Bundesamt für Energie
Office fédéral de l'énergie
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Swiss Federal Office of Energy

National Energy Research in Switzerland

Spring 1997

What is the purpose of this brochure?

In producing this brochure, the Swiss Federal Office of Energy (FOE) had no ambitions to add another publication to the long list of subject material already available in Switzerland. This brochure rather was created for several good reasons and also to mark a special occasion.

Motive number one: ***Every year in Switzerland, over 200 million Swiss francs (CHF) in public funds are used for energy research***, a substantial portion of which is devoted to promoting research by private industry. The public is kept regularly informed about the use of these funds, usually by short press releases. The public is also entitled to exact information – and a publication which is thorough but not too long can fulfil this requirement.

Motive number two: ***The combustion of oil products and natural gas for heating and transport purposes is a major source of pollution***. Research seeking new and more efficient energy technologies is therefore also of benefit to the environment.

Motive number three: ***Switzerland still relies on imports to cover about 80% of its energy needs***, primarily in the form of oil and oil-based products. In view of this import dependency and the fact that oil reserves are limited, energy research – the search for new and more efficient energy technology – is imperative for our survival. Turning research results into products and processes is a key aspect in R+D. The public ultimately decides on the acceptance and market success of these products and processes, and therefore needs to know what kind of research is being carried out (and how), and what the goals of this research are. This brochure sets out to provide this information in a concise form.

The special occasion is the restructuring of the Federal Office of Energy. The reorganisation is aimed at further improving the co-ordination of energy research within Switzerland, in particular with espect to practical implementation of research findings.

This reorganisation offered us a fourth motive for publishing this brochure, which ***strives not only to be interesting and informative***, but also to show ***readers with their own ideas how they may obtain support*** in the form of know-how and financing.

We hope that this publication will prove to be a successful compromise between completeness and conciseness and that all readers will be able to profit from its contents.

Federal Office of Energy

Spring 1997

»Energy is the life-blood of our economy
and a key to environmental protection«

Jeanne Hersch
Philosopher, Geneva

Published by:

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Copies of this brochure, and all annual and final reports on energy research, are available free of charge from:
ENET, Schachenallee 29, 5000 Aarau, Fax 062 - 834 033 23, or
Thunstrasse 115, 3000 Berne 16, Tel. 031 - 352 77 56

Energy research requires government participation too

For Switzerland, as an industrialised nation with only very limited domestic energy sources, new technologies are the key to assuring competitiveness in the world marketplace. This is true in all areas in which research is carried out, but especially so in the field of energy. Over the last thirty years, ***the priorities of energy research have shifted dramatically***. In the 1970s, the quest to secure sufficient energy supplies gave research an almost exclusively quantitative focus, whereas since the 1980s, quality of life issues, such as ***environmental protection and conservation of resources***, are considered of equal importance. This change in public values was quite soon reflected in Switzerland's energy policy and in the basic principles of government energy research.

About 10 % of all expenditure on research and development in Switzerland (***around 1 billion Swiss francs a year***) is devoted ***to energy research***. As a proportion of gross national product, this makes Switzerland a world leader, second only to Japan. Private industry carries about 4/5 of this sum. However, more than 80 % of this is channelled into product development and less than 20 % into actual energy research or basic development. This means that ***government and private industry contribute almost the same amount of financial resources to basic energy research***.

Government funding of research in private industry? Does this not stand in contradiction to the fundamental Swiss principle of separation of state enterprise and private business? Switzerland's industry has long been concerned with preserving its independence. ***Since the 1980s***, however, ***co-operation with the government in research matters has been intensified***, at least in the field of energy. Private industry therefore also plays an important role in defining government energy research. The approach by which the state takes responsibility for education and basic research while private industry carries out applied research and development is only partly valid in the energy sector. ***The low price of conventional forms of energy makes the introduction of new energy technologies difficult*** or even impossible simply because ***their development entails too great a financial risk for private business***.

The ***strong interest among the general public*** to encourage the breakthrough of new and especially environmentally compatible energy technologies obliges the government to closely co-operate with private industry in its energy research efforts. Although such co-operation gives rise to the problem of clearly defining responsibilities, it offers the reward of greatly facilitating the implementation of research results.

Swiss energy research is conducted on the basis of guidelines formulated in the ***Federal Government Energy Research Concept***. Every four years, these guidelines are reviewed and revised by the Federal Commission on Energy Research and officially approved by the Federal Council. The Federal Office of Energy is responsible for co-ordinating and monitoring energy research.

The first priority of Swiss energy policy ***is to ensure an energy supply that is safe, environmentally compatible and economically feasible in the long term.***

*Research in the field of **transport**: This energy-efficient, emission-free, low-noise electric vehicle produced by a Swiss manufacturer could become the taxi of the future – in 1996 it served as shuttle at the automobile show in Leipzig.*

*Research on **other forms of biomass**: At the Allmig composting facility in Baar, innovative methods are minimising environmental effects while providing a high-quality product.*

Definitions and concepts: energy research

Energy research seeks to acquire and implement scientific, technical, economic and social knowledge that could be of help in fulfilling the energy needs of today and tomorrow in an efficient, economic and environmentally compatible manner.

The ***focus of Swiss government energy research programme*** is on applied research. Research findings manifest themselves in products, energy conversion facilities, improvements in existing procedures or measures, etc..

Energy research is ***interdisciplinary*** – it combines mechanical and electrical engineering with physics, chemistry, material sciences, biology, information technology, economics and sociology. Synergies often result that are beneficial to energy research, especially in Switzerland, where often not only the same institute but even the same individuals are involved in energy research as well as research in other fields at the same time.

Pilot and demonstration projects play an important role in energy research because they facilitate the ***implementation*** of research results and promote practical applications.

In a ***pilot project***, equipment or procedures are converted from a laboratory to a field scale and subsequently tested.

The next step is to implement ***demonstration projects*** on a 1:1 scale. This permits a careful assessment of technical, economic and ecological features with respect to potential commercial use.

Finally, ***market introduction*** frequently needs to be preceded by research on questions of ***acceptance***, ***environmental impacts***, economic integration and ***sociological issues***.

Justification of public support

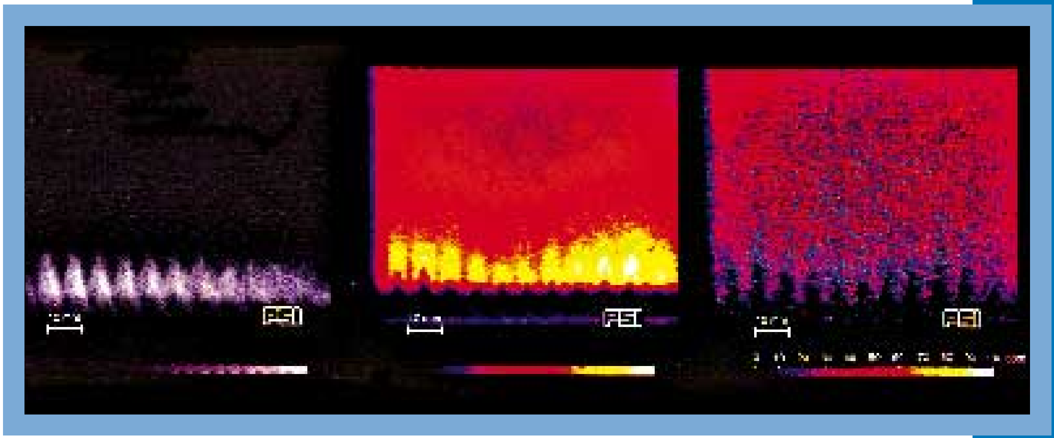
Energy research strategies for the near future

Whith the re-orientation of energy policy in the 1970s, energy research became a mainstay of energy policy in Switzerland. Over the years since then, the following guiding principles for energy research have been formulated:

- ❒ Energy research needs to be oriented towards the political goals stated in the Energy Article in the Federal Constitution. ***The federal and cantonal governments create within the scope of their competence the conditions necessary for a sufficient, safe, economic and environmentally compatible energy supply and for efficient energy use***.
- ❒ Research ***priorities*** are based on ***longer-term energy policy perspectives***.
- ❒ ***High quality, well co-ordinated research*** is aimed for. Continuity is to be achieved through long-term commitments of adequate financial and human resources.
- ❒ Energy research is to be expanded and further developed ***within existing institutions***.
- ❒ In high-priority areas of research, the ***establishment of well staffed, well equipped research groups*** is to be supported in order to maintain continuity and preserve know-how.
- ❒ ***Government funds are to be made available to private industry according to the principle of subsidiarity*** (i.e. in cases where the resources of private industry are insufficient).
- ❒ A ***holistic approach*** should be taken to energy research. In particular, the relationships between technology and environment should be addressed as well as socio-economic issues. Innovative ideas should be encouraged.
- ❒ Utilisation of research funding is to be made more efficient through ***international co-operation***.
- ❒ Public funded energy research is also responsible for training and ***further education of scientific and technical staff***, for ***putting the results of research into practice*** and for ***informing the general public*** about new findings.

These principles of Swiss energy policy are the basis of our ***research strategy for the near future***:

- ❒ Help ***reduce energy consumption by making end use more efficient, by developing new technologies and by improving existing technologies*** for generation, transformation, storage and distribution of heat and electricity. ***Utilization of renewable sources of energy***.
- ❒ Continue working to ***make heating and combustion technology cleaner and more efficient***, with a view to tapping new forms of chemical energy.
- ❒ ***Continuation of safe nuclear power production*** while continuing to study ***nuclear fusion as a future long-term option*** (though discontinuing research on breeder reactors).
- ❒ ***Consideration of integral relationships*** in research efforts, e.g. global material flow, grey energy, risk issues and sustainability.
- ❒ ***Inclusion of basic social and economic frames of reference*** as well as consideration of trends in energy demand and supply.



*Research in the field of **heating and combustion**: pollutant formation and distribution is studied on a commercial pre-mix gas burner for heating with the aid of laser technology at the Paul Scherrer Institute. From left to right: chemical luminescence of the flame, distribution of OH radicals, distribution of nitrogen monoxide. Studies such as this identify potential for further improvements.*

Principles and strategy

The organisational framework: divisions, programmes, projects, and experts

Co-ordination, support and international integration of government-sponsored energy research are the responsibilities of the Federal Office of Energy, which receives advice on these matters from the Federal Commission on Energy Research.

The Federal Office of Energy has divided energy research in Switzerland into three »sections«:

- ***Efficient energy use,***
- ***Renewable energies,***
- ***Special areas.***

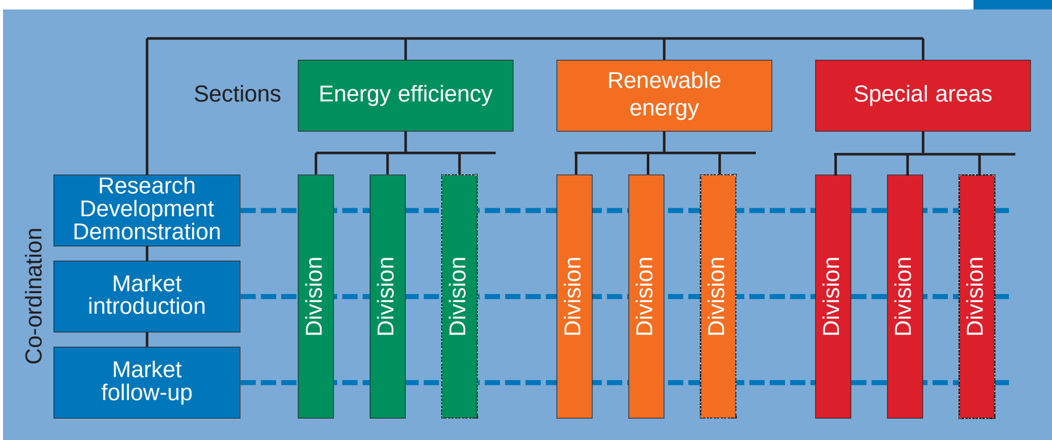
These three sections comprise a ***total of 14 »divisions«***, such as »Wood«, »Nuclear energy«, etc.:

- ***Every division is managed by a head of research*** (division manager)***.***
- ***A division may be divided into sub-divisions***. For example, »Transport« is sub-divided into »Traffic in general« and »Lightweight automobiles«.
- ***A 15th division, »Energy fundamentals«***, is not attached to any of the three sections because its purpose is ***to support and supplement the other divisions – all of which have a technical focus – in economic, social and political issues***.

A list of all the research divisions and sub-divisions, along with the addresses of all division and programme managers, is provided on the inside of the back cover.

Each sub-division has research and pilot and demonstration programmes as well as implementation and marketing programmes. In the »Active use of solar energy« division, e.g., there are programmes for both of the sub-divisions, »Solar heat« and »Photovoltaics«. ***Each programme is run by a programme manager, and often the division managers take on this assignment themselves***. ***The division manager is supported not only by the programme managers but also by a group of experts***. Together they draft a ***detailed plan of action*** for their division that reflects the federal government's energy research concept and considers basic political and economic frames of reference. This plan serves as the basis for the ***support grants awarded to various projects***. The majority of projects are run by public research facilities such as the Federal Institute of Technology in Zurich or the Paul Scherrer Institute. However, financial support is also given to industry, engineering companies and projects launched by individuals.

The ***Federal Commission on Energy Research*** was established in 1986, with representatives from industry, the energy sector, the Federal Institute of Technology, universities and technical schools, cantonal energy authorities, the Swiss National Research Fund, business development organisations and the Swiss Science Council. The members have personal mandates. The commission ***is responsible for advising the Federal Council and the Federal Department of Transport and Energy concerning federal energy research and the implementation of research results and thus plays a key role in defining guidelines for Switzerland's energy research***. The Commission updates the Federal Energy Research Concept every four years and organizes the Conference on Swiss Energy Research every second year.



The Federal Office of Energy reorganised energy research in 1996, primarily with the goal of facilitating the implementation of research results. Previously, research and development formed an independent unit responsible for all fields of interest. Now, however, an interdisciplinary approach is taken which integrates research, development and demonstration as well as market introduction and market follow-up.

Definitions and concepts: Organisation

Co-ordinating energy research means that the Federal Office of Energy keeps itself informed about all significant research activities in Switzerland (conducted by technical schools, private industry and other research institutions) and works to harmonise these efforts so as to achieve the greatest possible efficiency. The Federal Office of Energy seeks to prevent any duplication in research efforts and uses its professional expertise, national and international information channels and funding resources as co-ordination tools.

Project support: the Federal Office of Energy continuously monitors scientific and other aspects of the research activities which it sponsors. This support may take the form of auditing the research reports that project staff are required to periodically submit, assistance in practical implementation or direct contact or paying visits with the project leaders to their research facilities.

The ***Divisions*** represent defined subject categories to which all energy research activities in Switzerland are assigned, both in the public and private spheres. A division encompasses a distinct segment of energy technology or energy research, e.g. »Building shells«, »Geothermics«, »Photovoltaics«, »Wood«, »Nuclear fusion«, »Heat storage«.

A ***project*** is research work carried out on a special, clearly defined topic with a limited time frame, e.g. »Development of a facade system with integrated solar cell modules«.

Organisation of FOE Aid

Buildings as efficient energy systems

In Switzerland, as in all industrialised countries with moderate climates, ***the buildings segment is the largest energy consumer***. ***About half of all end energy*** goes into keeping residential and office buildings heated, ventilated and air-conditioned and supplied with electricity and water. During the economic boom years between 1960 and 1975, a great deal of shoddy building was carried out, even in a country as quality-conscious as Switzerland, and energy consumption factors were more or less ignored, since heating fuel was extremely cheap at that time. As a result, the infamous constructions of the 1960s consume more electricity and heating fuel today than older buildings do.

The oil crisis of 1973 gave rise to a radical change of approach in this sector, however. Since then, research has paved the way to ***major advances*** in all areas of construction. ***The electricity and heating requirements of buildings incorporating the latest developments are only a fraction of what they were before***. However, the positive effects of this progress on overall energy consumption are being felt only gradually, because new constructions are replacing older ones at a rate of only a few percent per year. Several decades normally pass before buildings are renovated, and their replacement takes considerably more time.

The problem of excessive energy consumption is therefore not one that can be solved through construction and building technology innovations alone. It is equally important that these innovations are put into practice quickly and on as broad a scale as possible. This goal is hampered by the fact that there is an abundance of research efforts which are rarely co-ordinated with each other, often duplicated and mostly difficult to keep track of. To minimise these obstacles and subsequently improve implementation, ***the Federal Office of Energy launched a research programme called »Efficient energy use in buildings« in the mid-1980***s. This programme has produced the following results:

- ❒ ***Planning aids***, e.g. a computer programme ***simulating air currents in building interiors*** -– a basic tool for the energy-efficient planning of air-conditioning and ventilation installations. Concepts for efficient construction and operation of schools and hospitals.
- ❒ Energy-saving, passive cooling systems for office buildings during the warm season have been developed and successfully tested.
- ❒ A standard software package has been developed for calculating ***ecology indexes for the most important construction and insulating materials***.

The Federal Office of Energy's ***»Solar architecture«*** research programme has ***complemented these efforts***. This programme has focused on measurement of all types of buildings – from single-family dwellings to factory complexes – and on new solar architecture components. It has identified certain mistakes that were made early on, collected and compiled information in ***data bases and computer programmes for planners***. These data pertain mainly to the properties of new window panes with high thermal insulation properties, daylight-based systems, solar air-heating systems, transparent insulation, atria, conservatories and glass-enclosed balconies, comprehensive energy planning and building renovation.

All these efforts have brought research an important step closer to its goals, and these have since been defined more precisely on the basis of an ***energy consumption »reduction curve« for buildings*** calculated by the Swiss Association of Engineers and Architects. By the year 2000, the average heating consumption of new residential buildings should be reduced to 180 MJ/m²a and by the year 2020 even

Definitions and concepts: buildings

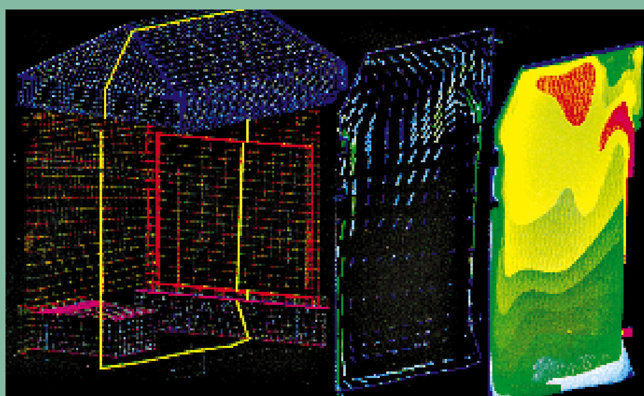
The term ***»building«*** includes single- and multiple-family dwellings, offices, and commercial and industrial constructions.

The ***building shell*** refers to those parts of a building that separate the interior from the outside world (atmosphere and ground). It comprises the outer walls (including those of the cellar), windows, doors and roof. Their heat conduction properties largely determine how much heat in a building is lost to the environment.

Transparent insulation is made of material that conducts light. It transmits sunlight to the building's outer walls but prevents heat being radiated away.

Solar architecture does not refer to a particular architectural style, but rather to the design of buildings in terms of shape, placement and size of windows, interior space planning and distribution of heat-retaining materials so as to make maximum use of the sun as a source of light and heat. The aim is to minimise reliance on non-renewable sources of energy, while preventing overheating during the summer months. A distinction is made between ***direct use of solar energy*** (use of the solar radiation through windows for heating and lighting purposes) and indirect use via external solar collectors (heating of water or air). Through ***systems integration*** the various components of solar architecture are co-ordinated in such a way that overall energy consumption is minimised.

Building ecology is concerned with all aspects of ecologically sound construction. ***Ecology indexes*** are a means of rating the environmental compatibility of construction materials or entire buildings. An ecology index is composed of a ***pollutant index*** (which rates the overall environmental pollution) and an ***energy index*** (the sum of the energy consumed by each step from the extraction of raw materials to their later disposal as waste). Ecology indexes do not simplify evaluations, but they do help identify weak-



Various research projects resulted in the development of a method of calculating air currents and temperature layers under difficult conditions, e.g. in large atria of office buildings (atria allow use of natural light). Left: an atrium in the town of Zug. Right: the simulation model (for the profile marked in yellow) showing air currents and temperature distribution (red = warm, green = cold).

further to only 100 MJ/m²a (the target for buildings renovated using energy-saving technology is set 50 % higher). In comparison, in 1970 this figure was 570 MJ/m²a for new buildings!

The research programme for the 1996-99 period is designed to ***provide the technical pre-requisites*** for meeting these targets. In order to take better account – from the point of view of efficient energy use – of the complex relationships between the various energy sub-systems of which a building is composed, the Federal Office of Energy merged the three divisions, »Building systems and shells«, »Building technology« and »Solar architecture and daylight utilization« to form a ***»Master programme for buildings«***. Its action plans are formulated on the basis of eight main objectives. By the year 2000, end energy consumption for hot water, room heating and cooling and electricity is to be reduced from 1990 levels by 10 to 25%, depending on the type (residential or industrial/commercial) and the age (new construction or renovation) of the building. By 2010 a further reduction by a similar amount is to be achieved. ***The emphasis is on upgrading the energy efficiency of existing buildings***, which means moving away from the »repair strategy« that is still common today. Building ecology and utilization of renewable forms of energy will be particularly taken into consideration.

In order to reach these objectives, research and development work within the »Master programme for buildings« will ***focus*** on the following:

- ❒ Developments in ***building systems and shells: simple planning aids for optimising*** comprehensive approaches ***in terms of energy efficiency*** and building ecology; new insulating materials with k-values of between 0.20 and 0.25 W/m²K at 5 to 8 cm thickness and which are easier to work with and fit; windows offering better energy indexes and window renovation systems; simple procedures for assessing quality in energy terms.
- ❒ Developments in ***building technology***: Guidelines for ***comprehensive, ecological assessments*** that also take account of degradability factors; ***standard solutions*** (that include new technologies such as heat pumps) ***for the renewal*** of outdated heating installations; ***oil-fired boilers*** with less than 70 kW capacity and ***at least 95% annual utilisation***; oil and gas burners that consume 50 % less electricity; high-efficiency insulation (e.g. vacuum-based) for heating installations; new, ***controlled ventilation systems for apartment buildings*** that adjust according to air quality.
- ❒ Developments in ***solar architecture and daylight utilisation***: catalogue of tested solutions, with an emphasis on low-energy-consumption houses, for intensive use of solar energy for lighting and heating (using direct collection or solar air systems); economical transparent insulation modules with integrated protection against over-heating; computer programmes and handbooks for planners of daylight-based systems.

Too little funding had been budgeted for P&D projects in the 1988 programme for the ***implementation*** of research results to be called an actual success. Nonetheless, the »Air currents in buildings« project produced important results for the ventilation industry. The 1996-99 programme will promote implementation by the exemplary renovation of apartment houses and office buildings that present common problems particularly difficult to solve, and accompany this with information campaigns. Better approaches to information transfer must be found, as architects and contractors have not kept abreast of developments, largely due to the large number of poorly written project reports.

This apartment complex in Plan-des Ouates served as a demonstration project. By applying latest know-how, its energy index was brought down to 250 megajoules per m² – one third less than ordinary, comparable buildings.

Traditional architecture can incorporate modern, energy-saving construction elements – this home at Gonten takes heat from air collectors and stores it in concrete ceilings integrated into the building shell.

nesses in products and procedures and they are a meaningful decision-making tool for the authorities.

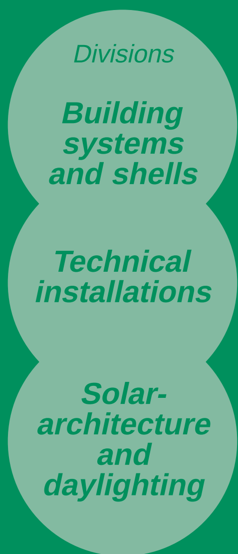
Daylight utilisation, or daylighting, focuses on lighting interior spaces with natural light. The goal is to save on artificial lighting and heighten the sense of well-being, especially in large offices. Daylight is channelled into those parts of a building's interior where it is needed by using optimally placed windows (e.g. skylights), atria (glass-enclosed areas), reflectors, mirrors and light ducts.

Building system refers to the shell, interior and technology of buildings and how these components interact to affect their energy consumption.

Building technology is a collective term for all technical installations in buildings: electrical, water and sanitary installations, heating, ventilation and air conditioning and wide-band communication (for monitoring and regulating other installations).

The ***energy index*** reflects the quality of a building from an energy technology perspective. The index expresses the energy consumed per m², or the ***specific energy consumption***. In 1970, the average energy index value was 570 megajoules per m² per year (MJ/m²a) for heating and 200 MJ/m²a for electricity. New buildings that incorporate the latest know-how reach much lower values (approximately 150 MJ/m²a for heating and about 30 MJ/m²a for electricity). By the year 2020, these values are likely to drop by another 50 %.

The demand for cooling systems during the warm season is growing, especially in the office building segment. Because ordinary air-conditioning systems are heavy energy consumers, ***passive forms of cooling*** are quickly gaining importance, e.g. use of night air, air cooled in underground pipes, ground water or sea water pumped into specially constructed floors and ceilings.



Electricity-saving installations and equipment

Early models of ***television sets and computers*** are a tangible example of ***wasted electricity*** – even on »stand-by« they help heat rooms and offices. Many ***heat circulation pumps*** also gobble up energy. The electricity lost through a single such device is not significant, but because millions of these are in operation, ***these »minor« losses represent a substantial amount of energy at national level***. In addition, there is often ***potential for improving the efficiency of electricity production and for reducing power distribution losses***.

Research and development work in connection with power production and distribution has always been the responsibility of producers. Nevertheless, in the late 1980s the Federal Office of Energy initiated ***research focused on reducing the power consumption*** of electrical devices and installations. The research programme launched in 1990 was a success, as demonstrated by two examples:

- ❒ Basic information for ***reducing stand-by losses*** in electronic office equipment and home entertainment products were made; manufacturers and consumers were then sensitized to these issues.
- ❒ A prototype ***small-size circulation pump has three times the efficiency*** of a standard pump.

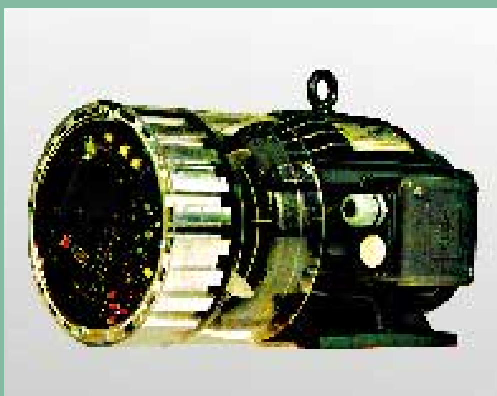
The 1996-99 programme identifies areas ***where further research is needed*** in order to fully tap the potential for further improvements.

- ❒ Transformers and cables made of ***high-temperature superconductors*** may make loss-free power transmission a possibility. Discovered in 1986 in Switzerland, superconductor ceramics are being investigated intensively all over the world. With a tolerable amount of cooling, they offer no electrical resistance and thus cause no energy loss through the generation of heat. However, superconductors are a ***brittle material***, which makes it difficult to form them into wires and strips.
- ❒ A study conducted in 1990 revealed that three-phase current, asynchronous standardised motors with a capacity of up to 22 kilowatts, commonly used in commerce and industry, exhibit particularly high losses. The drive systems (consisting of converter, electric motor, controls, gear mechanism and the system to be powered) are also not constructed with a view to minimising energy consumption. They therefore need to be optimised on the basis of an ***integral motor*** which is to be developed and which will incorporate a frequency converter (energy-saving speed regulator) and controls.
- ❒ Major power savings could potentially be achieved in ***data processing networks*** by using ***»Power management«***, a demand-oriented automated operating system for computers and network components (e.g. automatic shut-down at night and on weekends).
- ❒ ***Demand-side management***, i.e. targeted efforts to encourage efficient use of electricity among end-users, is to be promoted.

Projects seeking to generate power from renewable energy sources are assigned to other programmes, such as »Small-scale hydropower plants«, »Photovoltaics« and »Wind power plants«.

Research and development work on the stand-by losses of office and home entertainment electronics (»secret power guzzlers«) has had effects at both a national as well as an international level. Switzerland was the first country to introduce target values for this type of power loss; foreign manufacturers have since introduced new models that consume substantially less power. The findings of research now in progress will be ***put into practice in an equally effective manner***.

Switched off, but still drawing nearly 50W while on stand-by. »Secret power guzzlers« such as this photocopier were identified in Federal Office of Energy programmes, and manufacturers responded by making improvements.



This innovative 3 kW integral electric motor is a power-saving, »all-in-one« motor. It has an integrated frequency converter (left) that regulates speed as well as integrated controls.

Definitions and concepts: Electricity

The three-phase current generated in ***central power plants*** (e.g. hydropower and nuclear power plants) is converted to high voltage in ***transformers*** and transmitted through ***overhead power lines*** to ***distribution nodes*** (high voltage minimises transmission losses). At these nodes the electricity is transformed back to its low voltage form and then passed on ***to users*** via ***distribution lines***.

Together, the overhead power lines and distribution cables, transformers and distribution stations form a ***power network***. These networks can be linked to form a ***grid***, the purpose of which is to assure an uninterrupted power supply even if one of the power plants should experience a breakdown.

To minimise ***circuit power losses*** due to resistance, researchers are working to develop cables made of ***high-temperature superconductors***. The resistance of this material is reduced to zero when it is cooled to –150 °C (using liquid nitrogen).

Small, ***local power stations***, e.g. small-scale hydropower plants or photovoltaic installations can also feed power into the network, but because their production rates vary, they do not suffice as network supports.

Storage power plants are required to cover needs during peak consumption periods. Minor fluctuations can also be balanced out by ***power reservoirs***, e.g. accumulators or ***flywheel generators***.

Losses also occur at the ***electricity consumer level*** (motors and power-driven devices), usually because of resistance, but also due to less than optimal construction.

Efficiency is determined by the ratio of power produced to power consumption. ***Utilisation*** is the ratio of energy produced to the energy consumed. Often these two terms are used interchangeably.

Division

Electricity, Appliances

Utilizing environmental and waste heat

Low-temperature heat for room heating, hot-water preparation and industrial processes represents more than half the end-energy demand in Switzerland. Most heating systems burn ***oil or gas*** with a ***level of utilisation of fuel energy or end energy*** of around 80% for older systems and almost 100% (!) for the most up-to-date systems. Heating systems with an even better level of utilisation of energy are therefore a pre-requisite for higher energy efficiency. And if such systems also use renewable energy forms such as environmental heat, then nature will be thankful too!

Heat pumps and co-generation achieve higher energy utilisation levels and have been known for some time as isolated individual solutions. Only after the oil crises of 1973 and 1979 did their real potential for general room heating purposes become apparent. At the same time, the marked need for R&D was recognised in order to develop them into economical heating systems suitbale for winter service. R&D in this field has now been greatly increased in Switzerland (and also on an international level). At the end of 1995, the ***results of these research and development efforts*** were as follows :

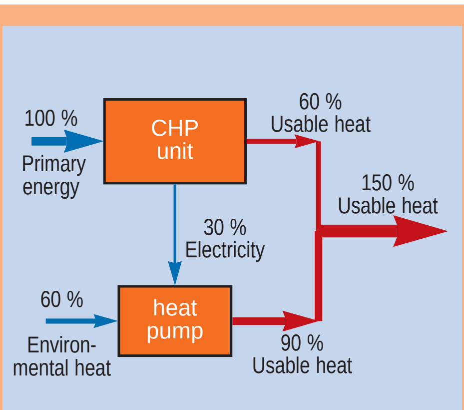
- ❐ In the field of ***heat sources*** (for environmental heat), knowledge concerning the best arrangement of geothermal probes was considerably broadened (cf. »Heat from the bowels of the earth«).
- ❐ ***Working fluids*** with lower or (even zero) greenhouse effect are now being used instead of chlorofluorocarbons. System components and processes need to be adapted to these refrigerants.
- ❐ ***Electric heat pumps***: attempts to adapt the heating capacity to meet actual requirements (thus saving a great deal of energy) using variable compressor speeds; development of a small heat pump with external air as its heat source, aimed at replacing electric storage heaters.
- ❐ Suitability and ***140% utilisation ratio*** of ***a new type of absorption heat pump*** (without motor or compressor) demonstrated by a Swiss inventor.
- ❐ The combination of a combined heat and power (CHP) unit and a heat pump (driven by the plant's electricity) results in ***up to 200% end energy utilisation***. Trials are planned with ***wood, diesel*** (***with de-nitrification of exhaust fumes***) and ***small-scale CHP units***.

There is ***still a need for R&D*** however with the following ***principal objectives*** 1996/1999:

- ❐ Development of reliable and ***economic heat pumps*** even for higher heating forward flow temperatures in older buildings.
- ❐ Closing the gaps in knowledge with regard to alternative, and especially ***natural refrigerants***.
- ❐ Construction and tests of ***fuel cell CHP units*** as P&D-systems (cf. page 18).
- ❐ ***Systems optimisation***, i.e. increasing the level of energy utilisation and security of operation of heating systems, e.g. combination of CHP units and heat pumps, or the new type of absorption heat pumps with a gas boiler (for covering peak demand).

The financial resources for promotion, especially of P&D plants, are rather limited; the choice of projects to be promoted needs to be based strictly on their degree of urgency and on quality criteria.

Just how successful ***transfer of R&D results*** has been in this field is demonstrated by the fact that at the end of 1995 more than 4'000 heat pumps for heating systems were installed in Switzerland. Further progress is reported regularly at ***conferences, courses and in reports***. Attempts are being made to bring about an even greater active commitment to R&D on the part of industrial partners.



If an electric heat pump is driven using the electricity generated by a CHP (combined heat and power) unit, the 100 % primary energy used yields 150 % or even more usable heat.

This new type of heat pump employs the Stirling principle. Its main component is a 5-meter-long resonance tube in which a vibrating gas column transfers the energy from a Stirling motor to a Stirling heat pump.

Definitions and concepts: Heating

Environmental heat is the heat contained in the air, the soil, groundwater, rivers and lakes. It is classed as a renewable energy.

Waste heat is defined as heat currents which occur in technical processes and which are expelled unused into the environment, e.g. the heat contained in exhaust air from buildings or passed on by motors to cooling systems, etc.

Environmental and waste heat are generally at ***too low a temperature*** to permit them to be used directly for heating, hot-water preparation or industrial processes.

Their use is possible in combination with ***heat pumps***, since these raise the temperature within certain limits (e.g. groundwater temperature of 10 °C to 40 °C for floor-heating). At the same time, they supply more energy than they require for their operation.

In heat pumps, the environmental or waste heat is used to evaporate a ***working fluid*** (e.g. ammonia). This gas is compressed and heats up as a result. During subsequent condensation in a condenser, the gaseous working fluid gives off usable heat to the heating system. A compressor is normally used. If this is driven by an electric motor, the system is referred to as an electric heat pump, and if it is driven by a combustion motor, it is referred to as a motor heat pump.

If the waste heat from a power generator is utilised, this process is referred to as ***combined heat and power***, or ***co-generation***. For example, a combustion motor drives an electricity generator in a ***CHP (combined heat and power) unit***, and the heat from the cooling water and exhaust gases is used for heating purposes.

Solar panels for hot water and heating

Certain elements of solar architecture (cf. pages 4/5) use solar energy solely on the basis of their design: windows, for example, let sunshine in but do not let heat radiation out again – and there are no moving parts. This is why this type of solar energy use is referred to as »passive«. But in ***collector circuits***, ***»active« elements such as pumps and valves*** control the flow of the heat transfer medium through the panels placed by the architect on the roof.

In Switzerland, »active« solar energy use already began to gain a foothold not long after the 1973 oil crisis. Small and medium-sized companies started introducing flat panels onto the market, followed soon by complete solar installations. Investment promotion efforts by the cantons ensured the continuous spread of solar installations, and continue to do so today. The implementation of results attained from research and development programmes promoted by the public authorities has contributed to the fact that installations for solar water heating and auxiliary (or even full) space heating can be considered as being fully developed. With over 500'000 m^2 of solar panel surface, of which around 50% is used for hay ventilation in hundreds of farms, ***Switzerland is among those countries with the highest density of panels per head of population***. A unique international testing centre for panels has now been set up at the inter-cantonal polytechnic in Rapperswil. Planners have highly advanced PC dimensioning programs at their disposal.

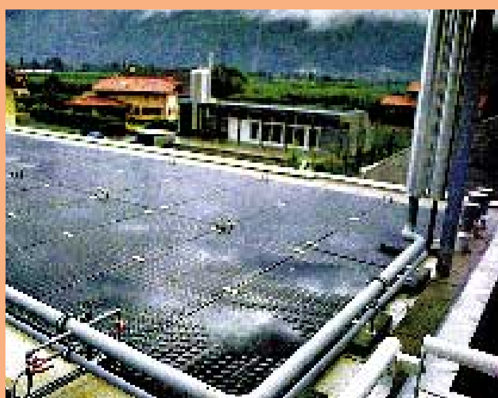
So why is further research needed? Because ***active solar energy use is regarded as a highly important means to substitute oil heating and thus contributes towards reducing air pollution*** (the annual yield from 1 m^2 of flat panel surface is over 350 kWh, the equivalent to 45 l of heating oil). Other reasons are that even the fully developed systems still have room for improvement, and ***the cost of solar systems needs to be significantly reduced*** to ensure the wide use called for.

Consequently, the reduction of heat production costs is the primary objective of the Federal Office of Energy's 1996/99 research programme, along with quality assurance:

- ❐ ***New materials and concepts will help glazed collectors and their components*** – absorbers, glass covers, heat insulation, pipe connections, solar pumps – achieve higher levels of efficiency and lead to lower production costs.
- ❐ ***Uncovered panels***, e.g. made of stainless steel, would be suitable ***for roof and facade integration***, but have first to be further developed into systems.
- ❐ Collector systems ***generally need to be adapted to permit simpler and more practical integration*** – e.g. in the form of facade elements.
- ❐ A ***compact standardised system for hot-water heating in apartment houses*** should be developed.
- ❐ Research on a prototype should open up the ***possibility of a small-scale solar power plant of 10 to 15 kW*** electrical capacity with vacuum panels and a special steam turbine for mountain regions.

In addition to conferences, reports and broadly distributed, easily understandable information, in order to promote ***implementation***, a large number of P&D systems need to be commissioned to provide property owners and builders with technically optimised, yet highly practical, easily understandable and inexpensive active systems for hot-water and heating purposes.

In 1990, Europe's leading testing and research centre for solar panels was established at the Interkantonales Technikum Rapperswil. The photo shows the open-air testing facility with fully automatic uninterrupted measurement.



New type of solar roof made of integrated stainless steel absorbers without glass cover: 1/3 less yield than covered collectors but only a fraction of the cost. Photo: a test installation in Saillon.

Definitions and concepts: Solar collectors

Solar radiation has a very low power density – in central Europe it averages around 0.1 kW per m^2 (combustion chamber wall of an oil or gas furnace = approx. 500 kW per m^2). This is why large surfaces are required for »collection« purposes. The higher the efficiency of such collectors, the smaller the surface and costs. Collectors are therefore the ***key elements*** in active solar energy use.

In a ***collector***, an absorber is heated by the solar radiation and in turn heats a gas or liquid to transport this heat. The many different types of panels can be divided into categories according to application or attainable temperature. The most important types for Switzerland are as follows:

- ❐ ***Flat panels*** (for domestic hot water and heating purposes) use a blackened metal or plastic plate as an absorber. The heat transfer medium is brine (water mixed with an anti-freeze agent) or air. In glazed panels, the glass retains most of the absorber's heat radiation. ***Efficiencies of around 35 % can be achieved and supply temperatures up to 150 °C***. Uncovered panels attain a temperature of up to 60 °C, but are considerably cheaper due to the elimination of glazing and seal.
- ❐ In ***pipe or vacuum collectors***, the absorber is surrounded by a glass pipe containing a vacuum which greatly reduces heat losses. Efficiency is over 50%, with attainable temperatures of up to 250 °C. This system is therefore suitable for process heat and steam production, but is expensive.

A collector system comprises a collector, supports and connection pipes. »Integrated« panels in the form of roof or facade elements are more economical than free standing units because they replace the usual roof or facade covering.

Electricity from roofs and facades

Photovoltaics (PV) is an attractive form of energy: a semiconductor wafer generates electricity from sunlight, without moving parts, sound, and emissions. Modules and systems have been commercially available since the 1970s. ***For Switzerland, PV is attractive for electricity production and as an export opportunity for PV-technology***. Promotion of research was therefore already introduced in the 1970s. The most important results of these R&D efforts up to the mid-1990s are as follows:

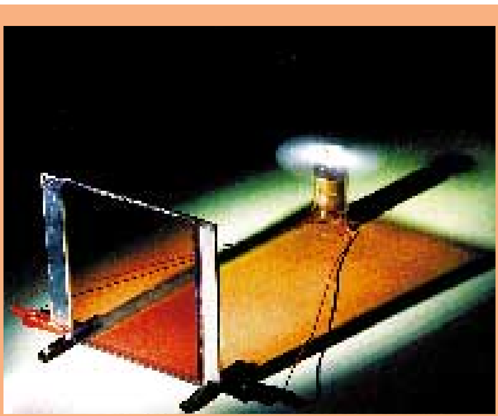
- ❒ Researchers and the industry now possess ***broad knowledge with regard to system planning, construction and components***, which – as well as in corresponding products – is also reflected in PC programs for the dimensioning and performance estimation of PV systems, as well as in databases concerning modules available on the market.
- ❒ ***Pioneer work has been performed on the development of components*** – such as inverters, mounting aids for modules and connection technology.
- ❒ Switzerland is also a ***pioneer in the field of building integration*** (principal reason: lack of available land). Solar roof tiles and PV facade elements are Swiss inventions which are also already available as products on the market.
- ❒ Thanks to fundamental research on ***new PV materials and cell technologies***, Swiss researchers are permitting Switzerland to keep pace with the leading countries in this field.

With thousands of installations – from tiny systems producing just a few watts to a PV power plant (Mont Soleil) with a capacity of 500 kW – and a total of 8 MW installed peak capacity, ***Switzerland has the highest solar cell density per head of population in the world***. Recent estimates indicate that 100 to 200 km^2 of roof surface and 45 to 75 km^2 of facade surface would be suitable (i.e. essentially facing south) for PV installations, and that the installed peak capacity (using currently existing solar cells) on these surfaces of between 15'000 and 27'000 megawatts would suffice to cover a considerable percentage of Switzerland's electricity demand.

However, ***high costs*** are still the main obstacle. The lowest cost of a kWh of solar cell electricity is around 0.90 CHF, compared with 0.05 CHF from hydropower and 0.10 to 0.15 CHF from nuclear power. So ***world-wide research is currently aimed at lowering the costs*** via cheaper manufacturing processes, new cell concepts, lower system costs or increased efficiency. Swiss research objectives for 1996/99 will also be pursuing similar objectives:

- ❒ ***Research*** and development in the materials sector, aimed at developing cells using extremely thin silicon layers, multiple layer cells (e.g. tandem cells, in which two thin cells of materials with differing spectral sensitivity – one, e.g., in the red range and the other in the violet range of solar radiation – are layered in order to attain higher efficiency), as well as ***new cell technologies***.
- ❒ Systems and products for ***integration into buildings***.
- ❒ Further ***simplifications of systems technology***.

Implementability has always been both the ***principal objective and the main selection criterion for the promotion*** of PV research. Modules (e.g. solar roof tiles), inverters and new solutions for integration into buildings (on roofs and facades) are being developed in co-operation with the industry. Planning aids and reference works support the implementation efforts, while P&D systems serve educational purposes (from vocational schools up to university level).



Novel »nano-crystalline« solar cells developed by the Swiss Federal Institute of Technology, Lausanne, are based on organic dyes. Still in their development stage, their long-term stability needs above all to be established.

Transparent roof tiles which have been fitted with solar cells permit the integration of photovoltaic solar cells into buildings with simultaneous daylighting.

Definitions and concepts: Photovoltaics

Photovoltaics, in short PV, is the name given to semiconductor solar cell technology. In solar cells a threshold layer is formed between two differently conducting semiconductors. Sunlight releases charge carriers at these threshold layers so that an electrical dc-voltage results. With most materials, this voltage is 0.5 volts. When fitted with a current collector on the front and back, the wafer forms a ***solar cell***.

The most ***suitable semiconductor*** is silicon. Gallium arsenide and cadmium compounds are also suitable for special cases.

Commercial solar cells are usually made of crystalline or amorphous silicon. Mono-crystallines achieve the highest efficiency at around 15 %, and in a typical solar cell size of 100 cm^2, they produce around 1.5 Wp (= peak capacity) in the midday sun in summer. Poly-crystallines achieve an efficiency of around 12 %, and amorphous crystallines around 6 % (the latter level decreases during the first six months of operation; this is referred to as ***degradation***).

More recent developments include thin crystalline silicon layers or ***dye-sensitised nano-crystalline layers*** (a dye converts sunlight into electricity).

Solar cells that are linked together and encapsulated so as to be weatherproof form a ready-to-use ***PV module***, and several modules form a PV field. A PV field with the necessary auxiliary aggregrates is referred to as a PV system.

PV systems can be operated ***in isolation*** (electricity supply without a utility connection) or ***connected to the grid***. Connection to the grid requires an ***inverter*** which converts the direct current of the solar cells into alternating current.

PV systems can be installed free-standing (e.g. on a roof or in the garden), or be ***integrated into a building*** (modules then form the roofing or facade).

More and clean energy from wood and other biomass

In Switzerland, enough biomass grows every year that it would be possible to cover a major proportion of the national energy requirements with its energy content. But it is only wood that has always been used in rural areas as a fuel for heating, and in more recent times for burning in fireplaces and stoves in urban areas too. And even this firewood only represents one third, 2.2 million m^3, of the total consumption of wood in Switzerland. The other two thirds are used in equal proportions for making paper and as timber for furniture and construction purposes. More wood grows than is harvested, which means that ***up to three times as much firewood could be used as today, without subjecting the forests to over-exploitation***.

Because ***biomass is a renewable domestic energy source and is therefore of interest from both a supply security and environmental protection point of view***, R&D work is publicly promoted. It is co-ordinated with the goal of achieving increased utilisation (also by a reduction of costs). The Federal Office of Energy has divided this research into two divisions.

In the ***»wood« division***, encompassing forest timber, residual timber and recycled timber, research has made a great deal of progress in the past few years. Thanks to the rapid implementation of the research results, there are now combustion systems in all performance categories on the market that are environmentally compatible and function with a high degree of efficiency. These range from hot-air fireplaces to wood-chip CHP plants. At the end of 1995, there were 620'000 wood-burning stoves and cookers, around 4'500 automatic wood-burning furnaces and 26 furnaces for recycled wood in Switzerland. ***Research requirements*** in the period from 1996/99 are only in selected areas:

❐ Manually operated ***small-scale wood-burning furnaces need to be more effectively adapted to requirements*** – low heating capacity and longer operating periods – of low-energy dwellings.

❐ With regard to ***automatic furnaces***, the ***main focus is on a further reduction of pollutant emissions***: combustion chambers that provide total combustion; measures to reduce nitric-oxide emissions; retention of soot particles.

In the ***division »other biomass«***, research is now only regarded as necessary in certain fields (and not at all with regard to organic waste from sewage treatment plants, waste incineration and refuse tips):

❐ ***Development and optimisation of biogas and gasification systems*** for agricultural, municipal and commercial waste.

❐ Continuation of ***trials using miscanthus grass or reeds for combustion purposes***, in order to solve problems such as ash slagging (in combustion chambers) and deposits (in boilers).

❐ ***Adaptation of motors to untreated ecological fuels*** (e.g. rapeseed oil), as well as the ***adaptation of fuels to motors*** (e.g. processing of biogas into a combustion gas with a high methane content similar to natural gas).

Implementation is promoted through P&D systems in addition to the publication of reports and the organisation of conferences. Examples of such P&D projects in the »wood« division include a system for low-emission combustion of recycled timber (for electricity generation using steam turbines), and in the »other biomass« division, a system for the esterification of rapeseed oil (for utilisation as a motor fuel).

A composting and fermentation plant at Baar processes 18'000 t of bio-waste each year. This new process is even able to supply surplus electricity and is also free of waste water thanks to a bio-filter (photo) for cleaning exhaust air.

Larger-scale plants for wood combustion use wood chips. For practical reasons, the wood is chopped directly on location in the forest using special wood-chip machines.

Definitions and concepts: Biomass

In energy terms, ***biomass*** refers to all organic materials and residual matter arising from agriculture, households, forests, gardens, trade and industry which can be processed to yield energy. Sources include solid dung, liquid manure, straw, wood, plants containing starch and sugar, waste water from the foodstuff manufacturing industry which contains nutrients, sewage sludge and refuse.

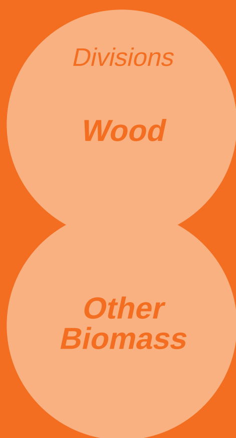
Since both humans and animals nourish themselves from plants, and since these grow with the aid of solar energy (with an efficiency of around 0.1%), biomass energy is a ***renewable energy***. The annual growth in plant biomass on our planet is estimated at around 200 billion t, the energy content of which is equivalent to that of all known fossil fuel resources (oil, gas and coal).

The most important ***conversion processes*** for obtaining biomass energy from biomass are combustion, gasification (through heating under deficiency of air), fermentation (to produce alcohols) and the use of vegetable oils as bio-fuels.

Biomass is ***a complex mixture of carbohydrates***. For this reason, ***pollutants*** are produced during their conversion into energy, and these mainly include ash, carbon dioxide (CO_2), nitric oxides, sulphur dioxide and hydrocarbons, plus soot and dust.

In comparison with fossil fuels, biomass offers the advantage of being ***»CO_2 neutral«***: just as much CO_2 is absorbed or required for the growth of new biomass as is produced during its utilisation as an energy form. But this only applies as long as exhaustion is avoided and no fossil fuels are used for processing the biomass.

Most ***recycled timber*** still tends to contain chemicals, e.g. wood preservatives, and therefore require special processes for the reduction of emissions during combustion.



Heat (and electricity?) from deep down?

Subterranean heat is ***an interesting, practically inexhaustible energy source also for Switzerland*** – which can be exploited with the aid of special technologies. In the mid-1970s the federal government set up a »Federal Commission for Geothermics and Underground Heat Storage«. The research carried out under the auspices of this organisation culminated in 1982 in a ***Geothermal map of Switzerland***, which demonstrated that the ***Central Plateau and Upper Rhine trough could be promising areas for providing hot water***. In 1980, a Swiss geologist invented the geothermal probe (GP). Research was directed primarily at these two technologies. ***R&D achievements in the mid-1990s*** included:

- ❒ ***Fundamental scientific questions concerning GP*** had been answered (e.g. subterranean layers do not cool over time), and ***good technical solutions were found***.
- ❒ The first ***deep-level GP for space heating*** was constructed at Weggis in 1995.
- ❒ ***Deep-level drillings for warm water*** proved futile in some areas, but were ***successful at Riehen*** (where a district heat network has been built). The geothermal map of the Central Plateau was completed (but cannot guarantee successful drillings).
- ❒ Estimated ***potential of GP and deep-lying water; 6 % of the national heat requirements***.
- ❒ In 1995 ***hot tunnel waste water*** from the Furka tunnel began to be used for the district heat supply to Oberwald. Studies on temperatures, output and chemistry of other tunnel projects (e.g. Hauenstein base tunnel, Mappo Morettina, Ricken and St. Gotthard road tunnel) are being carried out.
- ❒ ***Know-how in the fields of hot dry rock and hot wet rock*** has been gathered from participation in international research projects.

There is a need for further research in order to ***increase economic efficiency and improve environmental compatibility***, as well as to clarify fundamental problems.

- ❒ The goal of ***GP*** projects is to find backfills with better heat conduction properties, develop deeper probes and broader probe diameters, use geothermal probes for ***cooling in summer***, or open probes (i.e. which feed groundwater directly to heat pumps), ***optimise GP fields*** and energy piles, and subsequently to solve the problem of ***disposal of GP***.
- ❒ ***Basic measurements need to be carried out on deep-lying GP***, in order to optimise large-scale systems from both a technical and an economic point of view.
- ❒ Studies on the utilization of tunnel water in projects such as AlpTrans and the Gotthard base tunnel.
- ❒ Trials are to be carried out with ***drilling techniques with narrow drillhole diameters*** (slim hole drillings), which could save up to 50% of drilling costs.
- ❒ ***Multiple utilization of hot water in cascades*** should be studied, i.e. for different purposes as the temperature drops.
- ❒ ***Preparation of a Swiss hot dry rock or hot wet rock plant*** for producing electricity and heat.

The success in the ***implementation*** of GP (as also for deep-level probes) is reflected in the fact that Switzerland is world leader with over 6,000 systems. The continued co-operation between researchers and companies specialising in GP is aimed at increasing the performance of probes as well as cutting their costs. With regard to deep drillings for hot water, even failed explorations have served to extend the ***know-how basis*** for future endeavours.

At the geothermal deep-drilling plant in Reinach, canton of Baselland, noise barriers were used to shield nearby residents from drilling noise. After the drillings were completed, the terrain was returned to its original state.

A dozen GP for heating an apartment block have already been sunk into the drilled holes. The pipes to the heat pump in the basement are still exposed before being covered with earth.

Definitions and concepts: Geothermal energy

Geothermal energy, or geothermics, refers to heat which has its source in the earth's core (which has a temperature of 6000 °C) and in radioactive decay in the earth's solid crust. The temperature increases progressively from around 10 °C on the surface by an average of 30 °C with every 1000 m of depth, which means it is around 70 °C at a depth of 2000 m.

Geothermal probes (GP) use ***shallow geothermal heat*** down to several hundred m, or 20 to 30 °C. A plastic U-pipe with a diameter of a few centimetres is fed into apertures drilled to a depth of 150 to 200 m and is backfilled with heat–conducting material. Brine pumped through these pipes heats up by a few °C, and a ***heat pump*** raises the temperature to 30 to 50 °C for use in ***floor-heating systems***. In the summer, the brine can be used for cooling purposes, or the earth in the vicinity of the geothermal probe can be used for ***heat storage***.

Energy piles and subterranean curtain walls can also be used as GP. GP-fields can heat large buildings.

It is intended to use ***»deep-level« heat*** at depths of several thousand m where temperatures reach 200 °C, especially in ***»geothermal anomalies«*** in which the temperature increase (temperature gradient) is greater at increasing depth than the mean value of 30 °C per 1000 m. In addition to drilling for hot water, three other techniques are used here.

Deep-level GP, e.g. lowered into 1000 to 2000 m deep disused drill shafts from oil and gas exploration, yield temperatures of up to 70 °C, thus eliminating the need for using heat pumps.

With the ***hot dry rock method*** (HDR), hydraulic pressure is used to create fissures in deep-seated layers of rock in which cold water pumped in is heated up.

With the ***hot wet rock method*** (HWR), the idea is to drill into deep-seated veins containing water that has a temperature of over 100 °C.

HDR and HWR yield steam, usable for electricity and heat production.

Electricity from wind …

Wind power plants have experienced a world-wide boom ever since the 1973 oil crisis, especially in coastal regions. ***Switzerland only has few sites in mountain regions, e.g. on the Chasseral, which exhibit favourable wind conditions*** that can be compared to those of coastal zones. Since wind energy cannot significantly contribute to the national electricity supply, ***Swiss research into the technology of wind power plants has never been a matter for discussion***. Nonetheless, ***electricity from wind power could still play a role on a regional level***. For this reason, the Federal Office of Energy decided in 1987 to study the ***overall Swiss potential for »economically viable« exploitation***. The findings: around 1500 to 1800 gigawatt-hours per annum, which is ***roughly equivalent to 3 % of the present-day electricity demand***. But whereas at that time wind power plants had power ratings of 75 to 150 kW, in the 1990s typical design ratings have risen to 500 to 600kW, and the new plants produce more cheaply. The potential is therefore probably a great deal higher than originally estimated.

Following a 30 kW plant on the Sool in 1986, 11 more have since been put into operation between 1990 and 1996, with ratings of up to 600 kW, and further plants are planned. It is hoped to reduce electricity production costs to around 0.30 CHF per kWh (on the North Sea coast of Germany, 0.10 CHF have been achieved, and Swiss hydropower plants produce at 0.06 CHF).

To facilitate implementation, ***measurement programmes for wind power plants*** are being supported. The results are stored in a ***wind database*** intended to simplify identification and choice of suitable locations. A special ***wind map*** is to indicate the best sites for wind power plants.

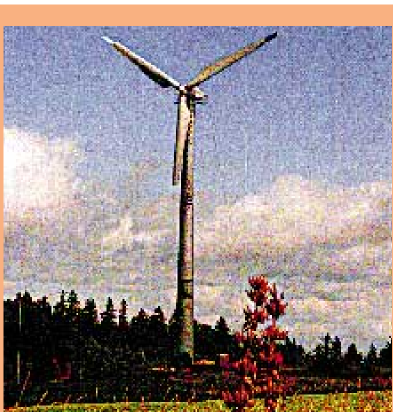
… and small-scale hydro

The first hydropower plants, built towards the end of the 19th century, were small. Thousands of them were constructed in Switzerland around 1900. Later, a large number of these were abandoned since new, large-scale hydropower plants had lower production costs. In the 1980s, small-scale plants were re-discovered as a ***supplementary, clean source of energy***. ***There were still 1000 plants functioning which supplied 9 % of the electricity produced by all of Switzerland's hydropower plants***. Some cantons began to support the reactivation, enlargement and modernisation of these plants.

In the ***DIANE »Small-scale hydropower plants« programme*** launched in 1992 by the Federal Office of Energy, the potential was estimated on the basis of the present situation: ***it is possible to double the electricity production from small-scale hydro***. This would require reactivating abandoned plants and enlarging existing ones as well as ***building new ones***. The latter could be installed in ***drinking water and waste water conduits*** with sufficient fall heights and water quantities.

The principal objective of research-promotion is an increase in production and economic efficiency, generally through higher efficiency, e.g. using small, variable-speed turbines. Mobile »pico« hydropower plants could be used to supply Alpine areas. Acceptance could be increased by improved integration into the landscape and the construction of fish ladders with low water quantity requirements.

For the ***implementation*** of research results, suitable P&D plants are being sought for promotion. Annual conferences and a large-scale exhibition are planned. In 1997, a »Handbook of Small-Scale Hydropower Plants« was published containing detailed information for constructors and operators.



Obergrenchenberg 150-kW wind power plant (height 30 m, rotor diameter 24 m, 140'000 kWh/year): demonstration of performance, assessment of visual impact on the landscape.

110-kW small-scale hydro on the Gonzenbach, Toggenburg, reactivated in 1996 with added environmental protection measures: original dam of 1894 (top left) retained, water duct underground, powerhouse (right) fitted with soundproof glass.

Definitions and concepts: Wind power

Modern ***wind power plants*** consist of a turbine and an electricity generator.

Unlike the broad windmill blades used in earlier times, modern ***wind turbines*** normally use a 2 or 3-blade propeller with a horizontal axis (mounted on a mast or tower, together with the generator). If rotors with vertical axes are used, the generator can also be placed on the ground. High-speed propellers have higher efficiency. Wind power plants are classified as follows: up to a rating of 100 kW small-scale wind power plants; up to 1 MW (with a tower height and propeller diameter up to 50 metres) medium-size wind power plants, and above 1 MW capacity large-scale wind power plants.

Terrain, vegetation and buildings slow down ***wind speeds***, which is why it is better to place wind turbines on high towers.

Definitions and concepts: Small-scale hydro

Plants with a capacity below 10 MW are classed as ***small-scale hydropower plants***, and those with a capacity below 300 kW are referred to as mini hydros.

Tried and tested turbine types convert hydropower into electricity, e.g. flow-through, Pelton, Francis and Kaplan turbines plus reversed pumps. Inexpensive ***pipe turbines*** utilise very small fall heights, attaining high efficiency and economic viability.

The ***pipe turbine***, first constructed in the 1930s in Switzerland, is a Kaplan turbine with horizontal axis, which permits a low construction height and consequently a low machine house, thus minimising the visual impact on the landscape.

The pre-requisites for small-scale hydro ***to be economical*** are optimum design, inexpensive construction and as ***constant a supply of water*** as possible throughout the year, plus ***unmanned (i.e. fully automatic) operation***.

Subdivisions

Wind

Small-scale hydro

Energy storage: solar chemistry, …

After the 1973 oil crisis, research on solar furnaces suggested using concentrated solar radiation not only for generating electricity but also for ***producing hydrogen and other chemical agents as means of storing solar energy***. Swiss research in the field of ***solar chemistry*** soon led the field, together with the USA, Germany and Israel. Recent Swiss pioneering efforts include the extraction of hydrogen through water fission in a ***solar cyclic process with iron oxides***, or cement production in a »powder cloud reactor«.

The 1996/99 research programme of the FOE places priority on procedures that appear to be industrially implementable in Switzerland within a reasonable period of time and economically viable:

- ❐ ***Continued development of solar absorbers*** producing temperatures of 80 °C to over 800 °C, applicable, e.g., for hot water, foodstuff dehydration and high-temperature solar chemistry.
- ❐ In the field of ***high-temperature solar chemistry***, water fission with metal oxides, reduction of metal oxides with natural gas and water for extracting metals and combustible gas.
- ❐ Utilisation of hydrogen, not only as a fuel (e.g. in motors) but also as a chemical raw material. Continuation of the search for better metal hydrides for hydrogen storage.
- ❐ As a contribution towards solving the CO_2 problem: ***extraction of high-grade chemicals***, e.g. methanol and amines, ***from*** CO_2 by selective catalytic reactions with hydrogen.
- ❐ ***Photoelectric water fission*** by means of special semiconductors.

Implementation of many of the research results in the field of solar chemistry willonly be possible ***in the distant future***.

Definitions and concepts: Solar chemistry vocabulary

The goal of ***solar chemistry*** is the low-emission extraction of raw materials and chemicals through the effect of concentrated solar radiation and/or solar heat. This utilization of solar energy has a high potential for substituting fossil fuels. Three fundamental processes can be distinguished (with many variants):

- ❐ The ***thermo-chemical*** method using solar heat to trigger chemical reactions with a very high energy requirement (e.g. cement production).
- ❐ Solar radiation directly absorbed by reactands in a ***photochemical*** process, as well as by catalytic converters which are in direct contact with the reactands.
- ❐ A ***photo-electrochemical*** process using solar-produced electricity (e.g. by photovoltaics) for electrochemical reactions (e.g. water electrolysis).

Combinations of these methods are also feasible.

… water tanks, and the ground

Heat storage has been an important topic in energy research since the 1970s, especially ***to compensate the fluctuations of solar energy*** (daily and seasonal). A large number of research projects co-ordinated by the Federal Office of Energy have yielded informative results – for example, the fact that latent heat accumulators hardly come into question due to the toxicity and lack of long-term stability of the known storage materials and too high costs. Another important finding is that aquifer storage (hot water forced into a layer of rock during the summer and extracted again in the winter) is only feasible under highly favourable conditions. ***Swiss pioneering*** includes the diffusion accumulator, and the fact that in hot water tanks a temperature stratification occurs which can be used to save energy.

The 1996/99 research programme is to focus on storage for domestic hot water and heating, both in existing buildings and for use in retrofitted buildings. Its priorities are:

- ❐ ***Hot-water storage for day/night carry-over*** (by far the most important storage application today) could be further improved by charging them with solar heat, e.g. through skilful temperature stratification, which increases the efficiency of the overall system at the same time.
- ❐ ***Diffusion accumulators*** for temperatures between 30 and 80 °C and of medium size, i.e. each with 10 to 100 geothermal probes (for apartment houses), ***are to be optimised*** with respect to probe type, geometry, active materials and system design.

Measurement projects are the main aids to ***implementing*** heat storage research.

Definitions and concepts: Heat accumulators

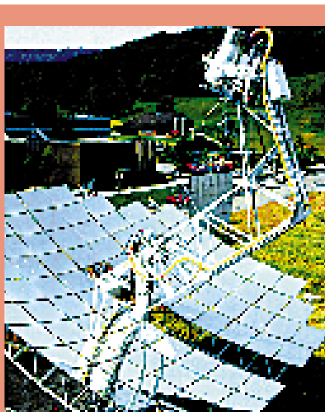
Heat accumulators are used to compensate differences in supply and demand for heat. Two important terms are:

- ❐ ***Sensible heat*** manifested as an increase in the temperature of the storage material.
- ❐ ***Latent heat***, absorbed or given off when a material liquefies or solidifies without changing its temperature during the process.

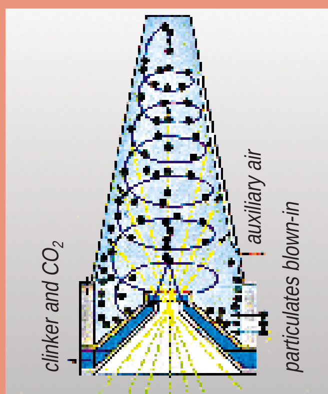
In practical terms, heat storage systems are classified as follows (selection only):

- ❐ Hot-water storages comprised of thermally insulated steel or concrete vessels (up to 100'000 m³, up to 95 °C.
- ❐ Latent heat storage including ice and certain salts.
- ❐ Diffusion accumulators in soil or rock charged and discharged via geothermal probes. The supplied heat or refrigeration diffuses in the soil.

Waste heat storage for apartments at Buchrain with nineteen 200 mm geothermal probes (2 per shaft, 3 horizontal heat-insulated collection pipes).



At the focal point of the 90 m² parabolic mirror at the Paul Scherrer Institute a cyclone solar reactor is heated by 56 kW of concentrated solar radiation.



Cement production in a cyclone solar reactor: injected limestone powder reacts to form clinker and CO_2.

Subdivisions

Solar chemistry/ hydrogen

Heat storage

Clean combustion with the aid of lasers and computers

The ***combustion of oil and gas*** covers most of the present-day energy requirements, but is ***also the main source of air pollution***. In the 1980s, this concern motivated international researchers to pay greater attention to the question of combustion. Until then, the construction of burners and motors had mostly been based on trial and error. ***In 1988, the Federal Office of Energy launched its »Heating and Combustion« research programme*** in order to create ***a basis of knowledge for the domestic industry*** in a field that was still in its infancy in Switzerland. Combustion research has mainly been carried out at the Federal Institute of Technology in Zurich and the Paul Scherrer Institute:

❒ Laser optical methods, the standard diagnostics for combustion processes, were given high priority. The principle: a laser ray is directed into, for example, the combustion chamber of a diesel engine, the laser light is dispersed by pollutant particles, and the dispersed light provides information – both optically and evaluated on a computer – about the type, size, concentration and speed of the particles. This in turn permits identification of the mechanisms of pollutant formation. ***A number of internationally acknowledged developments have been achieved at the Paul Scherrer Institute and at the Swiss Federal Institute of Technology (ETH) in Zurich*** in this field, e.g. a method involving a resolution time of 100 trillionths of a second for the study of highest-speed processes.

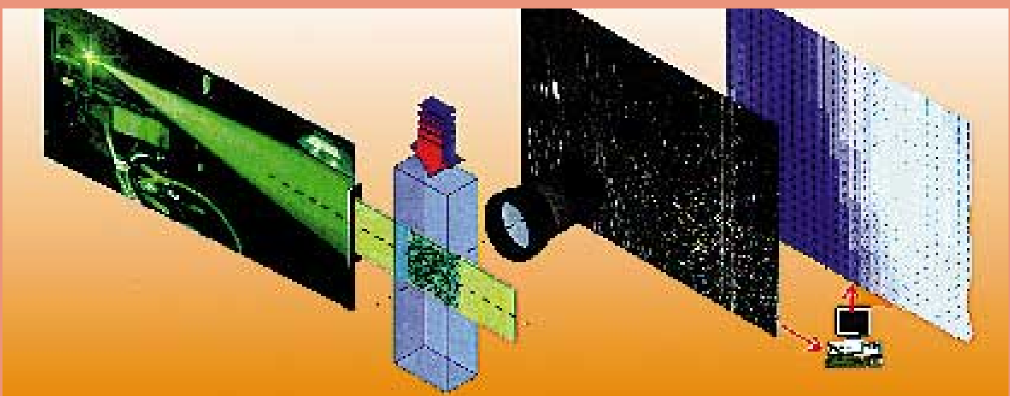
❒ A second main area was the ***numerical simulation of combustion processes***, i.e. their mathematical modelling via computer – a procedure that supplements laser optical procedures. Here, ETH researchers developed a simulation program which has already proved to be ***a significant time-saver*** for the construction of low-pollutant oil-fired burners.

❒ A third main area was the improvement of ***pollutant analysis*** and the study of ***pollutant formation*** in burners and motors, e.g. when diesel injection is used. One of the most significant results of this research is ***improved basic know-how concerning the reduction of nitric oxides in burners and combustion chambers***, which will be put into practice in the next generation of burners.

❒ The fourth main area was to develop ***new low-polluting combustion technologies***, e.g. catalytic combustion, and ***new retention procedures***, e.g. for diesel soot in heavy goods vehicles.

In the mid-1990s, in view of the intensified international research into combustion technology, it became apparent that the ***principle of trial and error had been abandoned once and for all***. For the 1996/99 research period, the goal is to selectively apply the gathered know-how for ***aid work in Swiss industry***, and help it get to know the new potentials at its disposal. The main areas cited remain applicable in order to ensure continuity and follow up international developments – computer and laser technologies are constantly opening up new avenues. An important goal for all these main areas is ***»integrated« pollutant reduction***, i.e. already avoiding the formation of pollutants during combustion rather than retaining them by means of a »chemical factory in the exhaust system«.

It is seldom possible to directly convert the results of combustion research at universities into commercial products. After a lengthy period of reservedness, ***an increasing number of companies are now interested in co-operation***. They have grown aware of the potentials offered by this research as well as of the extremely high costs involved in any research they may wish to carry out themselves. The intention now is to eliminate the remaining reservations through carefully planned joint pilot and demonstration projects.



The principle of laser diagnostics: a laser beam (from left) enters the combustion zone (blue). Laser light is dispersed on contact with combustion or pollutant particles. Laterally dispersed beams are focused through a lens (centre) onto a moving film, the light traces of which represent the movement of particles in the combustion zone. Evaluation on a computer identifies the speed field (right) in the plane of the laser beam.

Definitions and concepts: Combustion

Generally speaking, ***combustion*** is the rapid, heat-producing chemical reaction of a fuel with atmospheric oxygen under flame formation. It is the most widely used process for converting energy, ranging from wood fires to engines and industrial furnaces.

The composition of the fuel and the combustion temperature determine the ***formation of pollutants***: carbon (C) burns with pure oxygen (O_2) to form carbon dioxide (CO_2), which is the most important greenhouse-effect gas. During combustion with pure oxygen, pure hydrocarbons form CO_2 and water.

Fuels are, however, practically never pure, and technical combustion processes are never perfect. With some exceptions, air has to be used instead of pure O_2. In addition to 21% O_2, air contains 77% nitrogen (N_2) which, together with oxygen forms ***nitric oxides*** (NO_x) during combustion (the higher the temperature, the greater the quantity) – and these are greenhouse gases and help form ozone. If combustion is not total, e.g. due to air deficiency or too low temperatures, toxic ***carbon monoxide*** (CO) and ***soot*** are also formed in addition to CO_2.

There are processes for ***reducing the emissions*** of these and other pollutants (e.g. reducing nitric oxides by lowering the combustion temperature), for ***converting certain pollutants*** (with catalytic converters) or for ***burning*** them (e.g. soot from soot filters).

Combustion research is aimed at finding out how and where pollutants are formed in the combustion chambers of furnaces and motors in order to come up with constructive solutions.

In »cold« or ***»catalytic« combustion***, fuel (e.g. gas) and O_2 or air are combined via catalytic converters (in a similar process to that in motor vehicle catalytic converters), and by proportioning the fuel it is possible to regulate the heat down to room temperature.

Safety research for nuclear power plants

With a share of almost 40%, nuclear power plants are, together with hydropower plants, one of the mainstays of electricity production in Switzerland. This is why energy policy is abiding by nuclear power and continues to consider it as an ***option for the future***. ***This fact, together with the need to ensure the safe operation of nuclear power plants, calls for safety research***. Here a distinction is made between scientific and technical safety research and regulatory aspects. Since the two complement one another, they are supported by the public authorities and co-ordinated by the Federal Office of Energy. The researchers involved are required to constantly keep their know-how up to date with scientific and technological progress, and to participate in international projects.

The aim of ***technical and scientific safety research*** is to gain new scientific insights into reactor safety, to estimate the safety-margin of existing facilities and to study new safety measures. In Switzerland, this research is carried out at the Paul Scherrer Institute, where medium to long-term research projects have been set up. The adaptation of the priorities to new requirements and to technical and scientific progress is a gradual process. For the 1996/99 research period, the goal is to more strongly align the research work to the requirements of Swiss nuclear power plants and the safety authorities:

❐ For ***malfunction analyses***, certain problem situations are assumed, their course and the release of radioactivity are modelled mathematically, and the models are studied by special experiments. In this way, ways to improve the safety of nuclear power plants are found, and it is also possible to trace any deterioration due to ***ageing***, especially as a result of corrosion of certain components.

❐ Safety analyses concerning the planned ***final storage sites for radioactive waste*** are especially focused on the retention of radioactive substances in final storage barriers, e.g. in concrete.

As the supervising authority of the federal government, the task of the ***Federal Office of Energy's Nuclear Safety Board*** (HSK) is to assess the safety of Swiss nuclear power plants and demand any measures necessary in order to increase it. To assist this task, the Board carries out ***regulatory safety research*** by ordering research projects at the Paul Scherrer Institute, universities and engineering companies both at home and abroad. Another of its goals is to train new specialists and provide constant further education for them. The Board's research is a matter of continuity, which is the reason why the priorities for the period from 1996 to 1999 are the same as in the previous period:

❐ Improvement of malfunction analyses for Swiss nuclear power plants, from operating problems up to the worst foreseeable incident; analysis of foreseeable malfunctions on the basis of known findings; stipulation of protective measures in the event of any malfunctions.

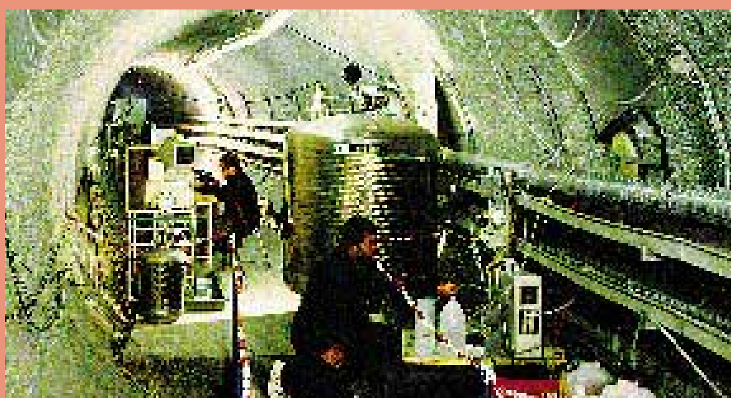
❐ Tracing the deterioration of mechanical and electrical components and of constructions due to ageing, with the goal of guaranteeing the safety of nuclear power plants regardless of their age.

❐ Development of reliable methods for assessing the safety of end storage sites.

❐ Expanding know-how about radiation protection both inside and outside nuclear power plants.

Alongside increasing the professional competence of researchers, the HSK and nuclear power plant operators, the results of safety research are mainly ***implemented*** by improving the safety of nuclear power plants in keeping with the requirements of the HSK, or as put into practice by the operators themselves. This type of »upgrading« is being carried out continuously.

The PANDA test plant at the Paul Scherrer Institute is used to demonstrate the functionality of passive safety systems.



At the field laboratory on the Grimsel Pass, which branches off from a shaft of the hydropower plant, experimental work is carried out with a view to the construction of an final storage site for radioactive waste – in the foreground, a measuring system for the migration of radio-nuclides in rock.

Definitions and concepts: Reactor safety

In the reactor of a ***nuclear power plant***, heat is released through controlled nuclear fission and used to generate steam. The steam drives a turbo-generator to generate electricity. During normal operation, nuclear power plants only release low quantities of radioactive material into the environment, which are regarded by the authorities as being safe.

In nuclear power plants, a wide range of operational breakdowns and ***malfunctions*** is possible. Malfunctions are defined as deviations from the stipulated functionality to such an extent that these result in emissions of pollutants into the environment and could represent a threat to public health and the environment.

Nuclear power plants are constructed to withstand ***major malfunctions*** (= the worst foreseeable incident). This scenario assumes that, as a result of the malfunction of the reactor cooling, destruction would occur within the reactor building (e.g. a reactor melt-down), but an inadmissible exposure of the population to radiation would be prevented.

Measures taken to ensure ***reactor safety*** include:

❐ Exploitation of physical effects for the safe shut-down of a reactor in the event of a malfunction.

❐ Reliable emergency cooling in order to prevent the overheating or melting of a reactor in the event of a malfunction.

❐ Sealing of radioactive fission products behind a series of special barriers – solid fuel, sealed fuel rod casing, reactor pressure vessel made of special massive steel, containment (thick steel-plated safety container surrounding the reactor), reactor building of solid concrete.

❐ Protection against external influences in the form of structural and organisational precautions.

Nonetheless, there still remains a potential (if only an extremely small one) for the occurrence of a major malfunction exceeding the worst foreseeable incident case – the »residual risk«.

Subdivisions

Nuclear technology and nuclear safety

Regulatory saftey research

Small steps towards a major goal: nuclear fusion

Fusion research – the attempt to imitate the sun on Earth – has been in progress since the 1940s. Three main factors have been the driving force keeping this activity going to date, even though it was soon found to be far more difficult than originally believed: sea water contains an essentially inexhaustible supply of deuterium (the fuel required for fusion); from 1 gram of fusion fuel, it is possible to extract as much energy as from 6 t of crude oil; and researchers promise fusion reactors that cannot go out of control and do not leave highly-radioactive waste.

Fusion research is not only difficult, it is also extremely expensive. For this reason, European nations already agreed in the 1950s to ***co-operate in EURATOM*** (see page 21) by pooling costs and tasks. Switzerland joined this organisation with full rights and duties in the 1970s. ***The main objective for the next few years is ITER***, a first genuine experimental reactor that releases more energy than it consumes and is based on the principle of magnetic confinement. The decisions regarding the design and exact location are to be made in 1998. In addition to EURATOM, Japan, Russia, and the USA are also involved in the ITER project.

Switzerland's tasks within the EURATOM programme are controlled by CRPP, the Centre for Plasma Physics Research at the Federal Institute of Technology, Lausanne. The CRPP also carries out the majority of the research work, while a second group is at work at the Paul Scherrer Institute.

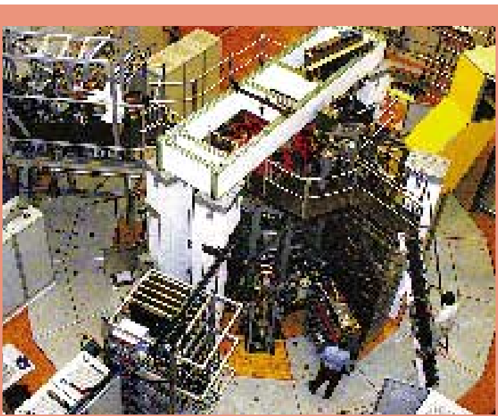
❒ Attempts are being made to answer ***physical questions regarding magnetic confinement*** both experimentally and theoretically. In the 1980s, at the Tokamak TCA plasma machine it was discovered that plasmas with cross-sections in the form of a D, O or S produce a higher plasma density than circular ones (and high density is one of the most important »ignition criteria« together with temperatures of over 100 million K). As a result, such cross-sections are now being studied on Tokamak ***TCV, Tokamak with variable configuration***. This machine permits extensive modifications of the height and width of the torus. Other experiments conducted on the TCV are devoted to plasma heating through coupling-in high-frequency radio waves. The theoretical work, supported by extremely complex numeric simulations, is aimed at modelling these experiments.

❒ A key factor in future fusion reactors is the ***»first wall«***, sealing the plasma chamber from the exterior. Being penetrated by neutrons that are almost as fast as light and which carry the fusion energy, it is radioactively »activated« and made brittle. Resilient construction materials that are hard to activate, in particular ***special steels and ITER components and coatings*** (for reducing the quantity of loosened atoms that soil the plasma) are currently being tested on a proton accelerator.

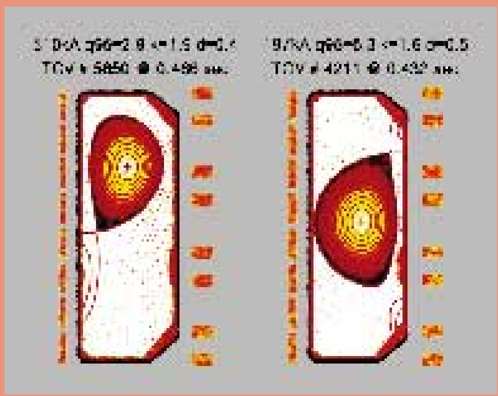
❒ Swiss tasks also include the ***development and testing of large-scale superconducting magnets*** for the strong magnetic fields of the ITER.

Should ITER prove successful, i.e. be able to attain a positive energy balance, and given the present-day status of knowledge it is unlikely that a fusion power plant could be constructed before the middle of the 21st century.

CRPP's findings are already being ***implemented*** today ***in high resilience plasma coating of tools***, e.g. with diamond coatings made by deposition from a carbon plasma, in collaboration with Swiss industrial companies.



The TCV (Tokamak with variable configuration) at the CRPP in Lausanne. On the bridge at left, the wave guides for extremely high frequency of 82.4 GHz are in the process of being installed, which serves as auxiliary plasma heating.



Research conducted on the TCV is being focused on the creation of interesting plasma forms. Here: two shapes calculated from measurement data in a cross-section of the TCV ring chamber.

Definitions and concepts: Nuclear fusion

Nuclear fusion is the basic process of energy production in stars: atomic nuclei of the lightest elements (normal, heavy and super-heavy hydrogen, and helium) »fuse«, with the result that energy is released. For example, if the nuclei of heavy and super-heavy hydrogen (deuterium and tritium, respectively) join to form one helium nucleus, this leaves a neutron with high kinetic energy.

The driving force behind efforts to bring about fusion reactions on Earth is the fact that 1 g of fusion material contains as much energy as 6 t of crude oil. The process involves bringing (positively charged) atomic nuclei so close together against their electric repulsion that their mass attraction becomes active. This is only possible if the atomic nuclei have very high kinetic energy or temperatures in the millions-K-range (K = Kelvin). In the sun, the temperature is 15 million K. At the same time, the density is 150 g/cm^3 as a result of its 300'000-fold Earth mass. Since it is not possible to attain this density on Earth (lead = 11.3 g/cm^3), the temperature has to reach at least 100 million K.

Fusion research focuses on magnetic confinement. Matter is already fully ionised at a few thousand K, i.e. separated into electrically positive atomic nuclei and negative electrons. Such a ***plasma*** can be confined with magnetic fields in the Tokamak (plasma machine) as follows: a ring tube (torus) is evacuated and filled with ionised fusion material. The torus forms one coil of a transformer. If this is activated, the fusion material becomes a ring current and the magnetic field forces it to flow in the centre of the torus. As a result of collisions between its particles, the plasma heats up to several million K. Further increase of temperature can be achieved by shooting in high-energy ion-rays, or by coupling in electromagnetic waves.

Batteries for households, automobiles and industry

Batteries are the most important electricity storage medium. Accumulators serve as starter batteries for automobiles or for emergency power supplies in hospitals. ***In Switzerland there are an estimated 3 million lead batteries in service, and every year over 50 million household batteries and small accumulators are sold for electric and electronic devices***.

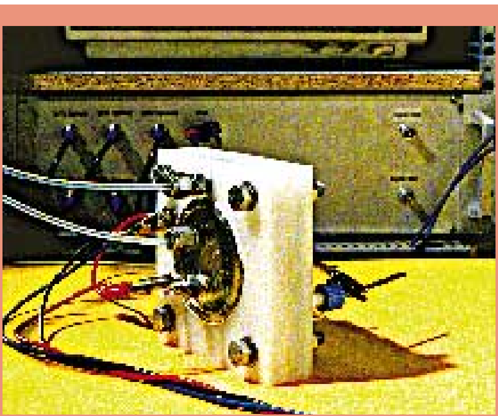
Batteries ***can present a disposal problem due the pollutants they contain*** (e.g. cadmium in some types) ***and the quantities used***. Used lead accumulators are almost fully recycled. Procedures do in fact exist for the disposal of other batteries, but collection poses a problem. Pollutants are now being reduced to an increasing extent by using materials that are more environmentally compatible.

Batteries that are not rechargeable also ***waste a great deal of energy*** since their manufacture requires fifty times more energy than they are able to produce. ***And present-day accumulators are too heavy for electromobiles***. The ***utilization of renewable energy*** with solar cells ***also calls for more efficient electricity storage systems***.

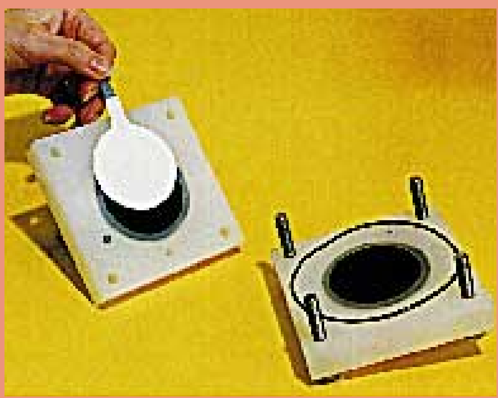
Consequently, there is a ***need for research on both conventional and new types of batteries***, including their environmental compatibility. Since the intention is to preserve the competitiveness of the efficient Swiss battery industry, the Federal Office of Energy has been promoting battery research since 1988. The 1996/99 research period will pursue all the activities carried out during the 1988/95 period which have ***already led to significant progress***. ***The focus is on four battery type***s:

- ❐ The ***continued development of lead accumulators***, by far the most economical type, particularly concerns their ***application in diesel/electric hybrid cars***. These are equipped with both diesel and electric drives. The main goals are the reduction of the electrode mass (currently around 11 kg in a car battery) and the development of intelligent chargers that automatically adapt to the charge status (with Switzerland concentrating on the key components in view of the world-wide competition).
- ❐ ***Zinc-air accumulators*** deserve full domestic development. In electric vehicles, this type offers the advantage of higher power density in comparison with lead accumulators. The main hurdles still to be overcome are moistening and stability of the air electrodes and the carbonization of electrolytes. By 1999, it is hoped that a functional model will be ready for use in electromobiles.
- ❐ The ***nickel/metal-hydride accumulator*** is intended to replace the nickel/cadmium type, since cadmium is toxic for the environment. Researchers are looking for better alloys for the metal hydride electrodes. This is a 100 % task for Switzerland.
- ❐ With 340 Ah/kg, the ***highest power density*** is expected from ***lithium/ion accumulators*** (present-day lead accumulators: approx. 20 Ah/kg). The electrodes are the highly reactive light-metal lithium and certain metal oxides as well as polymers. Since this accumulator is already being manufactured in Japan in series of millions for portable electronic equipment, the opportunity for Swiss research lies in special applications for lithium electrodes, a key component, and in safety aspects of the system.

The most likely opportunity for ***implementation*** appears to lie in focusing on promising types and components – which is why research priorities are being defined in constant collaboration between the industry and the Federal Office of Energy. As a P&D project, a nickel/metal hydride accumulator with 12 volts and 9 ampere hours has already achieved more than 600 recharge cycles.



Testing a rechargeable zinc-air cell which is being developed by the Paul Scherrer Institute for a future accumulator. The nominal capacity of the cell is 2.4 ampere hours, and its off-load voltage is approx. 1.4 V.



Components of the zinc-air cell: the zinc electrode (hand-held) covered with porous separator material; the dark area (at the right) is the bi-functional air electrode. The thin ring is the seal.

Definitions and concepts: Batteries

In ***electrochemical elements***, energy is released through chemical reactions at two different electrodes, and converted into electricity (and heat). Oxygen providers (such as air, oxides) and a fuel (e.g. lead, hydrogen, zinc) function as electrodes. These are separated by an electrolyte (e.g. acids, special polymers and ceramics). The electrolyte conducts ions as carriers of electrical charges from one electrode to the other, i.e. the result is an electrical current.

In ***primary elements***, the reactions cease as soon as the electrodes are exhausted. The processes are not reversible, and the elements not rechargeable. In ***secondary elements***, charging from an external source reverses the discharge reactions, hence these elements are called collectors or ***accumulators***.

There are numerous electrode/electrolyte combinations. The voltage generally is 1 to 2 volts. For higher voltages, a number of elements or cells are combined to form a ***battery***.

Only batteries that do not discharge themselves too quickly and which use inexpensive materials are of interest for practice. The most important primary elements are ***carbon/ zinc*** and ***alkaline/ manganese*** batteries; both of these are widely used as ***household batteries***, e.g. for flashlights and electronic devices. ***Lithium cells*** are replacing ***mercury batteries*** to an increasing extent in hearing aids, watches, and cameras.

The most important ***accumulator*** is the lead type which was discovered in 1859 and uses lead and lead oxide as electrodes, and sulphuric acid as electrolyte. Recently, however, the ***nickel/ cadmium accumulator***, which is used for cameras and electric tools, has gained in importance. New accumulators with potentially higher storage capacities are currently being tested with a view to use in electromobiles. The goal is to achieve as high an energy density (Wh/kg) and power density (W per litre of accumulator volume) as possible.

Fuel cells for heating, electricity and automobiles

The term »fuel cell« is appearing more and more in the media, and there is little hesitation with the use of superlatives. We learn that we can supply these cells with air and fuel, and obtain both electricity and heat with an 80% fuel efficiency. It is claimed that this »miracle« energy source is especially suitable for combined heat and power (CHP) plants, for example for residential estates, where it is able to replace aggregates with gas or diesel motors.

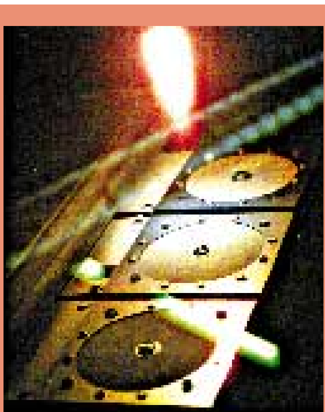
However, ***only test systems exist to date***. An English scientist named Grove observed already in 1839 that the use of fuel cells was feasible in principle, but it was only in 1945 that the first functioning fuel cells were developed in the USA for submarines and space flight. The costs, however, were astronomical, and the ***technical problems*** were still the same – these primarily concerned corrosion, electric contacts, uninterrupted supply of fuel and oxygen, and the drawing off of reaction products.

These problems are offset by the ***fundamental, convincing benefits*** such as ***high fuel efficiency, silent operation and lack of vibrations***. It was especially the ***potential of using natural gas as a fuel*** which encouraged the Federal Office of Energy to incorporate the promotion of fuel cell research into its programme. Natural gas, which is now available to over two-thirds of the Swiss population, is expected to play a leading role in future energy supply. Furthermore, Swiss industry provides favourable pre-requisites for the manufacture of fuel cells, both for the domestic and the export markets.

The 1988 to 1995 programme yielded satisfactory results, though no products that are anywhere near market readiness (the only one available anywhere in the world is the phosphoric acid type). It is clear that ***it is not possible to solve the material problems overnight***, so the 1996/99 programme will be continuing the work already commenced. The ***goals*** are the ***procurement of know-how*** for possible Swiss production, and a ***drastic reduction of costs***. The ***status of research and its main directions*** – aimed at the development of the most promising types for potential applications in Switzerland using natural gas – can be summarised as follows:

- The ***ceramic fuel cell*** is primarily foreseen for CHP units. Its development is centred around the HEXIS project launched by Sulzer Innotec, and this is now so far advanced that a module of 1 kW electric power is expected to be completed in 1999. The longer-term objective is a 15 kW module suitable for use in a CHP unit. It is hoped to lower costs by limiting the operating temperature to 820 °C (which permits the use of low-cost metal alloys), increasing the electrochemical power as well as reducing electric losses (for which purpose it will be necessary to improve the porosity of the natural gas electrode).
- The envisaged area of application for ***polymer fuel cells*** is ***electromobiles***. Even though trials with buses powered by such cells have been carried out in a number of countries already, specific problems continue to exist, in particular the reforming of the fuel, i.e. the separation of the hydrogen required for operation. The answer is partly to be found in improved polymer membranes.

Implementation is primarily to take the form of P&D projects, e.g. ATEL has been testing a Canadian polymer fuel cell in Niedergösgen since 1992, and in Geneva the communal utility has been gathering experience using a phosphoric acid cell from the USA. A HEXIS cell fully developed in Switzerland is to be tested under practical conditions as soon as possible.



A number of HEXIS membranes each with a diameter of 12 cm are being manufactured simultaneously here using plasma sprays in a vacuum.

The components of a HEXIS cell: ceramic membrane (green) with electrodes, channelled plate for fuel supply and combustion product draw-off.

A 7-kW HEXIS system: in the casing cell stack and auxiliary equipment, on the right the electronic control unit.

Definitions and concepts: Fuel cells

Fuel cells are electrochemical electricity generators. These differ from batteries through their constant supply of chemical energy in the form of a fuel. Two flat electrodes are separated by an electrolyte, a substance that only conducts ions (electrically charged atoms) of a specific type. There are different types of fuel cell depending on the electrolyte and fuel.

The electrolyte in a ***ceramic fuel cell*** is a ceramic of zirconium oxide which only lets oxygen ions pass. Air flows to one of the electrodes, the cathode. At the high operating temperature of up to 900 °C – and as a result of the catalysing effect of the electrolyte and electrode – the atoms of the atmospheric oxygen are ionised, i.e. they each receive two electrons. These ions move through the electrolyte to the other electrode, the anode. They pass on both electrons to the anode and react chemically with fuel atoms. This results in an electron surplus at the anode, and an electron deficiency at the cathode, giving rise to an electrical voltage between them of approx. 1 volt. The fuel used is, for example, natural gas.

The electrolyte in ***phosphoric acid*** and ***solid polymer fuel cells*** is phosphoric acid or a plastic. Other types include ***alkaline and molten-salt cells***.

Today, the cells are plates approx. 1 cm thick and up to 1 m^2 in size, and the electrical power is approx. 0.3 W/cm^2. For practical application, a large number of plates are placed on top of one another to form a module, or »stack«. All varieties currently achieve ***efficiencies of electricity production of around 50 %***. In theory, an efficiency of 70 % is feasible, and if the heat is also utilized, an overall efficiency of up to 90 % would be possible.

The potential applications for fuel cells include ***small power plants***, ***combined heat and power (CHP) units*** and ***electromobiles***.

Saving fuel on the roads

Road traffic and transport are responsible for ***about one third of Switzerland's end-energy consumption***. Of this third, the proportion of motorised individual traffic – as of 1994 – is around 56 %, that of goods transport 17 % and air traffic 22 %. This means that traffic was the largest single consumption group, followed by private households (29%), trade and agriculture (20%) and industry (19%).

Motorised individual traffic causes an over-proportionate amount of air pollution. First of all, vehicles are seldom designed for minimum energy needs. Secondly, emission-reducing catalytic converters only become fully effective after about 5 km, while 75 % of all trips are shorter than 10 km. Thirdly, the reduction of consumption made possible as a result of progress achieved in the field of engine design is largely compensated by buying behaviour, i.e. constantly heavier and more powerful cars. And finally, the demand for mobility, and therefore for fuel, continues to increase.

Generally speaking, there is a ***vast potential for the reduction of consumption*** in the traffic sector, ***especially in road traffic***, and it is the aim of Federal Office of Energy's »Efficient Energy Use in Traffic« programme to exploit this. Although Switzerland has no indigenous automobile industry, as an important test market it is nonetheless ***in a position to exercise an influence on model development and the policies of manufacturers*** thanks to its progressive legislation and strong ancillary industry.

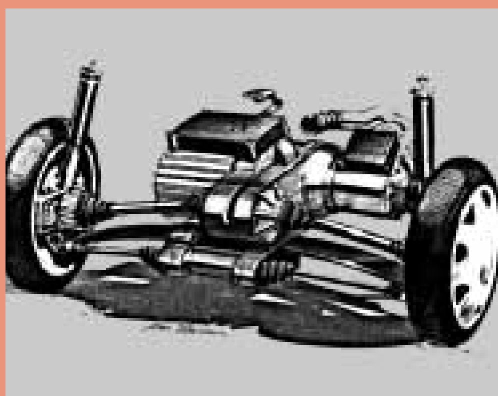
The main direction to be taken is ***research and development in the field of high-efficiency drive systems and vehicles for motorised individual traffic***, the area offering the greatest potential for saving energy. The medium-term objective is to implement the research results in a family car for everyday use that consumes less than 3 l per 100 km. A variety of possible solutions are being studied:

- ❒ It is hoped to reduce both energy consumption and emissions by introducing ***new drive systems*** – e.g. advanced Otto, diesel or electric motors, hybrid drives and fuel cells.
- ❒ New materials and designs are being sought in order to ***significantly reduce vehicle weight*** (a reduction by 10 kg reduces the fuel consumption of existing vehicles by approx. 1 %, which would be equivalent to the saving of around 40 million l of fuel a year in Switzerland).
- ❒ The ***kinetic energy*** in the form of unused heat generated in standard braking systems ***could be stored*** using high-capacity condensers, batteries and other technologies and re-used when required, e.g. for accelerating.
- ❒ ***Increasing the passive safety of light vehicles*** in order to eliminate existing prejudices.

The second priority of the promotion programme is ***goods transport by road***. There is still insufficient knowledge regarding its extent and inherent rules, so it is necessary to compile ***statistics on both national and international goods transport in Switzerland*** (e.g. who transports goods when, where from and where to?). The same applies for decision-making aids for the introduction of ***combined goods transport*** by road and rail, which combines the advantages of both methods more efficiently. Other goals include modular transport packaging and computer-aided goods handling systems.

In a ***large-scale trial*** with light electromobiles (the focus of the »light automobiles« P&D project) in Mendrisio, day-by-day use is being demonstrated and a study of mobility and buying behaviour is being carried out. The aim is to ***implement*** the findings to promote the distribution of high-efficiency vehicles throughout Switzerland (today approx. 2,500 such vehicles in use).

The safety of new light automobiles is being studied in realistic crash tests, e.g. the universities and the Swiss Federal Institute of Technology in Zurich. The findings are constantly being applied in order to bring about improvements.



Extremely efficient and low-emission parallel hybrid drive developed by a Zurich company using a combustion engine and parallel electric motor. Here a model for possible series production.

Definitions and concepts: Traffic

Transport encompasses railways, air traffic, shipping and road traffic. The latter is in turn divided into ***motorised individual traffic*** (cars, coaches, motorcycles and scooters) and ***goods transport*** (mainly with trucks and heavy goods vehicles).

Conventional motor vehicles are not very energy efficient. Their gasoline and diesel combustion engines are of relatively low efficiency, their drive mechanisms are far from being optimised and the vehicle mass is generally high.

Light(weight) vehicles or lightweight automobiles differ from conventional vehicles through their lower dead weight and higher energy efficiency.

Electromobiles use an electric motor (instead of the normal combustion engine burning gasoline, diesel or gas) which is powered with electricity supplied by an accumulator (»battery«), and in future perhaps by a generator powered by an integrated combustion engine or fuel cell. Today, the accumulators available are very heavy in proportion to their power storage capacity, and therefore tend to severely restrict the amount of useful space and permissible overall weight, as well as their road performance and range.

Light(weight) electromobiles are high-efficiency light automobiles which are able to operate with relative few (and therefore light) accumulators.

Hybrid vehicles (from the Latin term, hybrida = crossbreed) are equipped with two or more motors, e.g. an electric motor for use in urban areas and a combustion engine for longer distance travel. Batteries, high-performance condensers or compressed air accumulators are also feasible for energy storage purposes for use in acceleration and steep climbs.

Correlation between society, politics, environment and energy

Energy supply has long since been left in the hands of market forces and regarded by the latter primarily as a technical and commercial task to develop profitable power plants. It was only with the occurrence of the oil crisis in 1973 that aspects of safe supply and national economics began to attract attention and the formulation of an actual energy policy was prompted. It was not long before environmental protection and the use of renewable energies were included among the main issues. This meant that ***social, political and ecological aspects of energy supply were added to the strictly economic ones***. At the same time, a new branch of science came into being, which dealt with these extended »energy-economical fundamentals« – ***energy economics***. In this field, a number of questions were pursued in addition to various economic aspects, and these included the following in particular:

- ***Public acceptance*** (as an expression of value concepts and behaviour patterns in society), e.g. of nuclear power plants;
- The ***impact of political measures*** (e.g. energy taxes) and of long-term ***energy policy planning*** (e.g. for the replacement of nuclear power plants after 2005);
- ***Risks and costs of environmental pollution*** through the exploitation and use of energy.

Also, the ***internationalisation of energy markets*** , whether within the scope of the EU, or as a consequence of the globalisation of the economy, gave this new field added importance in recent times. How should the energy sector and energy policy adapt themselves to these developments?

Answering such questions, and thus providing both the energy sector and energy policy-makers with ***decision-making fundamentals***, is the task of research in the field of energy economics. This task is co-ordinated by the Federal Office of Energy. The focus of attention for the 1996/99 research period includes:

- The ***procurement of data***, e.g. for ***the provision of more accurate statistics*** in the industry and services sectors.
- Analyses of energy supply and demand, for which purpose the existing methods and models need to be further developed.
- ***Perspectives*** are drawn up concerning future energy demand on the basis of ***models***, which for example describe the fundamental laws of the increase in energy demand. Special attention is paid here to the impact of ***energy policy measures*** on demand trends and the economy.
- Analyses of the impact of measures (such as voluntary measures, tariffs, recommendations and legal requirements) which contribute towards a more efficient energy policy by checking their success.
- With reference to the ***costs and economic efficiency of energy systems***, one of the main concerns is to draw up ***strategies for internalisation***. Financial assessments, e.g. of damage which an increase in the greenhouse effect might cause in Switzerland, are especially difficult here.
- In the field of energy economics, practically everything is interwoven. The future international incorporation of the national energy supply is one of most prominent of these ***»inter-dependencies«***.

In addition to specialised reports and conferences, an ***important aspect of the implementation*** of the results of research in the field of energy economics is that they often form the ***basis for responses to parliamentary proposals***.

<u>Example:</u> ***<u>Effect of electricity tariffs</u>***

A project carried out in the subdivision of »Success control« in 1994/95 studied the ***»Impacts of a threshold-cost-based revision of tariffs on electricity demand«*** (threshold costs are those required for the production of additional electricity beyond the existing power plant capacities, i.e. for the construction of new power plants).

Researchers estimated the price elasticity on the basis of current, relevant findings, i.e. the level of electricity price increases at which consumers begin to consciously reduce consumption in order to save money. In addition, the influence of various other factors on electricity demand were determined. The researchers arrived at the following conclusions:

- In principle, electricity price increases in both peak and off-peak tariffs provide an incentive for consumers to save electricity. A pricing policy is therefore an effective instrument for saving electricity.
- Low electricity prices during the night encourage consumers to transfer electricity consumption from daytime to night-time, e.g. for the operation of hot-water boilers using night-time electricity only. As a result, the electricity companies are also operating at full capacity at night, which leads to lower operating costs and subsequently to lower electricity costs.
- Higher prices for peak-time electricity mean that the constantly increasing demand for peak-tariff electricity and the resulting need for the construction of new power plants can be slowed down.

The example cited above is allocated to the field of »Success control« because it is primarily the success of certain measures that is being studied here, price increases within the framework of a revision of tariffs, to be precise. The researchers were also active in other areas. For example, they used data concerning the findings obtained through tariff revisions, and models for assessing influence on electricity demand.

<u>Definitions and concepts: Energy economy</u>

The ***energy industry*** is the is the branch of the economy which is responsible for meeting energy demand at tolerable prices though the production, conversion and distribution of energy. This industry plays a key role in view of the importance of the energy supply for public and private life. Because of this, and since the dependence on location of many energy facilities, e.g. power plants, favours ***monopoly*** situations, on an international level the state exercises a major influence on the energy sector by means of its energy policy.

Economic efficiency refers to the choice and structure of energy facilities so that they yield earnings in line with market conditions. This market economy definition refers to ***»internal« costs*** arising from operating expenditure and on which the market price for the energy produced is based. ***»External« costs***, i.e. the costs of the consequences of energy production or utilisation for public health or the environment (e.g. as a result of air pollution through road traffic) which the companies do not have to bear (or not in full), are not included in these calculations. They are covered by third parties or the general public.

For environmental protection and the equal treatment of all energy carriers, external costs should be transformed into internal costs, or ***»internalised«***. Possible ways to do this include ecological regulations for avoiding consequential damages (e.g. catalytic converter requirement for cars) and taxes to compensate for pollution of the environment (e.g. increase of customs duty on fuels). However, the allocation of cause and effect is often not so simple, and it is also by no means easy to precisely calculate (or ***»monetarise«***) external costs. In order to ensure equal opportunities among the individual countries, internalisation needs to be harmonised at an international level and applied to as many goods and services as possible.

Division

Principles of energy economy

International co-operation – a necessity, long since practised

It is just as impossible for Switzerland to pursue an energy policy and conduct energy research in isolation as it is for her to develop and preserve her economy or sufficiently protect the environment. International co-operation is therefore an absolute necessity.

International co-operation can be of benefit to all parties concerned if it is based on true partnership. In this case it creates synergies, helps to avoid duplications, increases the efficiency of research, and is also able to strengthen the various industries concerned. Also, international co-operation promotes the harmonisation of regulations and laws.

But there are also some ***cases in which international co-operation is not necessarily appropriate or useful***. Generally speaking, for a small country that relies on exports, such as Switzerland, research projects which may be expected to give rise to patentable results in the short term are not particularly suitable for co-operation with other countries. As a rule, only a national patent is possible in such cases. The advantages and disadvantages of international harmonisation of energy research projects need therefore to be carefully weighed up in each case.

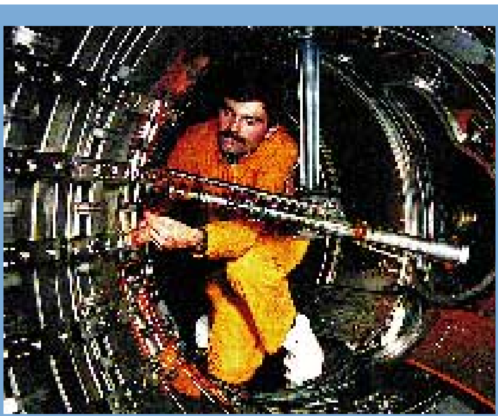
International projects are already an established tradition in Swiss energy research. Contact point is the Federal Office of Energy.

There has been co-operation within the framework of the ***International Energy Agency (IEA)*** since 1977, and this is now well established. Switzerland now participates in more than half of all IEA projects, and enjoys co-determination rights with regard to the preparation and implementation of projects.

As the European Union (EU) also functions as a partner for IEA projects, ***Switzerland is well familiarised with the EU's energy research projects***. There are also numerous ***agreements on participation in EU programmes*** such as COST, EUREKA and EURATOM. Swiss research institutions also participate in ***EU research framework programmes*** in the energy sector. However, there are still obstacles regarding their access to these programmes, and co-determination rights in connection with programme preparation and choice of projects are very restricted.

In the federal government's energy research concept, ***co-operation with Eastern and third-world countries is regarded as desirable***. Here it is mainly short-term aspects that are involved. Efficient co-operation is currently only possible via direct contacts and direct financing. The main aim is to strengthen and stabilise research groups in these regions through mutually beneficial projects. It is also intended to examine whether it might be possible to carry out field research in the East, the results of which could be transferred to Switzerland without difficulty.

Global co-operation and an ***increased commitment in third-world countries*** is regarded as important in the longer term, ***especially in the problem areas of energy and environment***.



*International co-operation on **nuclear fusion**: coatings with boron carbide developed in Switzerland for the Tokamak interior chamber – shown here inside JET – keep the plasma almost free from impurities.*

*International co-operation in **photovoltaics**: PV systems operating in an IEA project at the Swiss Federal Institute of Technology Lausanne demonstrate their integration into buildings.*

Definitions and concepts: International co-operation

The ***International Energy Agency*** (IEA) was founded in 1974 in Paris by the OECD when this organisation considered the energy supply to be endangered following the 1973 oil crisis (the OECD, Organisation for Economic Co-operation and Development, co-ordinates economic policy and development aid in industrialised countries). One of the goals of the IEA is to lower the proportion of oil used for energy supply in industrialised countries, and to use alternative energies to oil to an increasing extent. To aid this objective, the IEA offers a framework for carrying out research projects which are financed by the member states participating in those projects.

EURATOM stands for European Atomic Energy Community. It came into existence following the signature of an agreement between EU member states in 1957, and its objective is the formation and development of nuclear-related industries in these countries. Switzerland has been co-operating with EURATOM since 1979.

EUREKA is a West European initiative launched in 1985 for the promotion of international co-operation between companies and institutions with research projects that are closely linked to the market.

COST is a European co-operation venture in the field of scientific and technological research launched in 1971, in which research projects are co-ordinated. Its main objective is to increase the efficiency of research.

The ***EU Research Programme*** is intended to strengthen the competitive capacity of industry, especially in the field of energy. To achieve this aim, it promotes international research activities which require special efforts.

Turning research results into products

Generally speaking, researchers are not salesmen. They mainly carry out research in order to satisfy their thirst for scientific or technological knowledge. Once they have completed a project, they turn their full attention to the next one. What happens to the results of their research is often of secondary importance to them. This attitude is more widespread in fundamental research than in applied research and is more likely to be encountered in public research than in the private sector. In any case, research results that could be used to develop a new product or process or improve an existing one, but which are not implemented, or not to the potential extent or not sufficiently quickly, are wasted effort and squandered money.

Successful implementation is especially important in the field of energy research since it contributes towards a secure energy supply. Direct benefits for the economy, however, also arise as a result of a strengthening of the competitiveness of the industry through new products. For these reasons, increasing importance is now internationally being paid to the implementation of energy research results – an aspect that had been rather neglected in the past.

There are ***no simple recipes*** for the implementation of the results of energy research, however. It is important here to bring the often conflicting interests of researchers, industry, administration, the economy and consumers down to a common denominator. One theme may demand a quite different implementation strategy than another. And the industry is increasingly seeking results that are marketable with a minimum of delay, whereas government energy research also pursues longer-term objectives in the interest of future developments. ***Implementation therefore has to follow a large number of different paths***.

An international commission of experts which critically examined ***Swiss energy research*** in 1992/93 ***praised it highly from the point of view of implementation***. Here are some of the ***measures*** introduced by the Federal Office of Energy:

❒ The creation of ***ENET*** as an information and implementation centre through which all important findings are made available to the public. The Federal Office of Energy also supplies information for the compilation of an international database.

❒ ***Detailed annual reports*** are required for supported projects and ***made available to the public, and especially to the industries directly concerned***.

❒ Companies and associations that are not directly involved in energy research are invited to attend ***regular information events***.

❒ The possibility of providing ***support for P&D projects*** through the Federal Office of Energy and the cantons is one of the most important instruments available for the implementation of energy research results in Switzerland.

❒ Division managers are also required to draw up ***implementation concepts*** alongside detailed action plans for their section.

Numerous examples have demonstrated that the ***transfer of university graduates to industries operating within the same field*** has been very beneficial for implementation, since they are able to make use of their research findings by putting them into practice.

Definitions and concepts
Implementation:

Implementation can be defined as the act of turning research results into practice. Expressed in terms of an example from energy research, a research project has demonstrated that during the heating period transparent heat insulation on the south facade convey per m^2 over 100 kWh of heat into the building. As a result, a number of pilot and demonstration systems were set up, and these confirmed the research results. Subsequently, a number of Swiss companies began to manufacture the insulation material. Sales were hesitant to begin with, but soon increased. The implementation has proved to be a success.

Pilot and demonstration (P&D) systems are an important step in the implementation process. In a ***pilot project*** a system or process is, for the first time, transferred from a laboratory to a technical scale and subsequently tested.

The next ***step is a demonstration system***. Here the system is constructed on a scale of 1:1, permitting thorough assessment of technical, economic and ecological aspects with a view to its introduction onto the market, i.e. it fulfils the function of a market trial.

Pilot, and especially demonstration, systems are also intended to draw the attention of potential users to the new technology or new product.

Example: **Insolation atlas of Switzerland**

At the end of the 1970s it became clear to specialists that in order to achieve a widespread and efficient use of solar energy it was vital to chart the power and duration of sunshine for each town in Switzerland. Only in this way would it be possible to accurately estimate the energy yield of solar power plants or dimension panels and hot-water storage in advance. Although there are a number of meteorological centres which record sunshine data, Switzerland has some 3'000 municipalities, so there was clearly an urgent need for an »Insolation atlas« giving the solar radiation for each municipality. A team of meteorologists and users was formed for the METEONORM project, and financing was provided by NEFF and the Federal Office of Energy.

❒ 1982 to 1985: available data are of little use to solar energy planners since measurements had been too brief or imprecise. Hence, sunshine data recorded on a long-term basis at 69 meteorological stations were extensively processed, and satellite images for calculating the distribution of clouds were evaluated. This led to the publication of a new series of METEONORM reports presenting new meteorological data for solar energy planners, especially in the fields of solar water heating and auxiliary heating.

❒ 1986 to 1988: continuation of the project with measurements and evaluations, expansion of METEONORM to include data for photovoltaic systems.

❒ 1989 to 1990: additional measurements and evaluations, expansion of METEONORM to include data for wind power plants.

❒ 1991 to 1995: continuation of the project with measurements and the incorporation of advanced data processing methods. Publication of a manual with PC program for the precise calculation of solar radiation at any desired location for active, passive and photovoltaic utilisation.

Sales of over 12,000 copies of the 1985/88/90 editions (10% of orders from abroad) can be regarded as successful »implementation« of the project results. »METEONORM« is now an established tool of Swiss solar planners.

Research is by nature a venture into uncharted territory – one can never be certain of achieving the set objectives. Not every project leads to success, despite the most meticulous preparation and action. Above, and on page 23, the progress of a number of projects is outlined, some of which achieved their aims with ease, while others have had to overcome a variety of obstacles or are now well on their way to doing so.

In spite of the positive assessment, weak points in the implementation process became apparent in the mid-1990s. ***The Federal Office of Energy carried out a restructuring process in 1996*** in which it eliminated the organisational separation of research and market introduction. The new structure encompasses both research programmes such as pilot and demonstration plants and active market introduction within a given technological area or »division«, as a result of which it should be possible to considerably improve co-ordination between the 15 divisions and thus aid implementation.

For the 5th Swiss Energy Research Conference held in November 1995 at Yverdon, the Federal Office of Energy had chosen the theme »Implementation of results«. This yielded further proposals for eliminating weak points in the implementation process. These gave rise to a whole series of actions, the principal objective of which is the ***closer co-operation between government and industrial research***.

❐ For example, the ***industry needs to be*** approached more actively in order for it to become ***involved in research projects at the earliest possible stage***, so that these can be adapted to its requirements.

❐ ***More industry representatives*** with experience in the implementation of research results need to be included in the support groups for individual areas of research. These groups also assess applications for projects from a point of view of their feasibility.

The significance of implementation in the field of energy research is acknowledged in this brochure in that, at the end of each description of a division of research, the most important implementation measures within the corresponding programme have been summarised and emphasised in graphic form.

Example: **Photovoltaic elements for flat roofs**

In order to make solar power cheaper by saving on real estate costs, PV modules (see p. 8) can be installed in facades or placed on roofs and thus fully integrated into the building (in the sense of the adoption of an additional function, e.g. as roof or facade covering, thereby replacing standard elements). The countless unused flat roofs of office blocks and factories offer an immense potential for PV. A research group comprising an engineering office and a university institute specialising in PV, plus a future user, proposed the development of lighter supports that are simpler to install and therefore cheaper than the existing elements for flat roofs. The Federal Office of Energy supported this project from 1992 on.

❐ 1992 and 1993: models and tests of supports made of concrete, steel, aluminium alloy and Eternit for »sawtooth« installation. Integration of electrical cabling. Ecological assessment and price indicate concrete as the best choice.

❐ 1994 and 1995: five P&D plants on the roofs of schools and factories. Elements improved further and made cheaper (less than 50% of the cost of normal supports, thus permitting solar electricity costs of well below 1.- CHF per kWh for the first time). These elements are able to withstand all wind speeds without the need for special anchoring. PV modules are held in place using metal clamps.

Production of the complete installation system for PV modules commenced in 1996. The first large-scale plant – 102 kW peak capacity from 1200 standard photovoltaic modules on 2400 concrete bases – is installed on the roof of a new bank building near Lugano.

PV supports for flat roofs as an example of implementation: concrete bases each accommodate one PV module 120 cm in length and 52 cm wide. The weight of these bases alone is sufficient to ensure their ability to withstand strong winds.

Wood combustion as example of implementation: novel wood-fired stoves and ovens, combining optimum heating technology and modern design, suffice as the sole heating-source in low-energy houses.

Example:
Wood-fired heating systems

A large number of projects were promoted from the 1980s to the early 1990s aimed at ***economical and low-pollutant wood-fired heating systems***(cf. page 10). Today, highly-efficient and environmentally compatible systems are available for all areas of application – from wood-fired stoves for low-energy houses through to wood-fired district heating systems and CHP (combined heat and power) units.

Example:
Corrosion of oil-fired boilers

In the 1980s, a number of highly efficient household oil-fired boilers (condensing boilers) began to ***corrode*** after only a few years of service. A research project identified sulphuric acid, which was formed from the sulphur contained in heating oil and condensed in the boiler, as the culprit. In another project researchers were able to demonstrate that a layer consisting of thermally hardening artificial resins provided boilers with effective protection against corrosion.

Example:
Accumulators for electromobiles

A research project for the development of better ***nickel/metal-hydride accumulators*** (cf. page 17) in the 1990s resulted in a prototype for electromobiles that is regarded as internationally competitive. But since it is uncertain how the market for electromobiles will develop, the series manufacture of larger quantities of this type of battery appears to be too economically risky for the time being.

WHO and WHAT receives government support, an HOW?

No one questions the fact that energy research carried out at official research centres of the federal government and the cantons – such as the Swiss Federal Institute of Technology, universities, technical colleges or the Paul Scherrer Institute – should be financed by public funds. But whether the public authorities should also provide financial support for energy research in the private sector – for example, research projects carried out by industrial companies, engineering offices and private individuals – has been a matter of some dispute. The industrial sector, and especially large-scale corporations, rejected government support of research. The reason for this was very understandable: ***if you make use of public funds for research, you also have to make the results of that research publicly accessible*** – and thus run the risk that your rivals will also be able to profit from it.

In the meantime, however, models have been drawn up and tried out which grant companies ***a period of protection for »sensitive« research results***. The main reason for the ***marked increase in the demand for research promotion from the private economy*** was not so much this adaptation to the interests of companies in the industrial sector as the ***recession which set in at the beginning of the 1990s*** (in addition there was the factor of increased competition from abroad, for industrial research is supported by the state in a great many countries). It would appear that research funding is now viewed as a welcome aid (whilst internal research expenditure is being cut due to the recession).

As before, however, private companies still prefer to carry out research in areas regarded as especially important »under exclusion of the public«, i.e. without the aid of public funding. It is preferred to receive assistance for less important problems and for financially risky preparatory tasks that do not immediately result in new products.

»Task research«, which mostly involves aided research projects, permits countless engineering consultants to specialise in certain fields, thus giving them a stronger position in terms of competitiveness.

The main focus of promotion is on applied energy research, the results of which are reflected in a product (e.g. an energy-saving computer), an energy conversion system (e.g. a fuel cell), the improvement of existing measures (e.g. traffic control aimed at preventing traffic jams) or processes (e.g. energy-efficient air cooling).

Pilot and demonstration plants speed up the process of putting research results into practical application. ***This is why they receive support, though on condition that the industry or operator bears the greater portion of the costs***. This kind of participation forces the industry concerned to adopt a critical approach to their projects, which in turn increases the prospects of implementation by industry itself.

Selective direct promotion of energy research projects is granted by industrial energy research funds ***in addition to the Federal Office of Energy*** (cf. column at right).

Various cantons pay contributions towards P&D plants in the field of energy technology; information on cantonal support and the modalities of submitting applications is available from cantonal energy authorities (Energiefachstellen).

How applications are submitted and dealt with

Anyone, from a private individual through to an engineering consultant, company and university institute, is entitled to ***apply to the Federal Office of Energy*** for support for energy research projects.

The objective of the project must be in keeping with the Federal Government Energy Research Concept. On the basis of the valid concept and, above all, the execution plan for the field concerned, applicants should therefore verify that their project is in line with the federal government's objectives (both the »Concept« and the execution plans are available from the Federal Office of Energy).

An application should be submitted to the Federal Office of Energy in the form of a project outline or research estimate (the necessary special forms can be obtained from the Federal Office of Energy).

In certain cases, the Federal Office of Energy also calls for tenders for research projects and publishes the applicable conditions in the corresponding specialised press as well as in »ENET News«. Applications submitted as a result of these calls for tenders are treated as »free« applications.

The Federal Office of Energy notifies the applicant within one month whether the application will be considered or turned down. A definitive decision is normally taken within three months from the date of the application, after the project has been evaluated by a specialist committee.

The Federal Office of Energy decides on the amount to be granted for the project, after consultation with the corresponding experts and programme and divison manager. Contributions ranging from several tens of thousands of CHF to over 1 million are possible. The average duration of a project is three years.

See next page for contact addresses.

The legal framework of promotion

Direct promotion of research in the energy sector by the federal government is based on these legal foundations:

- ❒ Nuclear Power Law (Article 2) dated 23.12. 1959
- ❒ Research Law dated 7. 10. 1983
- ❒ Decree on Energy Use (Article 10) dated 14. 12. 1990.

In addition to the above, the federal government is vested with numerous special powers at the constitutional and legislative levels, which permit the promotion of energy research (e.g. environmental protection legislation).

The federal government's promotion takes the form of indirect contributions via the Swiss National Fund, to research programmes of the EU and financing of the Federal Institute of Technology and its research centres. Targeted, direct support is only possible through the Federal Office of Energy, however.

The Energy Article, which was adopted into the Federal Constitution in 1990, also gives the government the competence to promote pilot and demonstration plants, especially if these concern energy efficiency and the use of renewable energies.

The Decree on Energy Use, which has been in force since 1991, provides the legal basis for the support of P&D plants. It is due to be replaced in 1998 by the Energy Law which has the same legal basis.

Some cantons have formally adopted the support of P&D plants into their constitution, while others can only support local projects.

The cantons also contribute towards energy research through work carried out at cantonal polytechnics and advanced colleges of technology, etc..

Promotion of energy research

Contact address for general enquiries concerning energy research:

Federal Office of Energy
Research Co-ordination and Special Sections
3003 Berne
ph. 031 – 322 56 58, fax 031 – 382 44 03

Addresses
of Divisional and Programme Managers

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	TECHNICAL INSTALLATIONS (HVAC)	***Martin Stettler*** 031 - 322 55 53		
	SOLAR ARCHITECTURE and DAYLIGHTING	***Walter Luginbühl*** 031 - 322 56 41	***Robert Hastings***, ETH-Hönggerberg, 8093 Zurich Tel. 01 - 633 29 88, Fax 01 - 633 10 75 E-mail: hastings@orl.arch.ethz.ch	
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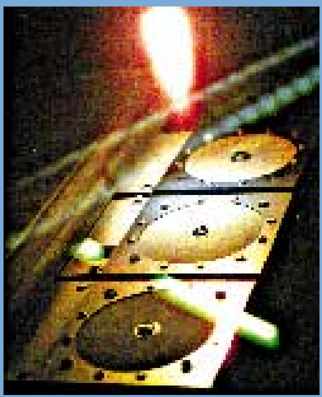
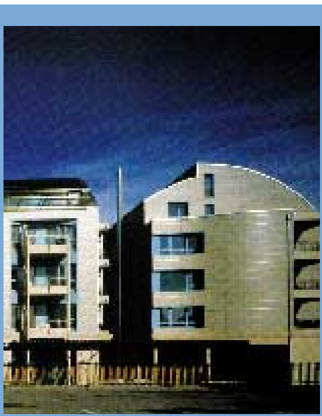

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