduction of the breeder reactor technology. The development of nuclear power capabilities, as in the case of other forms of energy use, is subject to world-wide socio-political conditions.

The increasing gap between demand and supply of fossil fuels is placing more pressure on finding energy supply substitutes. Of growing importance are safety and economics, more efficient use of resources in new concepts for nuclear reactors and the long term prospects for nuclear fusion.

With the TANDEM accelerator of the ETH Zurich deterioration of materials caused by radiation is induced to anticipate the performance of future nuclear plants. After the irradiation of materials, correlations between their material properties and microstructures are investigated at the PSI.

the modelling of the fast reactors of the fourth generation and comparing their efficiency regarding actinides management and their safety characteristics. The large facilities of the PSI (hot laboratory, Proteus, PANDA and so forth) are also used for experimental investigations of reactor concepts, nuclear fuels and waste regarding fourth generation systems. Future generations of researchers are being trained through their participation in such large scale experiments.

Also of particular significance is the specific material research at the PSI. Topics include the ageing of components in reactors currently in operation and the characterisation of materials which must withstand the extreme temperatures (850 to 1000 °C) of fourth generation reactors. The goal is to find materials which can fulfil their function for decades, not only under such high temperatures, but also under severe conditions of radiation, mechanical stress, exposure to corrosive media and changing stress. In international projects to develop high temperature reactors, Swiss material scientists are delivering a major contribution by investigating tension crack corrosion, corrosion of the cladding of nuclear fuel, and non-destructive test methods and the fatiguing of different steels. If reactors of the fourth generation are to be commercially available in the year 2040 it is essential for Switzerland to make the right strategic decisions for future technologies now, and to assure the education and advancement of the future generation of scientists and engineers.

Infrastructure for researching final storage

The competency developed over the past years in the disposal and end storage of radioactive substances can serve, when relevant, current and future work on final storage. For many years, PSI scientists have been investigating safety aspects regarding geological storage. This is the domain of the NAGRA (National Co-operative for the Disposal of Radioactive Waste). The PSI hot laboratory and also the rock laboratory Mont Terri near St-Ursanne, JU have been valuable in these investigations and can serve in the future for extended tests. The insights won from this work on radioactive waste can also provide a good basis for future investigations of other toxic materials. For this work the new beamline (MicroXAS) of the PSI Swiss Light Source can be applied. With this facility it is possible to carry out micro-scale spectroscopic investigations, also for radioactive substances such as those to be stored in a future final storage.

Milestones for the use of a great potential

Controlled nuclear fusion could in future cover electrical base loads. Fuel for nuclear fusion is virtually inexhaustible and the amounts needed so minimal that reactors pose no threat, even in densely built up areas. Fusion energy produces no greenhouse gases and the balance of waste as well as the short life of the involved radionuclides are, compared to nuclear fission, very favourable features. However, the technical challenges to achieving controlled nuclear fusion are enormous! Commercialisation is still far in the future but important milestones (ITER, DEMO) have already been set.

The international experimental fusion reactor is being built

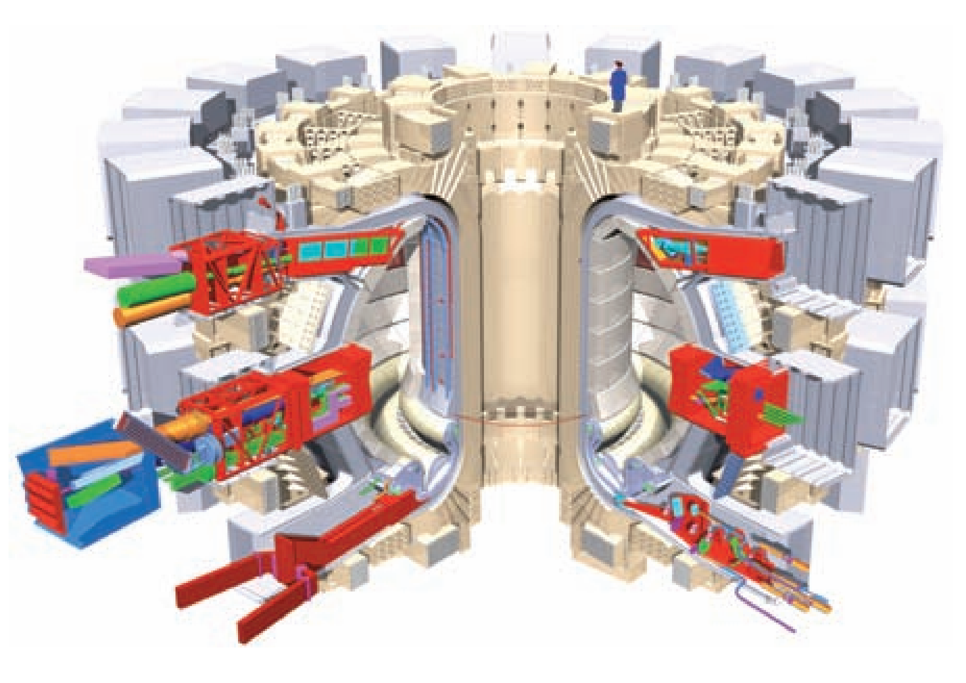
Today, the most advanced means of achieving controlled nuclear fusion use magnetic confinement of plasma. In temperatures of about 100 million degrees Celsius, deuterium and tritium nuclei collide with such force that their electromagnetic repulsion is overcome and nuclei fuse together. The energy set free in this fusion is converted to heat which can be harnessed to drive a conventional turbine to generate electricity. The scientific fundamentals have been worked out in a world-wide co-operation. Important contributions to these efforts have resulted from the use of the fusion research reactor JET (Joint European Torus) since the mid 80s. Switzerland has been an active participant in this work. Now, with the ITER a major step towards the technical development is possible.

The construction of the International Thermonuclear Experimental Reactor (ITER, Latin: the way) has been prepared since 2007. The site is Cadarache, near Aix-en-Provence in France. In approximately ten years the reactor should be ready to produce 500 MW of thermal power. In contrast to the JET and other research reactors, the ITER should demonstrate quasi-continuous operation. ITER will have a torus over 12 m in diameter, a plasma volume of 840 m^3 and should operate for 20 years. As a last step to commercialisation of nuclear fusion the international community plans to build a demonstration-fusion reactor, DEMO. While ITER should prove scientific and technical feasibility, DEMO will show the economic possibilities of generating electricity by nuclear fusion.

Competence in plasma technologies

The main site for Swiss fusion reactor research is the Research Centre for Plasma Physics (CRPP) at the EPF Lausanne. The CRPP provides needed infrastructure for developing fusion technologies within the framework of research co-operation Switzerland-Euratom. Examples of such infrastructure include: the Variable Con-

Since 2007 the International Thermonuclear Experimental Reactor (ITER) has been under construction in Cadarache, France. In approximately ten years nuclear fusion should deliver 500 MW of thermal power. Equipment placed around the torus will play a major roll in measuring the properties of the plasma.



Swiss Federal Nuclear Safety Inspectorate (ENSI)

The Swiss federal government created a regulatory body following the introduction of nuclear energy in the 1950's. Since 1983 the Swiss Federal Nuclear Safety Inspectorate (previously the HSK, now the ENSI) in Villigen, AG and as of 2010 in Brugg, AG has born this responsibility. The ENSI funds and co-ordinates research contracts in the framework of regulatory safety research. Thereby, current scientific, technical results are assessed and extended. Such new research work addresses safety issues regarding the operation of existing nuclear plants, as well as problems and phenomena relevant for nuclear plant safety in general.

The Swiss nuclear energy law of 2005 does not set the remaining life span of Swiss reactors. None the less, reactors currently in operation will have to be taken out of service in the foreseeable future. The ENSI must assure that legal requirements for the remaining years of plant operations are met, make observations on the ageing of the facilities and finally, oversee the decommissioning of plants. As this time nears, the ENSI will be increasingly occupied with determining exactly when plants should be taken out of service and assuring safe operation in their last years of operation. These tasks are reflected in the research priorities, for example:

- Projects investigating the mechanisms responsible for the ageing of materials as well as deterministic and probabilistic investigations of failures.
- Projects examining the interactions between man, the organisation and technology. Safe plant operation depends on this. In addition to investigating the technical causes of failures, the influences of human reactions during normal as well as breakdown situations are being evaluated.

The ENSI supports research activities on the disposal of radioactive waste. The regulatory body must assess the safety of the proposed solutions.

Because it can be expected that new nuclear power plants will be put into operation in Europe, the ENSI is investigating safety technologies for such facilities. New concepts involve, for example, passive safety systems for cooling by means of gravity, as well as the ”core-catcher” approach for the retention of a melted core within the containment shell. These concepts are already being applied in the new pressurised water reactors of the type ”European Pressurized Reactor” currently under construction in Finland and France.

To address all of these issues the Swiss Federal Nuclear Safety Inspectorate relies on international co-operation and the collaboration of Swiss research institutes.

figuration Tokamak (TCV), the TORPEX facility (Toroïdal Plasma Experiment) and the SULTAN-IT-Infrastructure for the simulation of turbulence phenomena. The CRPP is helping develop the needed theoretical and experimental fundamentals for the ITER and DEMO projects. It also contributes to works on heat production, diagnostics, controls and superconducting cables. Finally, it develops gyrotrons to heat up the plasma by means of high-energy ion beam emission (2 MW at 170 GHz).

Besides the CRPP, the Institute of Physics of the University of Basel is developing supporting technologies for nuclear fusion. An example is the investigation of surface properties for the production of a mirror system to measure the properties of plasma in future fusion reactors.

Stringent requirements for materials

The search for materials with a low activation is very important for the DEMO Reactor. New materials should be investigated using the International Fusion Materials Irradiation Facility (IFMIF).This search for highly resistant materials is analogous to development work for high temperature nuclear fission reactors. Also in this case, because the technology has a long time frame, new young scientists are needed to assure research continuity. The use of the facility provides challenging and at the same time educational opportunities for young chemists, engineers and physicists over the entire spectrum of their careers as researchers.

Nuclear fusion is an energy technology with great potential but its application on a commercial scale depends on solving numerous, difficult to anticipate challenges. It makes sense, especially for researchers from a small country like Switzerland, to benefit from the synergies of close co-operation with other countries. The positive influence on science and teaching must also be considered. Already today industry profits from the numerous results which have come out of the JET operation. Results have led to new products.

Boundary conditions for a sustainable energy supply

Energy production, distribution and consumption depend not only on available technologies, but also on economic and societal constraints. The research programme of the SFOE, Fundamentals of Energy Economics (EWG) addresses these issues.

Knowledge gained in this programme guides the long-term direction of energy policies and helps with political decisions in energy and related areas like environment and transportation. Research elements are the optimisation of both existing and new instruments. These serve not only political authorities, associations and other organisations, but also industry.

How can the 2000-Watt Society be achieved?

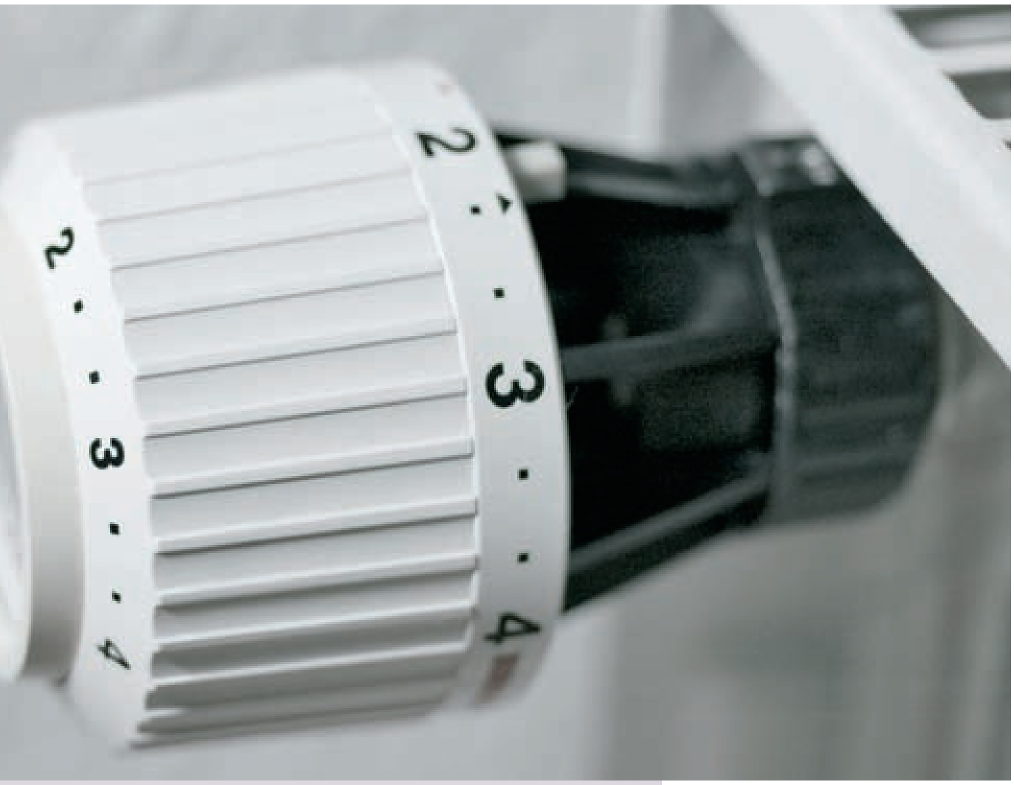
The research programme, Fundamentals of Energy Economics is oriented to help achieve secure and sustainable energy supply for Switzerland in the spirit of the 2000-Watt Society (see the keywords, page xy). It identifies how developments in the direction of the 2000-Watt Society can affect the economy. Results of the programme feed into the Energy Perspectives of the SFOE, pointing out which political instruments can help achieve the 2000-Watt Society.

The multitude of themes, disciplines and institutions

The research programme is structured in to two areas: applied research and policy research. Applied research is structured in three areas: innovation, behaviour and models. In the first area the whole innovation process of energy technology is investigated, from an idea through to marketing. Thereby, barriers and success factors are identified. In the behaviour area the decision-making process of consumers is analysed. Why are energy efficient appliances, which are less expensive in the long term, not purchased? How strongly are purchasing decisions influenced by whether relevant information about uncertainties is available, for example about future energy price developments? These are questions which must be answered in detail in order to understand the boundary conditions for developing optimal energy policy instruments. Finally, in the third area, models are developed to represent economic and technological realities. With such models the effect of political measures on applied technologies and economics can be forecast.

In policy research current questions of energy policy are investigated. The results serve as a basis to help the SFOE fulfil its political assignments. Responding to this variety of responsibilities requires the involvement of many research disciplines ranging from macro to micro economics and from political science to sociology and psychology. Of course assuring a technical basis for this work is essential. Two examples in the area of supply security are: the effect of greater use of renewable energy sources for the production of heat, electricity or fuel; and the public acceptance of large infrastructures. From 2020 onward, when Swiss atomic energy plants stop feeding electricity into the grid, a new energy source to fill this gap must be in place. Possible solutions include increased energy efficiency, construction of new large power plants, increased imports or large scale electricity production from renewable energy sources. An important question is what the boundary conditions for the production of electricity by renewable energy sources are. The potentials for all these solutions are largely known, however, far-reaching research into their economic consequences is needed.

The research is being carried out in many locations. In particular worth mentioning are the different institutes of the ETH, the universities, the universities of applied sciences, as well as the many private planning and consulting firms. The latter possess valuable knowledge which they bring to such studies. The research programme, EWG is accordingly concerned with national and international exchange of information between researchers and generating new methodological competencies.



Encouraging renters to consume energy responsibly through fair cost allocation of heat and hot water. This is the goal of the VHKA: consumption dependent heating and hot water costs sharing by renters. The beneficial effect of such an action has been proven and the VHKA has been gradually established in Switzerland since the 1980's. Yet, in many cantons this measure has a remained in the doldrums. This was shown in a study, which the SFOE carried out at the end of 2008 within the framework of the research programme, Fundamentals of Energy Economics. The study suggests several variations for the future of the VHKA. One of these variations is the obligatory introduction of this measure for all existing buildings in all cantons. Another variation proposes efforts at both national and cantonal levels concentrating fully on new buildings.

And in 50 years?

The research programme is preparing an information base for current discussions about new regulations and international agreements. At a national level, decisions are pending on CO_2 regulations after 2012. At a European level, discussions are in progress regarding the regulation of energy markets and certification of renewable electricity. Finally, on a global level the concern is the post Kyoto-Protocol process. A key question is to what extent Switzerland can make a commitment for after the year 2012.

Indeed, the time frame extends still further into the future: To what extent can the hopes for ecological tax reform help the implementation of new technologies and efficient applications of energy in the next 20 and 50 years?

Keywords

Energy Perspectives
The Energy Perspectives, periodically worked out by the SFOE, shows the options for long-term planning of energy politics. Such strategies must assure a secure energy supply, and be within tolerable limits with regard to environmental impact, economical and social burdens. The current Energy Perspectives have been published in mid-February 2007. They provide a basis for political discussions about future energy and climate politics.

Discount rates
In 2008 diverse projects were started to analyse the discount rate in households with the help of experiments. The higher the discount rate is, the stronger today's costs and gains are weighed compared to future costs and gains. This is an important factor to consider in purchasing electrical appliances and also a central issue for global climate discussions.

Innovation processes: not for the faint-hearted

Although more and more results of Swiss and international research do indeed find their way to the marketplace, Swiss national energy research aims to promote and accelerate this process. Where necessary this is done with public financing. Such intervention is necessary because in the energy sector developments in the direction of sustainability would not occur alone through market forces. It is essential that research, society, business and politics work together.

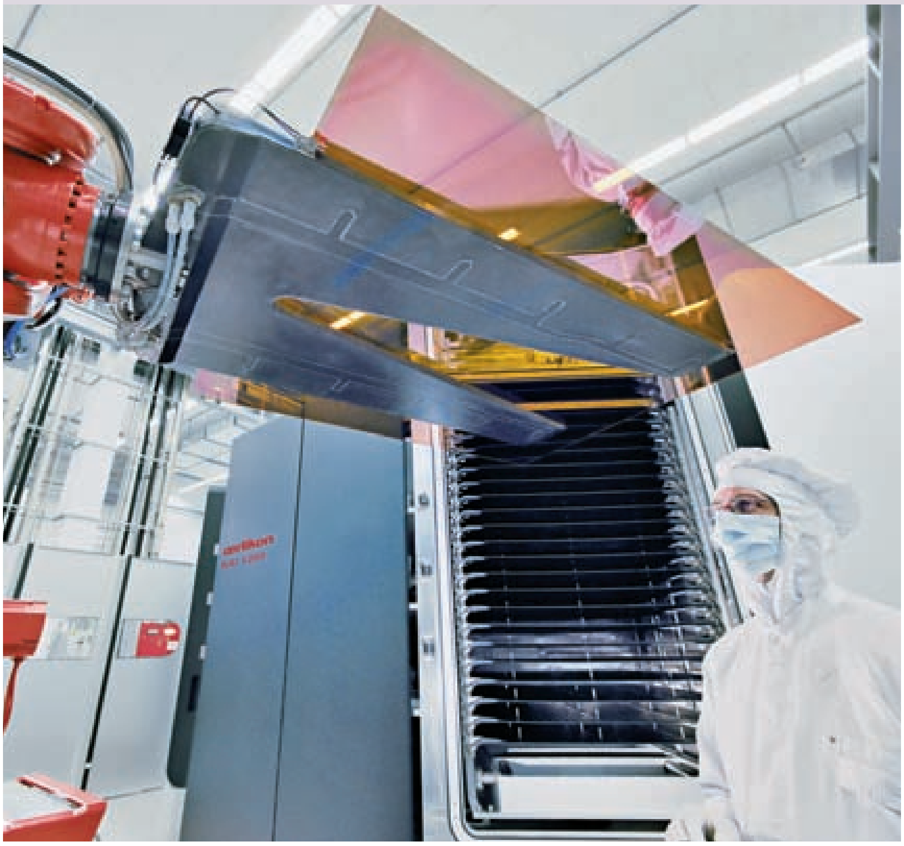
Complex conversion process

The development of new, future-oriented technologies takes place in multiple, often recursive steps from ground laying of fundamentals, applied science research, development and testing of technical systems through putting the work into practice and marketing.

The future development of energy demand and the contribution of various energy sources depend on several further factors. Of particular relevance are the economic, ecological, regulatory political and societal boundary conditions (prices of resources and labor, laws, regulations, taxes and assessments, societal values and life style). Beside economics, also having an important role are safety and environmental tolerance of innovations (also for future generations as well as for developing and emerging countries).

The SFOE is promoting the innovation process through all stages of the development chain. This is accomplished by the energy research programmes of the SFOE and SwissEnergy, the partnership federal programme for energy efficiency and renewable energy sources. Thus all factors are considered. An attempt is made via a countermove, to provide a positive influence with newest research results. Knowledge and technology transfer is complex but a central process which needs special attention. It is the job of science and technology transfer institutions to facilitate and promote the transfer horizontally (i.e. from one enterprise to another) and vertically (i.e. from academic research centres to industry partners) along the technological value chain.

The nuclear fusion research centre of the ETH Lausanne has shared its knowledge in plasma technology with the University of Neuchâtel in support of its efforts to develop thin film solar cells. In 2002 a contract of co-operation was signed between OC Oerlikon, a world leader in the area of plasma screens, and the University of Neuchâtel. First amorphous and later micro-morphic silicon solar cells should be mass produced with the goal of sharply cutting prices. The research results from this project have lead to spin-off firms. An example is VHF-Technologies Inc., founded in 2000 in Yverdon and specialized in thin film photovoltaic cells.



Keywords

P&D Projects
The abbreviation P&D stands for pilot and demonstration projects. Pilot projects should prove the technical feasibility of a development, whereas demonstration projects should increase the market acceptance and prove economic viability of innovative technologies and solutions and prove their profitability.

SwissEnergy
SwissEnergy is a partnership programme of the federal government to accelerate the introduction of energy efficiency and renewable energy sources. It promotes the collaboration among the federal, cantonal and community governments together with partners from industry, environmental and consumer organisations, and public and private economic agencies.

Business Network Switzerland
The Service Centre of the Business Network Switzerland is the official contact point for enterprises to obtain answers to questions regarding doing business abroad. The Swiss Federal Office of Energy has a co-operation contract with this network organisation under the State Secretariat for Economics (SECO). This guarantees an optimal collaboration between the two organisations.

REPIC (Renewable Energy Promotion in International Cooperation)
The interdepartmental REPIC platform promotes renewable energy and energy efficiency in international collaboration. It supports the putting into practice of global climate protection agreements and also promotes sustainable energy supply in developing and emerging countries. In this way, it is an important element in the implementation of Swiss political goals for sustainability at an international level.

Added value as a goal
Fossil energy sources (heating oil, gasoline, etc.) supply about 70 percent of the final energy demand in Switzerland. If sustainability is to be achieved (reduction of annual CO_2 emissions to 1 ton per person) this consumption must be reduced by a factor six. To achieve this, in the short term technologies and concepts must be improved. In the long term completely new technologies must be introduced. Out-of-date technologies will be pushed out of the market. Behaviour patterns have to be understood and strategies planned to use available resources better than today. On the other hand, such activities offer Swiss research the opportunity to test innovations and businesses can test export potential. Improved products and services can be offered worldwide.

To this end, pilot and demonstration projects (P&D projects) are particularly important. They allow technical and economic feasibility, and user acceptance of innovative technologies and solutions to be tested. In addition, by carrying out pilot projects researchers and entrepreneurs come in close contact. This facilitates knowledge transfer and accelerates applications.

Collaboration is the key
Targeted measures are being taken to reduce friction at the interfaces between research institutions and industry in order to facilitate technology transfer. To this end, instruments of the government at the federal and cantonal level, as well as private enterprise are being systematically applied. Gaps identified in the process can be bridged with the research budget of the Swiss Federal Office of Energy (SFOE). Such financing must be seen as being supplemental to other sources.

Learning from marketing activities
A functioning domestic market is an important prerequisite for successful exporting. Exporting Swiss firms profit in particular from the dynamics of the international market-place, which often can be traced back to promotional efforts of governments. In this growth market Swiss innovation must prove itself. Success depends on research and development leading to competitive products and systems. In the case of foreign business the Swiss Federal Office of Energy collaborates with the Business Network Switzerland of SECO.

To accelerate the world-wide application of technologies increasing efficiency or using renewable energy sources it is important to collaborate with developing countries. These countries are experiencing growing energy demand as their economies grow. It is therefore highly relevant that the energy they use serve the intended function as efficiently as possible while remaining affordable. This is the goal of introducing such new technologies. The platform REPIC co-ordinates projects from different federal offices working towards these goals.

Synergies from looking beyond the borders

Keywords

EU research programme
The so called Framework Research Programmes (FRP) are support programmes of the European Commission. The seventh FRP started at the beginning of 2007 and has a budget of 54 billion Euro, of which four billion Euro are for the EURATOM programme. Over its seven years duration an annual budget of 300 million Euro is foreseen for research co-operation in the energy area.

International Energy Agency (IEA)
The IEA, with its headquarters in Paris, supports its 26 member countries in their efforts to provide a dependable supply of energy. Increasingly important in this effort is the application of improved and new technologies. For Switzerland the IEA opens the door to international collaborative research including non-European countries.

The goal of the European Technology Platform "SmartGrids – an Electricity Network for the Future" is to maximise the use of both large power generating plants as well as small, distributed electricity production in order to create a dependable and cost effective energy supply system.

International collaboration in energy research has a long tradition. To a large extent, this occurs in Switzerland through participation in activities of the International Energy Agency (IEA) of the OECD and through the framework of the research programmes of the EU. The IEA offers a flexible infrastructure for countries which elect to pursue a certain research area. Projects are defined in a "bottom-up" approach and financed by the participating countries directly. In EU projects, theme areas are advertised and interested research teams (public and private from multiple countries) apply for funding. Projects are financed from the EU research budget, which also includes a contribution from Switzerland.

Case by case decisions

International collaboration may or may not be appropriate or useful, depending on the specific case. Collaboration can result in synergies, help reduce wasteful duplications of efforts and increase the efficiency in carrying out a research project. It can also help strengthen the industrial partnerships involved. In some cases, however, research at a national level is more appropriate, e.g. issues specific to Switzerland. Where an innovative solution is involved and Swiss industry is particularly well positioned to profit from it, the desire to limit the work to a national level is understandable. Advantages and disadvantages of pursuing a research activity nationally or through international collaboration have to be judged on a case by case basis.

Carrying out research co-operations in the EU

Energy is one of the nine main topics of the EU research programmes. Themes range from the application of renewable energy, reduction of CO_2 emissions, increasing the efficiency of energy use and creating an intelligent energy network; to questions of political regulations and international collaboration. Nuclear energy research is funded through a separate programme in the framework of the European Atomic Energy Community (Euratom).

World-wide co-ordination

IEA projects are carried out within so-called "implementing agreements" in which participating countries sign an agreement to co-operate. Currently, there are approximately 40 such agreements running. Switzerland participates in 17 of these agreements. Agreements are very flexible. They cover topics from basic and applied research to evaluation of technologies; and range from economics and ecology to exchange and dissemination of research results.

Domain	Programmes	Research: Programme managers	Research: Divisional managers 1)	Market: Divisional managers 1)
I. Rational Energy Use	Buildings	**Charles Filleux** Basler & Hofmann AG • Forchstr. 395, 8032 Zürich • Tel.: 044 387 11 22 Fax: 044 387 11 00 • charles.filleux.@baslerhofmann.ch	**Andreas Eckmanns**	**Olivier Meile**
	Transportation	**Martin Pulfer, OFEN**	**Martin Pulfer**	**Hermann Scherrer**
	Accumulators and Ultra-Capacitors			—
	Process engineering			**Martin Stettler**
	Electricity technologies and applications	**Roland Brüniger** R. Brüniger AG, Zwillikerstr. 8, 8913 Ottenbach • Tel.: 044 760 00 66 Fax: 044 760 00 68 • roland.brueniger@r-brueniger-ag.ch	**Michael Moser**	**Felix Frey**
	The Electrical Grid	**Michael Moser, OFEN**		—
	Combined Heat and Power Generation	**Thomas Kopp** HSR Hochschule für Technik Rapperswil • Oberseestrasse 10 8640 Rapperswil • Tel.: 055 222 49 23 • Fax: 055 222 44 00 thomas.kopp@hsr.ch	**Andreas Eckmanns**	**Richard Phillips**
	Combustion	**Stephan Renz** Beratung Renz Consulting • Elisabethenstr. 44 • Postfach • 4010 Basel Tel.: 061 271 76 36 • Fax: 061 272 57 95 • renz.btr@swissonline.ch	**Sandra Hermle**	
	Power Plant 2020	**Peter Jansohn** PSI, 5232 Villigen-PSI • Tel.: 056 310 28 71 • Fax: 056 310 26 24 peter.jansohn@psi.ch	**Gunter Siddiqi**	
	Fuel Cells	**Stefan Oberholzer, OFEN**	**Stefan Oberholzer**	—
II. Renewable Energy Sources	Hydrogen	**Stefan Oberholzer, OFEN**	**Stefan Oberholzer**	—
	Photovoltaics	**Stefan Nowak** NET Nowak Energie & Technologie AG • Waldweg 8, 1717 St.Ursen Tel.: 026 494 00 30 • Fax: 026 494 00 34 • stefan.nowak@netenergy.ch		**Urs Wolfer**
	Industrial use of solar energy	**Pierre Renaud** Planair SA, Crêt 108 a, 2314 La Sagne NE • Tel.: 032 933 88 40 • Fax: 032 933 88 50 • pierre.renaud@planair.ch		
	Solar Heating	**Jean-Christophe Hadorn** Base Consultants SA • 8 Rue du Nant, c.p. 6268, 1211 Genève 6 Tel.: 022 840 20 80 • Fax: 022 840 20 81 jchadorn@baseconsultants.com	**Andreas Eckmanns**	
	Heat Pumps, Cooling	**Thomas Kopp** HSR Hochschule für Technik Rapperswil • Oberseestrasse 10 8640 Rapperswil • Tel.: 055 222 49 23 • Fax: 055 222 44 00 thomas.kopp@hsr.ch		**Richard Phillips**
	Wood energy	**Sandra Hermle, OFEN**	**Sandra Hermle**	**Daniel Binggeli**
	Biomass			**Bruno Guggisberg**
	Hydropower	**Klaus Jorde** St. Leonhardstr. 59, 9000 St.Gallen • Tel.: 071 228 10 20 Fax: 071 228 10 30 • jorde@entec.ch	**Michael Moser**	**Bernard Hohl**
	Geothermal Energy	**Rudolf Minder** Minder Energy Consulting • Ruchweid 22, 8917 Oberlunkhofen Tel.: 056 640 14 64 • Fax: 056 640 14 60 • rudolf.minder@bluewin.ch	**Gunter Siddiqi**	**Markus Geissmann**
	Wind Power	**Robert Horbaty** Enco AG, Munzachstrasse 4 • 4410 Liestal • Tel.: 061 965 99 00 Fax: 061 965 99 01 • robert.horbaty@enco-ag.ch	**Katja Maus**	
III. Nuclear Energy	Nuclear energy and safety	**Jean-Marc Cavedon** *a.i.* PSI, 5232 Villigen – PSI • Tel.: 056 310 27 24 • Fax: 056 310 44 81 jean-marc.cavedon@psi.ch	**Michael Moser** 2)	—
	Regulatory safety research	**Reiner Mailänder** ENSI, Industriestrasse 19, 5200 Brugg Tel.: 056 460 86 19 • Fax: 056 460 84 99 reiner.mailaender@ensi.ch		
	Nuclear Fusion	**Claude Vaucher** SBF/SER, Hallwylstrasse 4, 3003 Bern • Tel.: 031 322 74 79 Fax: 031 322 78 54 • claude.vaucher@sbf.admin.ch		
	Radioactive waste	**Simone Brander, OFEN**	**Simone Brander**	—
Cross-cutting programmes				
IV. Cross-cutting issues	Energy – economy – society (EES)	**Nicole Mathys, OFEN**		
	Knowledge and technology transfer (KTT)	**Yasmine Calisesi, OFEN**		

1) Coordinators at the Swiss Federal Office of Energy (SFOE). Email: firstname.lastname@bfe.admin.ch • Fax: 031 323 2500
2) The Swiss Federal Office of Energy generally is the point of contact for information. However, research activities in domain III.1 are managed by the Paul Scherrer Institute PSI, those in domain III.2 by the Swiss Federal Nuclear Safety Inspectorate ENSI, and those in domain III.3 by the State Secretariat for Education and Research SER.

Swiss Federal Office of Energy
Mühlestrasse 4
CH-3063 Ittigen
Postal adress: CH-3003 Bern

Phone: ++41 (0)31 322 56 11
Fax: ++41 (0)31 322 25 00

contact@bfe.admin.ch
www.bfe.admin.ch

06.11 200 860269416