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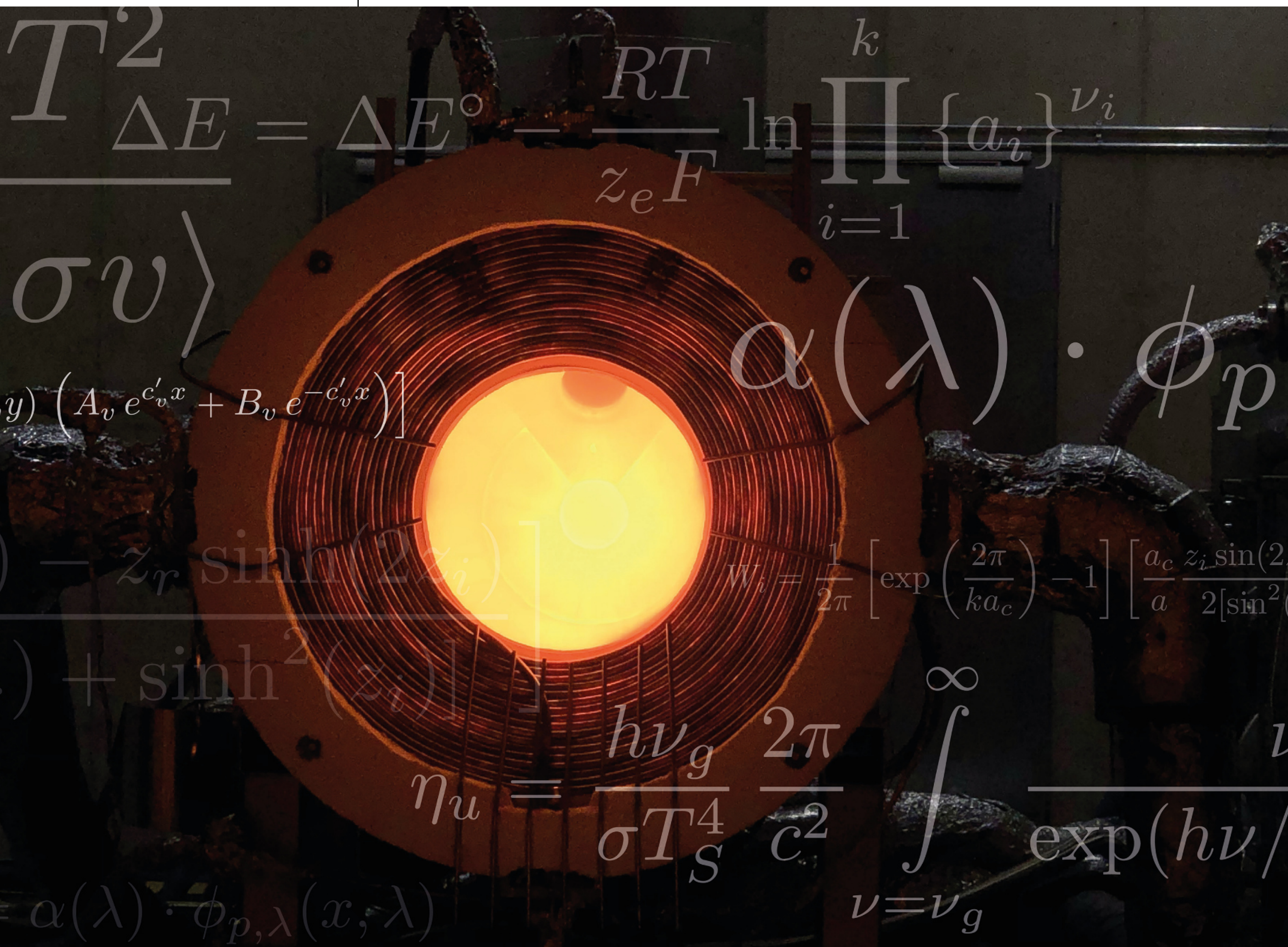
Swiss Federal Office of Energy SFOE

Energy Research Masterplan 2021–2024



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Abstract

As a result of the fundamental decision taken by the Federal Council and Parliament in 2011 to gradually withdraw from the use of nuclear energy and bring about the necessary step-by-step transformation of the Swiss energy system by 2050, the importance of federal energy research has increased significantly. The research programmes developed by the Swiss Federal Office of Energy (SFOE) encompass the entire spectrum of research in the fields of energy efficiency and renewable energy.

SFOE as major provider of support

In 2018, the public sector spent 404 million Swiss francs on energy research. The greatest proportion (39 %) was provided by the ETH domain, followed by Innosuisse (Swiss Innovation Agency) with 13 %, the SFOE (9 %) and the Swiss National Science Foundation SNSF (8 %).

The 35.3 million Swiss francs provided by the SFOE were allocated as follows: around 18.5 million for energy efficiency projects, 16.9 million for projects relating to renewable energy and approximately 2 million for projects in the fields of social sciences and the humanities.

Promotion of international cooperation

One of the main duties of the SFOE is to secure the integration of Swiss researchers into international research activities. Alongside various multilateral agreements and the promotion instruments of the European Commission, this primarily concerns research programmes of the International Energy Agency (IEA). The latter (which are referred to as Technology Collaboration Programmes, or TCP) are a key component of Switzerland's promotion of energy research. The SFOE is responsible for providing the necessary framework conditions for the participation of Swiss researchers and holds a seat in the respective management committees. It also provides subsidiary support for participants in the TCP.

Energy research as a key component of the Energy Strategy 2050

Following the completion of the capacity expansion of the Swiss Competence Centres in Energy Research (SCCER) at the end of 2020, the competencies at Switzerland's universities and in the SCCER will have to be consistently oriented on the objectives of Energy Strategy 2050. To accomplish this, the SFOE has created a new research programme («SWEET») focusing on thematic calls for tenders relating to consortia projects. This twelve-year programme will enter into effect in 2021.

Entry into effect

The SFOE's Energy Research Masterplan 2021–2024 will enter into effect on 1 January 2021. It will be published electronically in German, French and English.

Contents

Figures and Tabels

1 Introduction

As a result of the fundamental decision taken by the Federal Council and Parliament in 2011 to gradually withdraw from the use of nuclear energy and bring about the necessary step-by-step transformation of the Swiss energy system by 2050, the importance of federal energy research has increased significantly. The two national research programmes initiated by the Federal Council in 2011 and managed by the Swiss National Science Foundation (SNSF) – «Energy Turnaround» and «Management of Energy Consumption» – were concluded at the end of 2019, and the capacity expansion of the eight SCCER[1] as specified in the «Swiss coordinated energy research action plan» was completed at the end of 2020. For the two national research programmes and the capacity expansion of the SCCER, the Federal Council and Parliament provided a total of 237 million Swiss francs in the period from 2013 to 2020.

In order to fully utilise the competencies and capacities built up at Swiss universities and universities of applied sciences to achieve the objectives of Energy Strategy 2050, the SFOE has created a new research promotion programme called SWEET (Swiss Energy research for the Energy Transition), which is to be used for conducting thematic calls for tenders for consortia projects focusing on specific areas of research (chapter 3.5).

This Energy Research Masterplan of the SFOE applies to the period from 2021–2024 and is closely aligned with the Federal Energy Research Masterplan for 2021–2024, which is being prepared by the Federal Energy Research Commission (CORE).[2]

The SFOE as central promotional body

With its various research programmes plus its pilot and demonstration programme, the SFOE possesses its own promotional instruments (sector research) for the implementation of this research masterplan.[3] The SFOE's energy research mandate extends beyond specific sector research: the intention is for the various programmes to coordinate all energy research in Switzerland and provide subsidiary support for research activities and pilot and demonstration projects that further the attainment of the objectives of Energy Strategy 2050.

The SFOE publishes the annual federal energy research statistics[2] a report that provides information about energy research that is financed through public funding. It also contains a detailed summary of finance flows. According to the most recent survey (2018), the SFOE accounted for 9 % of the energy research funding and was the third-largest support bodies after the ETH domain and Innosuisse (Swiss Innovation Agency). The SFOE is thus one of the most important public sector promotional bodies (Figure 4).[4] The conclusion of the two national research programmes, the completion of the capacity expansion of the SCCER and the creation of the SWEET programme mean that the SFOE will become even a more important provider of public funding in the energy sector.

1 SCCER: Swiss Competence Centres in Energy Research. The SCCER encompass the following areas of research: grids, storage, biomass, geothermal energy and hydropower, efficiency in buildings, efficiency in industrial processes, mobility and socio-economics.

2 www.energieforschung.ch

3 The research carried out by the federal administration is referred to as «sector research». This concerns research, the findings of which are required by the federal administration and/or government for the performance of their duties, or which they initiate because it is in the public interest. Sector research is described in the Federal Promotion of Research and Innovation Act. www.ressortforschung.admin.ch

4 Alongside the public funding bodies, it is the universities – above all the Federal Institutes of Technology – that provide the highest level of financial support.

2 Overview of energy policy

Switzerland is facing major challenges with respect to its energy policy. In order to meet the objectives specified by the Federal Council in its Energy Strategy 2050 it will be necessary to greatly accelerate the expansion of renewable energy capacities and significantly increase the level of energy efficiency in buildings, in industry and in the transport sector, as well as of electrical appliances. In its review of the «Swiss coordinated energy research action plan» the Federal Energy Research Commission (CORE) noted that, in order to meet the objectives of Energy Strategy 2050, significant progress in the field of energy research will also be required after 2020.

Long-term focus

In view of this, new mind sets will be required, as well as new approaches and new technologies. But departing from well-established paths calls for a support strategy that does not equate the financial resources invested in research with the immediately achieved savings in kilowatt hours. Research requires room for manoeuvre in which new ideas can be conceived and tested. The research support provided by the SFOE facilitates this in that it promotes both implementation-oriented research, as well as application-oriented basic research. The SFOE is the sole public sector body that also supports areas of energy research via national research programmes with a duration of ten or more years.

With its new SWEET programme, the SFOE is also promoting long-term consortia projects focusing on selected areas of research, and is providing funding for research into disruptive technologies.

International integration

Successful research always has an international orientation: international cooperation increases the efficiency of invested resources and facilitates exchanges of know-how among researchers. Scientifically recognised and high-quality contributions from Switzerland are a prerequisite for successful cooperation, especially within the framework of IEA and EU projects.

Alongside active support for scientifically risky research projects and the closure of gaps in the innovation chain (Figure 1) networking Swiss researchers at the national and international levels is one of the SFOE's main tasks in the field of energy research. The SFOE actively looks for auspicious projects via a comprehensive network of contacts, and it links research projects with a similar focus and helps researchers look for third-party funding.

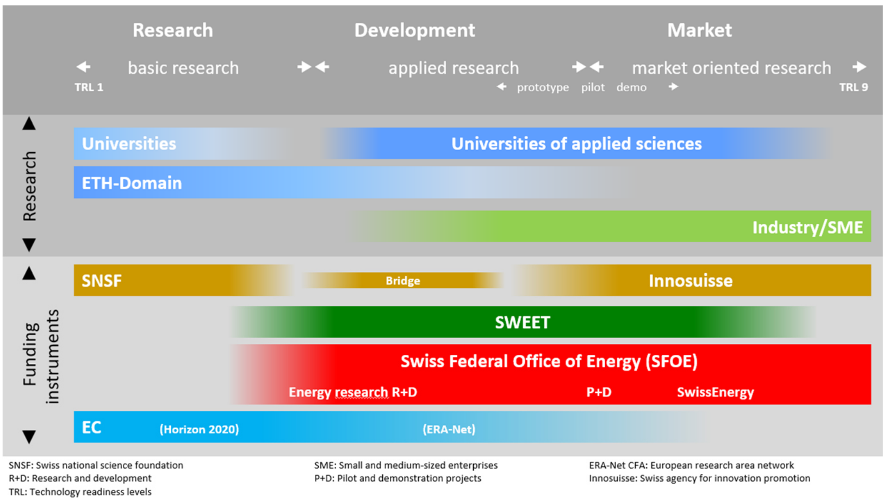

Figure 1 Innovation chain
Research support provided by the SFOE covers the entire field of application-oriented research through to pilot and demonstration projects (source: SFOE)

Switzerland is integrated into the most important IEA research programmes via the SFOE. Here the main focus is on TCP. Switzerland is a participant in the most important of these programmes for energy research.[2] The SFOE pays the costs of participation, finances the seats of Swiss researchers in the steering and management committees of these programmes, and provides Swiss researchers with financial support within the framework of calls for tenders for research projects.

Switzerland participates without restriction in the EU's energy-relevant European Research Area Networks (ERA-Net). Via its participation in the EU's Strategic Energy Technology Plan (SET-Plan), it is able to actively contribute towards the development of ERA-Net and also finances the participation of Swiss researchers.

2.1 Strategic focus of energy research

The focus of the SFOE's duties is on the sustainable supply and use of energy and on the security of Switzerland's energy supply. The energy research supported by the SFOE therefore focuses on these objectives and on efficient knowledge and technology transfer. Here the scientific framework is determined by the Federal Energy Research Masterplan developed by the Federal Energy Research Commission (CORE)[2], in which special attention is paid to the correlations between technology and the environment and to social and economic aspects.

The SFOE supports a segment of the innovation chain that is not covered by the SNSF and Innosuisse (Figure 1). Unlike the latter two institutions, the SFOE is able to directly support researchers from the private sector, especially those involved in pilot and demonstration projects, in order to secure the direct implementation of research findings in a commercial environment, or if the knowledge of private sector players is essential for pre-competitive research projects. However, in order for federal government funding to be deployed in the private sector, the involved companies are required to make a reasonable contribution towards the expenditure.

This means that the SFOE is able to support targeted areas ranging from application-oriented research through to evidence of economic viability in a real environment.

Strategic focus of energy research

The SFOE's promotion of research focuses on energy efficiency, renewable energy and issues relating to social sciences and the humanities. Thus its research programmes can be classified in these three categories.

Many issues such as storage, sector coupling and digitisation cannot be clearly allocated to a specific topic and therefore have to be addressed and examined on a cross-programme basis. In addition, certain topics such as smart cities and smart grids also call for interaction among a broad variety of disciplines and are consequently of special interest for the SFOE's energy research.

In view of this, the SFOE supports cooperation between inter- and transdisciplinary groups of researchers and on cross-programme issues.

2.2 Challenges

The SFOE's energy research focuses on the objectives of Energy Strategy 2050. In addition to the objectives in the fields of technology, social science and the humanities described in chapter 3, other objectives include linking the SFOE's research with all the major national and international energy players and securing the integration of Swiss researchers into the research programmes of the IEA.

SWEET: a new promotion instrument

The further development of research expertise in Switzerland's universities and universities of applied sciences within the framework of the SCCER was completed at the end of 2020. In order to orient the competencies and capacities built up in these institutions on the Energy Strategy 2050, the SFOE has created a new research promotion programme called «SWEET» (Swiss Energy Research for the Energy Transition). This is a twelve-year programme with a budget of 52 million Swiss francs (2021–2024).

The initial series of calls for tenders will be published at the beginning of 2021, and these will be followed by further calls in the ensuing years. Thus the biggest challenge for the SFOE will concern the organisational structuring of the programme and the content and implementation of the calls for tenders.

2.3 Legal bases

The commitment of the federal government to research and its promotion is governed by Article 64 of the Federal Constitution (SR 101), in accordance with which the federal government is to support scientific research and innovation.

The promotion of research by the SFOE is based on the Federal Energy Act (SR 730.0): in accordance with Article 49, the federal government promotes basic and applied research, as well as developmental research into new technologies, especially in the areas of economical and efficient use, transmission and storage of energy and the use of renewable forms of energy. The federal government may also support pilot and demonstration projects, as well as field studies and analyses that serve to foster the testing and assessment of energy technologies, the evaluation of energy policy measures or the collection of the necessary data.

In accordance with Article 29, paragraph 2d of the Federal Water Retaining Facilities Ordinance (SR 721.101.1), the SFOE is also responsible for research in the field of dams and reservoirs.

Here, the necessary support is governed by the Federal Subsidies Act (SR 616.1) and the Federal Promotion of Research and Innovation Act (SR 420.1).

The SFOE's support of research projects within the framework of the EU's European Research Area Networks (ERA-Net) is based on the parliamentary motion submitted by Kathy Riklin (10.3142), which empowers the Federal Council to facilitate the participation on an equal footing of Swiss research institutions and Switzerland's industry sector in the Strategic Energy Technology Plan (SET-Plan) initiated by the EU Commission.

With its new SWEET programme (chapter 3.5), the SFOE plans to support additional research projects focusing on the safety and security of nuclear facilities and energy infrastructure. In this context, as the relevant supervisory authority the SFOE is governed by Article 86 of the Federal Nuclear Energy Act (SR 732.1), which stipulates that the federal government may support application-oriented research relating to the peaceful use of nuclear energy, and in particular the safety of nuclear facilities and the disposal of nuclear material. In addition, Article 77 of the Federal Nuclear Energy Ordinance (SR 732.11) specifies that the two relevant supervisory authorities (the SFOE and the Federal Nuclear Safety Inspectorate) may, within the scope of approved credits, provide financial support for application-oriented research projects in the areas of safety and security of nuclear facilities and disposal of nuclear material.

Overview of the applicable legal bases:

- Federal Energy Act (SR 730.0), Article 49;
- Federal Subsidies Act (SR 616.1);
- Federal Promotion of Research and Innovation Act (SR 420.1);
- Federal Water Retaining Facilities Ordinance, (SR 721.101.1), Article 29;
- Federal Nuclear Energy Act (SR 732.1), Article 86.

3 Research topics, 2021–2024

Principles of research promotion

In the area of energy efficiency, the research support provided by the SFOE primarily focuses on increasing efficiency levels, improving system properties (e.g. in the field of networks) and enhancing supply security. In the field of renewable energy, the main focus is on reducing costs and increasing the energy yield. In the areas of social sciences and humanities, the focus is primarily on issues relating to the energy-relevant behaviour of the various players, the structure of energy markets and the nature and impacts of energy policy measures.

Figure 2 and Figure 3 show the technology readiness level (TRL) for each research programme that is the focus of the SFOE's financial support. TRLs cannot be directly applied to research in the fields of social sciences and humanities. Here, application-oriented research, including basic research, is admissible.

Research programmes: energy efficiency

Research programme	TRL
Fuel Cells	3–8
Electricity Technologies	3–8
Buildings and Cities	3–8
Industrial Processes	3–8
Mobility	4–8
Grids	3–8
Combustion Based Energy Systems	3–8
Heat Pumps and Refrigeration	4–8

Figure 2 Technology readiness levels (TRLs) in the area of energy efficiency

Research programmes: renewable energy

Research programme	TRL
Bioenergy	3–8
Geothermal Energy	3–8
Photovoltaics	4–8
Solar Energy at High Temperature	2–8
Solar Heat and Heat Storage	4–8
Dam Safety	2–4
Hydropower	4–8
Hydrogen	2–8
Wind Energy	3–8

Figure 3 Technology readiness levels (TRLs) in the area of renewable energy

A checklist for assessing the eligibility of a given research project for support can be viewed on the SFOE website.[2]

Research objectives oriented on the Federal Energy Research Masterplan

The SFOE's research programmes are grouped into three categories: energy efficiency (chapter 3.1), renewable energy (chapter 3.2) and social sciences and humanities (chapter 3.3). The other promotion instruments of the SFOE are the pilot and demonstration programme (chapter 3.4) and SWEET (chapter 3.5).

The SFOE's Energy Research Masterplan is closely oriented on the Federal Energy Research Masterplan, which describes specific medium- and long-term objectives. It outlines the research topics that are of relevance to the SFOE.

The Federal Energy Research Masterplan 2021–2024 and the SFOE's Energy Research masterplan are available on the SFOE website,[2] together with detailed information about the individual research programmes. The respective contact details are also listed on this website.

Digitisation

Digitisation is a comprehensive topic of special importance. It is present in the majority of the SFOE's research programmes, but often concerns varying aspects and priorities. For this reason it is not the subject of a separate research programme. While energy research primarily focuses on specific energy-related aspects of digitisation, in the framework of pilot and demonstration projects, it is possible for solutions to be studied and tested beyond the bounds of the energy sector.

Sector coupling

The term «sector coupling» refers to the networking of various end-use sectors (electricity, heat and refrigeration, mobility and industry). The aim here is to develop potential solutions using a holistic approach in order to render the overall energy system more efficient and in particular to facilitate the integration of a larger proportion of renewable energy up to 100 %. Examples include the use of renewable electricity in the field of e-mobility or in combination with heat pumps in the heating sector, and the production of synthetic gases and fuels (power-to-gas, power-to-liquid) for use in the transport, heating and industry sectors. Coupling various sectors also leads to greater flexibility in the overall system and thus has the potential to significantly reduce the need for storage in certain sectors (notably the electricity industry). This approach also contributes towards supply security. As a research topic, sector coupling is approached on a cross-programme basis and is also especially addressed in large-scale pilot and demonstration projects. While in technologies such as photovoltaics and heat pumps, which are already widely disseminated in the market, sector coupling mainly concerns systemic as well as regulatory issues, in other areas such as power-to-gas the focus is also on technological research topics.

Energy storage

Energy storage is a special case for which there is no separate research programme because certain aspects are addressed in a broad variety of other research programmes. Please consult the SFOE's energy research website to find out whether current research projects and topics are being actively promoted.[2]

Energy can be stored with the aid of a variety of technologies, ranging from chemical, mechanical and electrical through to thermal storage systems. Depending on the specific circumstances, energy storage may involve the use of accumulators, ultra-capacitors, hydrocarbons, hydrogen, biomass, flywheels, specially designed springs, compressed air, dams, the underground, adsorbents and superconductor coils. Storage technologies are therefore researched in the corresponding SFOE programmes.

Research in the field of nuclear energy

The SFOE does not manage any programmes in the field of nuclear energy. Information about nuclear energy research can be obtained from the following websites:

- Fusion: Federal Institute of Technology, Lausanne, Swiss Plasma Centre (SPC). www.epfl.ch
- Nuclear technology and nuclear safety: Paul Scherrer Institute (PSI). www.psi.ch/nes
- Regulatory safety research: Federal Nuclear Safety Inspectorate (FNSI).

  www.ensi.ch/de/kernanlagen/sicherheitsforschung

3.1 Energy Efficiency

3.1.1 Batteries

Background information and issues

Battery storage is playing an increasingly important role, both at the stationary level (renewable energy) and in the field of e-mobility. In view of the huge importance of storage technology in the context of the expansion of renewable energy capacities in order to reduce levels of greenhouse gas emissions, major efforts to develop new batteries are being made throughout the world, and rapid progress is being achieved. Today the battery cell market is dominated by Asian manufacturers (with a share of more than 90 %), but initiatives have also recently been launched in Europe (e.g. European Battery Alliance) aimed at speeding up expertise and manufacture here. Manufacturing processes, the utilised materials and safe disposal are decisive factors for the ecological footprint of batteries, and safety and performance aspects are also associated with fundamental material-related issues.

Swiss players are focusing on a variety of areas of battery research, including low temperature, high temperature (salt) and redox flow batteries. Other areas of activity include system development and the integration of battery systems in mobile and stationary applications.

The SFOE is able to provide subsidiary support for research activities in this field via a small programme focusing specifically on batteries in conjunction with its promotion options in the framework of pilot and demonstration projects.

Research priorities, 2021–2024

Materials research and electrochemistry

- Substitution of lithium-ion technologies with concepts based on more readily available elements such as sodium, magnesium and aluminium;
- Further development of lithium-ion technology through to batteries with solid electrolytes in order to increase safety and storage density.

System development

System integration and characterisation

- Ecological aspects such as second life and recycling

3.1.2 Fuel Cells

Background information and issues

Fuel cells are electrochemical transducers that convert chemical energy directly into heat and electricity with a high degree of efficiency. Their characteristics also include low pollutant and noise emissions, a high level of efficiency at partial load and low maintenance requirements (no moveable parts).

Fuel cell types differ according to the type of electrolyte and thus in particular in terms of operating temperature (high and low temperature fuel cells). In Switzerland, the focus of activity is primarily on research and development in the fields of polymer electrolyte fuel cells (PEFC) and solid oxide fuel cells (SOFC).

Fuel cells are used in stationary areas of application (combined heat and power, especially SOFC), in uninterruptible power supply systems (PEFC), for portable systems (PEFC), as well as in the mobility sector (fuel cell powered vehicles, PEFC).

The relatively high investment costs pose a challenge, but these have fallen sharply in the past ten years thanks to major progress in fuel cell development. They can be expected to continue to fall as a result of economies of scale in production and an increasing number of product suppliers. Increasing the service life of fuel cell systems represents a further challenge.

Research priorities, 2021–2024

Solid oxide fuel cells (SOFC)

- Better understanding of degradation phenomena;
- Development of materials for interconnectors;
- Internal steam reforming;
- Manufacturing issues.

Polymer electrolyte fuel cells (PEFC)

- Modelling and validation;
- Degradation;
- Bipolar plates and cell design;
- Stack development;
- Non-invasive analysis methods.

Fuel cell systems

- Efficient compressors;
- System integration (fuel cell powered vehicles);
- Performance analysis;
- Fuel cell tests.

3.1.3 Electricity Technologies

Background information and issues

Electricity for the use of countless applications is penetrating everyday life in modern-day society, both in the private sphere and the business world. With a proportion of around 20 % of overall energy demand, electricity is of central importance in the energy sector. Despite ongoing efficiency gains, electricity demand is set to increase sharply again due to the increasing process of decarbonation in the transport (e.g. e-mobility) and heating (e.g. heat pumps) sectors.

This means that intensified efficiency gains in the fields of production, distribution and consumption of electricity will be decisive. In addition, the use of storage technologies to balance the fluctuating production over various time scales will be an important factor for sustaining the future energy supply.

The aim of the research programme is to make a contribution towards a substantial and sustainable efficiency increase in all areas, as well as towards research on new storage technologies. In close coordination with the Grids research programme in particular, the ongoing activities are being supplemented and additional synergy effects are being created and utilised.

Research priorities, 2021–2024

Conversion technologies

- Material and system related efficiency increases of power electronics; new power electronics components (e.g. wide band gap semiconductors);
- Measures to speed up the market launch of efficient power electronics technologies;
- use of low-level waste heat for additional electricity production;
- Evaluation and analysis of development of promising materials for specific conversion technologies (e.g. materials for innovative magnetocaloric motors/generators);
- Clarification of feasibility and potential of new conversion technologies; efficiency analyses and technology research where potential for efficiency gains is foreseeable. Here the prerequisites are a corresponding energy efficiency potential and a significant contribution towards the costs from the national industry.

Storage technologies

- Closure of specific knowledge gaps concerning critical system components in the field of compressed-air storage; studies of compressed-air storage systems;
- Study and analysis of new and sustainable types of electromechanical storage technologies.

Efficiency technologies

- Electric motors and drive systems: analysis and support of potential efficiency increases with focus on systemic approach (inclusion of process); efficiency improvements through targeted integration of inverters;
- Energy-related impacts of digitisation; innovative digitisation concepts for increasing energy efficiency in industry and the private sector;
- Energy-related issues in the areas of Internet of Things, smart metering, smart home and efficient IT and communications equipment;
- Minimisation of the standby consumption of network-based IT and communications equipment;
- Use of new technologies and materials (e.g. high-temperature superconductors) for increasing energy efficiency. Here the prerequisites are a corresponding energy efficiency potential and a significant contribution towards the costs from the national industry;
- International exchanges of findings relating to energy efficiency through participation in the activities of the IEA TCP, «Energy Efficient End Use Equipment» (4E).

3.1.4 Buildings and Cities

Background information and issues

Buildings account for around 45 % of Switzerland's end energy consumption and 33 % of its CO_2 emissions. They are therefore a centre of focus of Energy Strategy 2050. Specific reduction targets have been formulated in both the Swiss Engineers and Architects Association's «Energy Efficiency Path for Buildings» and the «Accounting Model for the 2,000-Watt Society» for individual buildings as well as entire districts.

In order to meet the respective targets, and thus the CO_2 reduction criteria of the Paris Climate Agreement, it will be necessary to drastically increase the current renovation rate of around 1 %. Enhancing energy efficiency through renovation is another major factor for attaining the declared targets.

Research priorities, 2021–2024

Sites and districts

- Further development of existing sustainability strategies such as «2,000-Watt Sites» and «Smart Cities and Communities» in the direction of climate neutrality; demonstration of these approaches;
- Optimised interaction of production of electricity, heat and refrigeration from local renewable energy sources, including recovery, short-term and seasonal storage, distribution in site networks and demand-driven consumption in buildings while taking account of network requirements;
- Buildings and sites as energy providers: load and production flexibility at what cost? Role of innovative IT and communications concepts;
- Concepts for adapting buildings, sites and cities to render them more resilient with respect to the global climate development and the increased prevalence of microclimates in urban centres in the future (e.g. heat island effect).

Buildings

- Pragmatic approach to renovation: identification and utilisation of the most effective actions in terms of energy demand and efficiency, taking account of the overall life cycle;
- Non-technological measures and concepts for the long-term reduction of the energy consumption of old buildings in towns and cities;
- BIM[5] in life cycle assessment: role of BIM in life cycle assessment and energy optimisation (e.g. through BIM-based facility management);
- Potentials and fields of action in the construction process to facilitate and accelerate the implementation of new technologies and concepts: grey energy, minimisation of material flows, use of energy, material and building data at the planning and operation stages;
- Building shell issues: conflict between living area, greenery, solar facility and re-cooling; development of innovative systems, new technologies and materials for opaque and transparent building shells, thermal insulation and energy storage – environmentally compatible, affordable and space-saving;
- Importance of cooling in view of the future climate: impact on energy demand, concepts and technologies for cost-effective, energy-efficient and resource-saving passive or active room cooling;
- Building automation, monitoring and system optimisation: low-cost reliable systems for networked operation, assessment of energy consumption (planned versus actual consumption), extrapolation of recommendations; options and impacts of self-regulating systems;
- Heating systems with low CO_2 emissions and low electricity consumption in the winter, including in renovated buildings.

Consumers, market, policy

- Focus on users: creation of awareness of personal energy consumption through feedback systems; incentive systems for sufficiency;
- Users' needs in terms of acceptance of building automation solutions – influence of privacy and security, flexibility of use, user interfaces.

5 BIM: building information modelling

3.1.5 Industrial Processes

Background information and issues

Industrial processes account for almost 20 % of Switzerland's overall energy consumption – more than half of which is used for process heat.

Efficiency measures are a key factor for reducing the energy consumption of industrial processes. Here, energy efficiency should not be regarded as an isolated factor, but rather viewed in a broader context of resource efficiency and emission minimisation throughout all product life-cycles. Process-specific requirements in terms of temperature levels and availability pose challenges to the integration of renewable energy.

The exchange of energy and material flows within processes and locations through to regional networks facilitates efficiency increases and greater flexibility with respect to energy management. Innovative processes for converting thermal or electrical energy into materials and chemical energy sources are a decisive factor for efficient sector coupling. Progressive digitisation opens up new opportunities for optimisation and intelligent coupling at all system levels.

Thus industrial processes can simultaneously function in the energy system as consumers and producers, as well as providers of network stabilising services. Technological progress and innovative business models will be required in order to ensure that these roles can be played sustainably, both for individual processes and for the overall system.

Research priorities, 2021–2024

Exemplary issues are listed below for each priority.

Resource-efficient value chains

- Integration of predictive ecological balance concepts into product and process design methods;
- Minimisation of energy consumption when closing product and material cycles;
- Systematic approaches to energy-conscious retrofitting of processing plants.

Innovative process technologies

- Innovative methods of process intensification (micro-reactors, catalysis, hybrid processes, etc.);
- Bioprocesses with low energy requirement;
- Resource-efficient, additive manufacturing processes for streamlining supply chains;
- Digitisation concepts for measuring, regulating and optimising networked dynamic processes.

Integration of renewable energy sources

- Processes for refining complex biomass as a raw material for substances, combustibles and fuels;
- Electrification of processes for use of decentralised electricity production.

Integrated processes and networked systems

- Greater flexibility of energy consumption of processes;
- Optimisation methods for the development and operation of complex process networks;
- Integration of industrial facilities into multi-energy systems with fluctuating energy sources.

Technologies for the energy system of the future

- Efficient systems for the recovery, networking and storage of chemical, thermal and electrical energy;
- Innovative processes for the efficient conversion of electricity surpluses (power-to-X);
- Sustainable production, re-use and disposal of batteries, fuel cells, etc.

Economic and regulatory issues

- New business models and management systems in highly interconnected systems;
- Financial and regulatory incentive systems for energy efficiency measures;
- Risks and opportunities of decentralised production versus economies of scale.

3.1.6 Mobility

Background information and issues

Mobility (road and rail transport, shipping and aviation) accounts for around one-third of Switzerland's end energy consumption and half its CO_2 emissions. As a result of demographic developments and changing mobility behaviour, the demand for mobility will continue to increase in the future. In order to achieve Switzerland's declared climate and energy policy targets, suitable options will have to be provided that meet society's future mobility requirements and simultaneously minimise the associated ecological and economic impacts. Comprehensive research efforts will be necessary in order to provide corresponding technologies and solutions.

As before, thanks to multiplication effects across all forms of transport, substantial energy savings and emission reductions can be achieved through technological innovation at the components, subsystems and vehicle levels. On the one hand, this optimisation potential is subject to limits of a technological and practical nature, while on the other hand mobility is in the throes of a fundamental transformation: the new opportunities presented by digitisation are giving rise to increased sector coupling and fundamentally new mobility concepts.

In order to take account of this development, the perspective of mobility will have to be broadened and focused on the challenges at the overall system level. This means that research will have to more intensively address topics in which mobility is regarded as a unified and interconnected system with interactions with other sectors. On the demand side, there is substantial energy efficiency potential that can be more effectively utilised, for example by providing adequate mobility services and optimally coordinating user behaviour with these services. Thus energy research will also have to focus more strongly on the social, economic and humanities-related aspects of mobility.

Research priorities, 2021–2024

New mobility concepts

- Alternative drive systems in heavy goods transport and other innovative goods transport solutions, new concepts for urban logistics
- Integrated multimodal transport systems including micromobility for the last mile;
- Integration of electromobility into a holistic energy system, use of the vehicle battery to support the grid and system, vehicle-to-grid (V2G) solutions;
- Technological and economic challenges in the fields of production, distribution and use of synthetic and biogenic fuels in the mobility sector;

Fundamentals, analyses and perspectives of the mobility system

- Life cycle analyses of existing and future mobility systems, at the drive system, vehicle type and overall system levels;
- Influence of new drive systems and fuels (synthetic and biogenic) on the electricity and gas networks, and on the overall energy consumption and emissions into the environment;
- Scenarios for changes in mobility behaviour due to societal change, new business models, crises and changed political framework conditions;
- Questions relating to the collection, availability, security, use and ownership of mobility-relevant data.

Technological optimisation of vehicles and drives

- Optimisation of the energy management of vehicles, in particular with support from geoinformation systems, big data and artificial intelligence;
- Optimisation of the drive train and auxiliary units;
- Increase in efficiency through optimisation of aerodynamics and vehicle weight.

3.1.7 Grids

Background information and issues

Here the challenge concerns the integration of production, conversion, storage and application technologies to form an efficient overall system that can be operated on an interoperable basis, as well as safely and reliably.

To be able to safely operate the local distribution networks with the inclusion of large quantities of renewable energy, new concepts and technologies will be required for influencing the power flows in a targeted manner within the various network levels, and for securing coordination between the latter. Furthermore, either singly or bundled as flexibility options, these technologies can help balance the overall system while taking account of market considerations.

Increasing digitisation and new sensor technologies are opening up additional opportunities for safe network operation, for example monitoring (network transparency), control and adjustment of network components, safety concepts and sustainable maintenance.

Here, research support is focused on technological issues, primarily in the field of electricity networks and systems, as well as on the integration of, and interaction with, other energy sources (sector coupling). Thus research findings, above all at the components level, from other fields (e.g. electricity technologies, batteries, hydrogen, heat storage units, and non-technological research) are increasingly being taken into account.

Research priorities, 2021–2024

Flexibility

- Quantification and evaluation of flexibility on the supply (production, networks, storage, consumers) and demand (energy, chronological, spatial) sides;
- Provision of system services via distribution networks (aggregated resources);
- Utilisation of industrial flexibilities;
- Integration of renewable energy sources, storage systems and e-mobility;
- Fundamentals for standards and interoperability.

Network operation

- New distributed sensor systems; related methods for enhancing network transparency and concepts for safety and error detection;
- Dynamic phenomena;
- Subsidiarity (central vs. decentral control systems);
- Risk-based and resilient operation (e.g. through automation of processes).

Digitisation

- Data management (big data, Internet of Things);
- Methods for suitable anonymization of data for various application purposes;
- Use of artificial intelligence in planning, operation and maintenance (asset management);
- Interoperability of software (e.g. protocols) and hardware (e.g. smart meters);
- Energy-specific aspects of data security (cyber security); protection of critical infrastructure.

Energy systems

- Importance and interaction of various types of network infrastructure (electricity, heat, gas, etc.);
- Architecture and integration of various network infrastructure components (sector coupling);
- Risk-based auxiliary tools for planning resilient networks and systems, taking account of uncertainties (nature, technology, politics, society).

3.1.8 Combustion Based Energy Systems

Background information and issues

In Switzerland, combustion processes account for 70 % of useful energy production. The targeted decarbonation calls for the substitution of fossil energy carriers as well as numerous improvements and changes in combustion-based energy systems. These should use the exergy of the utilised chemical energy carrier as efficiently as possible. The objectives are to increase the overall efficiency, enhance the flexibility of use and reduce pollutant emissions. This applies to the use of fossil energy carriers as well as combustibles produced from biomass, waste or synthetic (e.g. electro) fuels. Which types of combustibles will prevail for which uses in the future is not yet foreseeable. Close collaboration between developers of combustibles and combustion researchers is therefore essential.

Combustion engines in cars will be increasingly supplemented by electric motors (hybrid vehicles) or fully substituted (electric vehicles). However, goods transport by road, water and air will continue to largely rely on the use of chemical energy carriers, and the same applies to construction and agricultural machinery. Furthermore, systems for electricity production such as gas turbines and combined heat and power plants will be used, which can efficiently and flexibly contribute towards a secure electricity supply, especially during the winter.

Research priorities, 2021–2024

Combustion technology

- Greater understanding of the complex processes and influencing factors in combustion, especially with respect to new fuels;
- Accurate simulation models for these processes, with validation in trial vehicles;
- Improved combustion methods in order to eliminate unburned fractions of gaseous combustibles;
- Further development of diesel combustion processes in order to reduce the internal formation of pollutants in the engine.

Variability of combustibles

- Development and optimisation of combustion systems for combustibles such as hydrogen, methane, methanol, HVO,[6] DME,[7] OME,[8] which can be obtained from renewable energy sources;
- Dual-fuel systems for utilising gaseous and liquid combustibles in variable fractions;
- Multi-fuel systems for utilising combustibles of variable composition and quality;
- Highly efficient systems for low calorific combustibles or combustibles obtained from chemical precursors.

Optimisation of the overall system

- Highly flexible systems for rapid on/off cycles and high partial-load efficiency with low emission levels;
- Increased efficiency of the overall system, for example through the use of exhaust energy for additive exergetic or chemical processes;
- Reduction of pollutant emissions by optimally aligning internal engine measures and exhaust aftertreatment.

Flexible electricity production

- Further development of gas turbines for the use of hydrogen and other combustibles obtained from renewable energy sources;
- Combustion and turbine technologies for load variability at high efficiency levels;
- Combined heat and power systems as a binding sector-coupling element for flexible use and for the utilisation of various combustibles.

Life-cycle analyses

- Identification of the ecologically and economically best technology paths for various combustibles, combustion systems and applications.

6 HVO: hydrotreated vegetable oils
7 DME: dimethyl ethers
8 OME: polyoxymethylene dimethyl ethers

3.1.9 Heat Pumps and Refrigeration

Background information and issues

Thermal energy flows at low to medium temperatures (20° to 150° C) are required in many areas of application, and these are often generated with exergetically high-grade energy carriers in furnaces or electric boilers. By contrast, heat pumps can raise heat flows to the desired temperatures with the use of low-level exergy. There are many available suitable heat sources, for example in the air, beneath the ground, in surface bodies of water or in the form of waste heat from commercial or industrial processes. If a heat pump is operated with electricity from a renewable energy source, decarbonation can be achieved very efficiently in the heating sector.

In small residential buildings, the use of heat pumps for providing room heating and hot water is rapidly increasing. For the technically suitable and economically acceptable use of heat pumps in larger buildings, additional improvements are required, and the same applies with respect to their use in district heating systems and in industries where very specific requirements have to be met. There is a great need for improvements with regard to cooling applications. The integration of heat pumps or cooling appliances into the energy system opens up potential and supplementary uses, for example for coupling the electricity and heating sectors or in energy hubs.

Heat pumps can already achieve 50 % of the theoretical flow efficiency today, but in practice they are often operated well below this level. For this reason, the integration and operation of these systems need to be improved and attuned to the building system and user behaviour. Digitisation opens up new opportunities for optimising their operation as well as for integrating photovoltaic and storage systems. The shift from standard refrigerants with high greenhouse gas potential to climate-friendly alternatives is another challenge.

Research priorities, 2021–2024

Unless explicitly stated to the contrary, the following priorities also apply analogously to refrigeration technology.

Improvement of technology

- Greater flow efficiency through the use of improved compressors and components;
- Improved adaptive output control;
- Micro heat pumps for decentralised or mobile applications;
- Increased range of uses, including higher temperatures for industrial applications, various temperature increases in thermal networks;
- Further development of sorption technology;
- Monitoring of non-conventional heat pump technologies.

Special applications

- Heat pumps for e-mobility at low temperatures;
- Heat pumps for end-user equipment.

Climate-neutral refrigerants

- Heat pumps with climate-neutral refrigerants and their efficient system integration.

Integration into application systems

- Efficient and flexible combination of heat pumps with solar energy and storage;
- Flexible provision of heat and refrigeration for large buildings and urban areas;
- Heat pump control mechanism in the building control system;
- Integration of renewable energy sources (photovoltaics, solar heat, waste and ambient heat) into commercial and industrial systems.

Integration into the energy system

- Concepts for reversible heat/refrigeration and electricity production;
- Heat pumps and cooling systems in thermal networks and energy hubs;
- Maintenance of the efficiency of heat pumps and cooling systems in swarm networks for flexibility services in the electricity network.

3.2 Renewable Energy

3.2.1 Bioenergy

Background information and issues

Bioenergy in the form of electricity, heat and fuel can be produced from biomass. Which biomass fractions should be used in the future in conjunction with which technologies to obtain which end products in order to make a substantial contribution towards Switzerland's energy system and at the same time achieve a higher degree of efficiency? A system-based concept is gaining in importance, e.g. in the context of energy storage issues or bio-economic criteria. Here, interactions with other energy technologies (e.g. in terms of manageability, flexibility, storage) have to be taken into consideration, as well as increasing cascade-like use and the recycling economy.

As before, in addition to the incorporation of bioenergy systems into the overall energy system, technological development and the optimisation of existing technologies remain essential in order to make more efficient conversion processes available for the market. With regard to all innovative concepts for the efficient and ecologically viable conversion of biomass into energy and its direct or indirect use for reducing emissions of climate-damaging substances, it will be necessary to demonstrate the technological feasibility and economic viability, not only in the laboratory, but also in the form of pilot and/or demonstration projects. In addition, market barriers will have to be eliminated and their causes identified.

Research priorities, 2021–2024

Biomass as substrate

- Biomass procurement and logistics: how can the existing potentials be mobilised? Are there any innovative logistics concepts?
- New biomass substrates: are there any biomass fractions that have not yet been considered?
- Biogenic waste: suitable recycling of substances and the biogenic fraction in waste for energy purposes.

Biomass for supply of electricity and heat, and as a fuel

- Process heat: what contribution can bioenergy make towards the supply of process heat in industry? What are the existing technological challenges?
- Integration of combined heat and power plants with biogenic energy carriers into the overall energy system (flexibility, availability, emissions);
- District heat networks: optimal design configuration with the integration of other energy production systems (e.g. solar heat, geothermal energy);
- Small-scale processing of biogas for decentralised utilisation concepts;
- Biofuels as drop-in fuels to minimise the impacts on the refinery process and distribution infrastructure.

Biomass in the bio-economy

- Combination of material cycles across various sectors in order to generate material and energy-related value-added and to close material cycles;
- Higher value-added of bioenergy plants (new concepts, products and distribution channels);
- Use of residual substances from industrial production for material-related, energy and reprocessing purposes (fermentation residue, whey, CO_2, etc.);
- Energy-related aspects during the production of bio-based platform chemicals (efficiency, energy optimisation, integration, ecological balance, etc.);
- Biomass as a resource for material and energy-related recycling in the industry sector (bio-refinery);
- Higher value-added through new areas of use for waste products that result from the provision of bioenergy or in other industry sectors (e.g. protein-rich fractions of animal by-products or lignin for bioplastics production);
- Bioenergy and carbon capture and utilisation: which options are feasible in Switzerland? Bioenergy and carbon capture and utilisation as precursors for bioenergy with carbon capture and storage.

3.2.2 Geothermal Energy

Background information and issues

Inexhaustible domestic resources, low associated greenhouse gas emissions and reliable availability round the clock make geothermal energy an attractive source. This applies both to electricity production as well as to the supply of heat and refrigeration through the direct utilisation of geothermal energy, which is distributed via heat networks, or through its indirect utilisation with the aid of heat pumps. The use of geothermal reservoirs as energy storage systems is also an important option. Geothermal energy will play an ever more important role in the heat market of the future. According to studies conducted by the Paul Scherrer Institute, the technically realisable potentials are in the TWh range. The challenges associated with research in this field are diverse, and concern aspects such as the characterisation and exploitation of the underground, the integration of geothermal energy into regional energy systems, the long-term utilisation of the underground and the problem of public acceptance.

Research priorities, 2021–2024

Electricity production and use in combined heat and power plants

- New prospecting methods in order to increase the probability of success of exploratory drilling operations;
- Improved modelling methods in order to reduce uncertainties associated with the discovery and exploitation of reservoirs;
- Development of new deep drilling and exploitation methods in order to reduce technical production costs;
- Utilisation of CO_2 as a heat exchanger medium in geothermal reservoirs for electricity production;
- New methods for monitoring and analysing induced seismic activity and minimising the associated risks;
- Safety research with regard to the combined presence of hot water and hydrocarbons beneath the ground;
- Sustainable strategies for the utilisation of the deep underground;
- Detailed studies in order to identify and manage risks, as well as to develop risk management strategies and gain public acceptance for geothermal energy.

Heat production through direct utilisation

- New prospecting methods in order to increase the probability of success of exploratory drilling operations;
- Demonstration of new methods for planning and implementing heat storage systems;
- Development of the smart grid concept in the context of thermal networks, focusing on variable demand and supply and the options for contributions to sector coupling;
- Management of technical and operational risks associated with chemical precipitates, as well as potential environmental risks and risks associated with the long-term behaviour of heat storage systems;
- Acceptance issues relating to direct utilisation.

Production of heat and refrigeration through indirect utilisation

- Preparation of principles of good practice that foster the establishment of geo-structures and other concepts for the utilisation of near-surface geothermal energy;
- Long-term development of the underground (in particular, underground temperature in urban areas);
- Sustainable and optimised concepts for the use of the underground, taking account of the various stakeholders and their interests;
- Life-cycle analyses and environmental impacts of decommissioned geothermal probes.

3.2.3 Photovoltaics

Background information and issues

In comparison with various options for the provision of renewable energy, photovoltaics has a great deal of expansion potential with low production costs. This technology will thus play a decisive role in the energy supply, both globally and at the national level. In various areas of photovoltaics, Swiss researchers and industry players are among the international leaders.

The main challenges in the field of photovoltaics are as follows: (1) to continue to reduce costs via the entire value chain, by bringing about further increases in the efficiency of the individual components and through the industrial implementation of new products and manufacturing processes; and (2) to improve quality assurance and increase the reliability of photovoltaic installations. The utilisable potential of solar power systems on Swiss buildings is around 67 TWh per annum (110 % of the national electricity consumption). In view of this, new solutions for optimal integration of photovoltaics in buildings and in the electricity distribution network are of central importance. Issues relating to sustainability (reduction of the use of energy and materials in production or recycling) are also of great importance.

The Photovoltaics research programme coordinates the support of projects that focus on research which could provide potential solutions for all the associated topics.

Research priorities, 2021–2024

Cell technologies

- Further development of crystalline silicon solar cells: heterojunction technology, advanced passive emitter rear contact (IBC)[9]
- CIGS (copper indium gallium selenium) thin film solar cells (flexible substrate);
- Tandem concepts for high-efficiency cells;
- Manufacturing issues (e.g. intercell connections).

Module and inverter technologies

- Building integrated photovoltaics: colour, form, surface structure, bifaciality, etc.;
- Concentrating modules;
- Manufacturing issues (e.g. lamination, lightweight construction);
- New inverter technologies.

Quality assurance and performance

- Characterisation and testing of modules;
- Long-term testing of modules and systems;
- Testing of inverters;
- Soiling issues;
- Installation concepts.

Monitoring and sustainability

- New concepts for prediction (e.g. big data analysis, artificial neuronal networks);
- Life-cycle analysis.

Network integration and systemic aspects (storage)

- Decentralised storage systems and storage management;
- Improved network integration concepts;
- Photovoltaics and mobility;
- Seasonal optimisation (winter power supply).

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9 IBC: interdigitated back contact

3.2.4 Solar Energy at High Temperature

Background information and issues

Concentrating solar thermal systems convert direct solar radiation into high temperature heat for the production of electricity or for triggering chemical reactions. Here the solar radiation is focused with the aid of mirrors onto a heat receiver located at the focal point or in the focal line, where the energy is then either transferred to a heat medium or utilised directly. The electricity production costs of solar thermal power plants (STE[10]) are higher than those for photovoltaic systems. Nonetheless, this technology gives rise to benefits in terms of integration into the energy system thanks to thermal storage, which to some extent permits base load production.

One of the priority activities supported by the SFOE is solar thermal chemistry (the process of producing hydrogen and synthesis gas – solar fuels). Here the focus is primarily on practical implementation in large output ranges. Another of the SFOE's priorities concerns the development of innovative elements for solar thermal electricity and process heat production: receiver systems with new thermal fluids, new high temperature storage systems, active reflector cleaning systems, combination of concentrated solar energy and process heat.

Because in Switzerland there is no potential for the use of this technology (with the exception of solar process heat), the research concerns the development of innovative solutions for exportable technologies. Another priority concerns the use of systems for generating process heat in Switzerland based on various pilot facilities with scientific support. Here, detailed studies are being carried out. The objective is to obtain fundamental data regarding both the technological and the economic potential of systems of this type in Switzerland.

Research priorities, 2021–2024

Thermal chemistry and solar fuels

- Development of new reactors;
- Gas-absorbing and volumetric receivers;
- Hybrid systems;
- High-temperature storage;
- High-concentration photovoltaics for fuels.

Concentrating solar power and solar thermal electricity

- Development of new receivers;
- High-temperature storage;
- Soiling;
- Solar resource evaluation and forecast.

Solar process heat

- Long-term monitoring and performance analysis of existing (pilot) facilities in Switzerland;
- High-temperature process heat;
- New system integration (storage) concepts.

10 STE = solar thermal electricity

3.2.5 Solar Heat and Heat Storage

Background information and issues

On average, heat accounts for more than 75 % of energy consumption in private households. In the industry sector, too, demand for heat is very high, for example for room heating, provision of hot water and industrial processes. The aim of the solar heat and heat storage research programme is to support the development of pioneering solutions for securing the efficient use of solar heat. This includes the provision of heat via solar thermal components as well as the storage of the produced heat, which is an important factor for the development and integration of systems into renewable supply systems. The programme focuses on technologies for the heating and cooling of buildings, sites and districts.

Research priorities, 2021–2024

Solar thermal collectors

- In order for thermal and PV/T collectors[11] to make a relevant contribution towards the objectives of Energy Strategy 2050, they will need to be simple to install and safe to operate, as well as reliable and efficient;
- Innovative solutions for preventing heat stagnation need to be further developed and demonstrated;
- With the increasing size of collector fields (for example for apartment houses and for integration into heat networks) it will be necessary to develop effective and affordable function control mechanisms that make use of the new opportunities presented by digitization.

Heat storage

- The exergetic quality of water-based (layered) heat storage systems needs to be maximised, the heat exchangers of ice storage systems have to be improved and technical solutions for higher-density thermal storage systems need to be demonstrated;
- A variety of solutions are being studied in order to further reduce heat losses and the costs of thermal storage systems, for example by improving the technology and lowering the costs of vacuum and other heat insulation concepts;
- The integration of local heat storage systems into the energy system is to be studied; here the focus is on the further development of seasonal heat storage systems;
- In the field of thermochemical storage the main focus is on the technical and economic optimisation of system integration and utilisation.

Systems

- The aim here is to improve system concepts in order to reduce the costs of solar energy. Systems need to be designed so that they offer efficient solutions for attaining the specified targets of various building standards (model provisions of the cantons in the area of energy: MuKEn, Minergie standard) and planned so that they can be readily integrated at low cost;
- Aspects of particular interest to researchers include drain back concepts, optimised combinations of photovoltaic-thermal collectors and heat pumps, and the integration of solar thermal energy into (intelligent) anergy or heat networks with short- and long-term heat storage;
- Smart solar/solar thermal systems with large collector fields are being integrated into energy management systems to an increasing extent and equipped with function monitoring and automated error reporting systems, as well as new value-enhancing features such as own consumption management in photovoltaic-thermal systems.

Planning tools

- Here, the SFOE supports research on concepts that give rise to automatic optimisation, for example through the integration of solar radiation forecasts and/or learning algorithms.

[11] PV/T: photovoltaic-thermal

3.2.6 Dam safety

Background information and issues

The aim of the Dam Safety research programme is to improve the fundamentals for ensuring the safety of water retaining facilities (dams and reservoirs). Here the main focus is on the stability of the retaining structures (dam walls, dams, river weirs). The programme also focuses on the stability of ground slopes in the vicinity of reservoirs, as well as on auxiliary installations such as relief and discharge systems (overflows, bottom and middle outlets).

The research priorities are based on the requirements of the SFOE as the supervisory authority responsible for the safety of water retaining facilities in Switzerland. Currently the three research priorities are extreme natural disasters, ageing processes and monitoring methods.

Research priorities, 2021–2024

Extreme natural disasters

The aim here is to permit more effective assessments to be made of the impacts of floods and earthquakes on water retaining facilities, as well as to facilitate a more accurate understanding of the behaviour of water retaining facilities under these extreme circumstances. The objectives include:

- The formulation of basic principles for incorporating the latest findings and data relating to the estimation of extreme flood events into the safety assessments of water retaining facilities;
- Development of methods for assessing the behaviour of sliding slopes in the vicinity of water retaining facilities in the event of a seismic incident;
- Preparation of procedures for assessing the behaviour of surfaces sealed with asphalt concrete in the event of a seismic incident.

Ageing processes

Here the aim is to gain a better understanding of the ageing processes (for example, alkaline aggregate reaction) to which dams are subjected. In this context, procedures for assessing the impacts of ageing processes, as well as for evaluating potential countermeasures, are to be further developed. The objectives here include:

- Creation of the prerequisites for identifying comprehensive measurement series that describe the ageing processes of selected dams and can be applied as the dataset for the development of models for predicting these processes.

Monitoring methods

Here the focus is on developing and applying new methods for the more efficient monitoring of dams and reservoirs, as well as on improving analytical methods for interpreting recorded observations. The objectives here include:

- Implementation of pilot applications for detecting deformations of dam wall surfaces in order to determine the suitability and potential application of such measurement methods for monitoring water retaining facilities.

3.2.7 Hydropower

Background information and issues

The expectations placed on hydropower are on the one hand for it to make a greater contribution towards electricity production in Switzerland, and on the other to improve the ecological situation with respect to residual water, fish migration and bed load transport. These aspects contradict one another by their nature. At the same time, hydropower has to be adapted to the changed hydrological conditions and other impacts of climate change.

For the hydropower industry, in particular storage power plants, the restructuring of the electricity supply is giving rise to greater challenges in terms of flexibility and energy storage, which in turn is in contradiction to the need to reduce the effects of turbine-related surges (hydro-peaking). But the existence of potential technological solutions alone does not necessary lead to success. The extremely low electricity prices on the European market in recent years and the limited acceptance for new hydropower projects are hampering the implementation of existing technological concepts. Due to the extremely lengthy lead times prior to the start up of new or enlarged hydropower plants it would be necessary to already initiate their implementation today in order to meet the objectives of Energy Strategy 2050. This means that the necessary framework conditions have to be created in order to facilitate investment decisions.

The general objective of the programme is to achieve the maximum possible utilisation of Switzerland's hydropower potential in consideration of all significant aspects. The programme can support all forms of hydropower use. Generally speaking, its preference is to support facilities in which major potentials can be exploited or further utilised, or it is possible to improve the economical operation of the plant or the ecological conditions of the body of water.

The priority areas of research listed below cannot be unequivocally allocated to large or small hydropower plants. With respect to many aspects, the installed capacity is of secondary importance. Aspects that are not explicitly listed can in principle also be supported as long as they are in line with the general objectives.

Research priorities, 2021–2024

- Adaptation to the impacts of climate change (glacier retreat, increasing sedimentation, extreme meteorological events, etc.);
- Options for transferring production from summer to winter and for increasing production during the winter;
- Measures to increase the degree of operational flexibility;
- Adaptation of components and measures (operation, monitoring) to highly flexible operating methods;
- Options for provision of system and network services;
- Identification of as yet unexploited hydropower potentials;
- Improved forecasting models for increasing production levels and economic viability;
- Improvement of the ecological condition of bodies of water (including fish migration, problem of hydro-peaking, sediment management, residual water management);
- Development of decision-making instruments for granting new operating licences and enlarging existing facilities;
- More effective marketing strategies (for example, through integration into own consumption collectives or in combination with e-mobility);
- Low-cost standard technologies.

3.2.8 Hydrogen

Background information and issues

The use of hydrogen in the energy system facilitates flexibility in that renewable energy (electricity) can be coupled into other sectors (sector coupling and power-to-gas). This is an especially attractive option in situations in which the direct use of electricity is not possible, for example in electric heavy vehicles. The long-term storage capacity of hydrogen is especially beneficial in terms of seasonal compensation when very high proportions of renewable energy are utilised, as well as to a certain extent in the context of network services. The use of renewable hydrogen as a chemical raw material in industry can also make a significant contribution towards the reduction of greenhouse gas emissions in this sector. The level of industrial consumption of hydrogen in Switzerland is around 13 thousand tonnes per annum, more than 90 % of which originates from fossil sources.

The main drawback in comparison with the direct use of renewable electricity concerns higher conversion losses during the production and use of hydrogen. The utilisation of hydrogen for energy purposes is being expedited through its application in the mobility sector (fuel cell powered vehicles). However, the operation of these vehicles calls for the availability of a specific hydrogen infrastructure, which in view of the low number of such vehicles is relatively cost-intensive («chicken-and-egg» situation). But it is possible to significantly reduce these costs through economies of scale.

The main focus of the SFOE's co-funded activities is on material-oriented basic research, system development and demonstration and testing in the framework of pilot projects.

Research priorities, 2021–2024

Production of solar hydrogen

- Photo-catalysis;
- Production of solar thermal hydrogen/syngas.

Electrolysis

- Transport losses in PEM electrolysis cells;
- Degradation and durability in PEM electrolysis cells;
- Analysis and characterisation;
- Solid oxide electrolysis cells.

Bio hydrogen

Hydrogen storage

System aspects

- Hydrogen refuelling and safety;
- Distribution of hydrogen;
- Power-to-gas.

3.2.9 Wind Energy

Background information and issues

The bulk of wind power production is based on a relatively well-developed technology involving the use of horizontal axis turbines. The long-term target specified in Energy Strategy 2050 for the expansion of wind energy is around 4 TWh. This figure already takes account of conservation areas. In order to reach this target and improve the economic viability of wind energy projects it will be necessary to obtain more detailed findings regarding the elimination of specific obstacles. Because of its particular environment, Switzerland cannot always apply international findings relating to wind energy. The focus of the support provided by the Wind Energy research programme is above all on technological research that helps close Switzerland's knowledge gaps. Accompanying research at the interface between wind power and other disciplines such as ornithology and noise research is only to be initiated in cooperation with other involved federal authorities and with their financial support.

Wind energy is a well-developed technology, but relevant research issues still exist because it is positioned at the interface between several other sciences (aerodynamics, materials, acoustics, and digitisation). According to an estimate by the National Renewable Energy Laboratory, wind energy research could contribute towards a reduction of the costs of this energy source by around 50 % by 2030.

In Switzerland, optimising the yield per facility and the park layout is of particular importance in order to further increase the degree of economic viability, as well as to optimally utilise the limited number of suitable sites. Practically all the suitable sites in Switzerland are located in the (low) mountain ranges, and this gives rise to a variety of technological challenges due to the higher turbulence intensity and the harsh climate. Thanks to innovative optimisation, the aim is to pave the way for identifying potential new sites or making better use of existing locations.

The programme is essentially focusing on the further development in Switzerland of the use of the existing technology with wind power plants in the megawatt range. In view of the limited market volume throughout the world and the fact that the residential areas in Switzerland generally have inadequate wind conditions, developing new concepts is of secondary importance. Research on small wind energy plants is excluded from the programme due to budget restraints.

Research priorities, 2021–2024

Optimisation of wind parks

- Development of data-related methods for the planning, layout and operation of wind parks;
- Development and validation of control strategies for optimising overall performance (for example, new forecasting options such as micro-meteorology).

Alternative wind energy technologies (over 1 MW)

Optimisation of turbines

- Optimisation of components, especially for the use of wind energy in complex terrain;
- Development and validation of components for use in cold climates and for accurate forecasting of ice formation;

Noise abatement strategies

3.3 Research in Social Sciences and Humanities

3.3.1 Energy–Economy–Society

Background information and issues

The Energy–Economy–Society research programme focuses on application-based energy policy research, i.e. economic, sociological, psychological and political issues across the entire energy value chain. The aim of the programme is to support the development of the scientific principles for the various upcoming energy policy decisions.

The Federal Council's Energy Strategy 2050 calls for the step-by-step withdrawal from the use of nuclear energy while simultaneously meeting the declared climate objectives and maintaining the high level of supply security in Switzerland. This means that energy efficiency will have to be increased, as will energy production from renewable sources.

The goal of research in the areas of energy, economy and society is to gain a better understanding of the behaviour of the involved players and the functioning of the markets. Here, the relative potentials and costs of various measures are to be identified and optimised. In addition, efforts are to be made to obtain an overview of the restructuring of the energy system and gain a better understanding of the interconnections and interactions between various measures and forms of behaviour.

Within the scope of the research programme, instruments are to be identified and developed and framework conditions are to be defined that will make it possible to transform the energy system at the lowest possible cost to the economy. The SFOE is particularly interested in research in the areas of «companies and households», «markets, regulation and policy measures«, and «modelling and system-wide analyses».

Research priorities, 2021–2024

Companies and households

- Analysis of energy-relevant consumption and investment behaviour of various players, based on psychological, sociological and economic methods; formulation of recommendations for action.

Markets, regulation and policy measures

- Structure and regulation of energy markets, formulation of policy measures for a renewable, safe and efficient energy system;
- Creation of framework conditions for integrating renewable energy into the system; structure and regulation of energy markets in decentralised energy systems;
- Analysis of the interactions of energy policy measures with those in other areas, and assessment of the influence of energy and climate policy measures; Switzerland's position in international energy markets.

Modelling and system-wide analyses

- Development and improvement of models and scenarios that identify the potential future developments of the energy system – and the main drivers of these developments;
- Better understanding of the political, economic and social framework conditions of scenarios, and analysis of the economic impacts and interaction of various policy measures;
- Factors influencing the social transition; interactions between technological, social, political and individual transition.

3.3.2 Radioactive Waste

Principles of the research programme

The Federal Workgroup for Nuclear Waste Disposal commissioned the radioactive waste research programme, which describes potential independent research projects and studies relating to interdisciplinary and/or inter-authority waste disposal issues at the federal level that cannot be addressed elsewhere or for which no other body exists (repository for research issues). In this way, the workgroup is able, for example, to make proposals for studies, point to gaps in knowledge and learn from the obtained findings. The projects are financed by those authorities that participate in the interdisciplinary research. Responsibility for the implementation of each research project is borne by the management appointed by the workshop, which in turn is responsible for quality assurance and communication.

Organisation of the research programme

The Federal Workgroup for Nuclear Waste Disposal is supported by a secretariat that is administratively affiliated with the SFOE. The workgroup organises an annual research retreat to which it invites the Federal Nuclear Safety Inspectorale (FNSI). A project team comprising members of the workgroup is deployed for the implementation of each research project. All projects within the scope of this programme must have a solid scientific basis and at the same time focus on practical application. Upon completion of each research project an evaluation is carried out in order to determine whether a follow-up project relating to the involved topic is necessary and purposeful.

Research priorities, 2021–2024

Preservation of know-how and selection of deep geological repository sites

– Within the Nuclear Energy Agency (NEA), the SFOE participated in the initiative entitled «Preservation of Records, Knowledge and Memory across Generations». As of 2020, these activities will be pursued within the new «Working Party on Information, Data and Knowledge Management».

Deep geological repositories sectoral plan process

– Some important steps will be taken in the next few years in Switzerland's procedure for the selection of suitable sites for deep geological repositories. In 2022, the National Cooperative for the Disposal of Radioactive Waste (Nagra) is expected to announce the sites for which it will prepare general licence applications. In 2024, Nagra plans to submit the corresponding applications. Pending research issues relating to the areas of social sciences and humanities will be clarified within the scope of the research programme.

3.4 Pilot and Demonstration

Background information

Trialling innovations and new business models under real conditions in the form of pilot and demonstration projects as well as field studies is essential in order to transfer them from the laboratory to the market and obtain information about their feasibility, functionality, applicability or economic viability. Especially in the case of lengthy and costly technological developments in the energy sector, private investments in this decisive phase tend to be limited because they are subject to stringent performance criteria. This hampers the development of many technologies. The pilot and demonstration programme closes these gaps by providing subsidiary support and can thus facilitate investment decisions by private companies.

Target group and award process

The programme's main target group is small and medium-sized companies that are developing the energy technologies of the future in Switzerland. 68 % of the supported applicants in the period from 2013 to 2017 were companies in this category. The supported projects are not restricted to one specific topic, but rather they encompass the entire spectrum of energy technologies in that they promote the use of renewable energy, increase energy efficiency, develop storage technologies and optimise the national electricity networks. Pilot and demonstration projects are characterised by substantial innovation content and high energy and market potential. In the past few years, projects in areas such as micro-grids, production of biofuels, buildings, machines and electric vehicles have received increasing support. In these areas, the content in terms of innovation has to be considered to a greater extent in the future and the projects will have to concern fundamentally new or further developments with high application potential.

In principle, solutions or system components already available on the market are not eligible for support. For a complete and detailed overview of the applicable criteria, plus information about submitting applications and how they are evaluated, please refer to the directive[12] of the pilot and demonstration programme. Applications for financial support for projects within the scope of the programme may be submitted at any time. We recommend presenting a brief description of the project before submitting an application to the programme management. A decision concerning approval of the application and the amount of granted financial support will be made within three months after submission of the complete application.

[12] www.bfe.admin.ch/pilotdemonstration

3.5 Promotion Programme SWEET

As the federal authority responsible for Energy Strategy 2050, the SFOE is able to optimally align those topics for which a call for tenders is to be issued within the scope of SWEET to the specified energy strategy objectives, and secure the necessary coordination with the other involved public sector support bodies.

Generally speaking, SWEET's focus is based on the existing rules governing sector research.[3] While the SFOE's research programmes are intended to support individual projects across the entire spectrum of energy efficiency and use of renewable energy, SWEET exclusively supports consortia projects that are subject to competitive calls for tenders and focus on selected research topics.

SWEET covers research projects ranging from oriented basic research through to market-oriented research. Its main focus is on application-based research and demontation. Calls for tenders may be issued in the following areas:

- Energy efficiency;
- Renewable energy;
- Storage;
- Networks;
- Non-technological (for example, socio-economic or socio-psychological) research;
- Safety and security of nuclear facilities and energy infrastructure.

SWEET is a twelve-year programme. The goal is for the individual consortia projects to be carried out over a time frame of six to eight years.

Preference is given to cooperation among various types of universities and between academies, research institutions, the private sector, the public sector and semi-public enterprises (Swiss Federal Railways, Swiss Post, etc.). Thus the aim is to support inter- and transdisciplinary consortia. Special attention is paid to aspects of energy research relating to social sciences and humanities.

Private sector players are required to make a reasonable contribution towards research projects. In pre-competitive research activities, the financing of private entities is possible if their know-how is a significant factor for the success of the project. Researchers working at institutions abroad can also receive financial support by way of exception if their expertise is a significant factor for a consortia project.

Private investors are seldom involved in non-technological research and at lower technology readiness levels. As a rule, these projects rely on (in some cases, full) public sector funding. Thus SWEET is able to finance up to 100 % of the costs of research projects.

Coherent integration into the existing instruments of the SFOE (sector research, pilot and demonstration programme, SwissEnergy) is assured. The SFOE's pilot and demonstration programme in particular is closely coordinated with SWEET.

Knowledge and technology transfer (chapter 6.3) is a significant criterion for the selection of consortia projects. In view of this, preference is given to projects with a high degree of practical relevance. Thus high priority is attached to submitted applications involving the participation of business partners from the industry sector, small and medium-sized companies, the public sector (municipalities, cities) and semi-public enterprises.

SWEET also provides a separate small budget for competitive project concepts aimed at promoting the development of disruptive technologies.

4 Financing

4.1 Public Sector Expenditure

In 2018, the SFOE accounted for a share of around 9 % of public sector expenditure in the field of energy research and the development of market-oriented technologies. Figure 4 shows the trend in public expenditure for energy research in the period from 1990 to 2018. The SFOE's share of financial support fell from 23.4 % in 2000 to 9 % in 2018.

As a consequence of the 2011 Fukushima disaster, annual public sector expenditure for energy research constantly increased from 257 million Swiss francs in 2013 to 405 million in 2018. The most significant factors were the measures listed below that were adopted by the Federal Council and Parliament in the wake of Fukushima. Numbers in parentheses refer to the approved budget in million Swiss francs between 2013 and 2020 and do not correspond to the actual paid out amounts.

– Implementation of the two National Research Programmes, «Energy Turnaround» and «Management of Energy Consumption» (45);
– Contributions to research infrastructure (40), expansion of personnel capacity (20) for the ETH domain;
– Increased ceiling of the SFOE's pilot and demonstration programme (160);
– New SFOE flagship programme (80);
– Sponsored professorships at the Swiss National Science Foundation SNSF (24);
– Competitive funding for research projects at Innosuisse (65);
– Expansion of personnel capacity in eight SCCER (192);

Thus a total of 626 million Swiss francs was budgeted between 2013 and 2020.

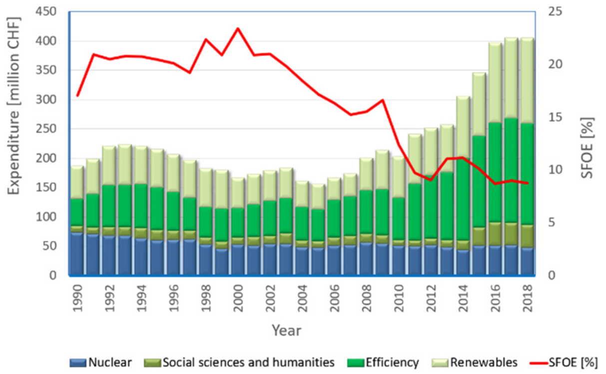

Figure 4 Trend in public sector funding for energy research (source: SFOE, excluding adjustment for inflation

Figure 5 shows the trend in SFOE funding for research and development and for pilot and demonstration projects.

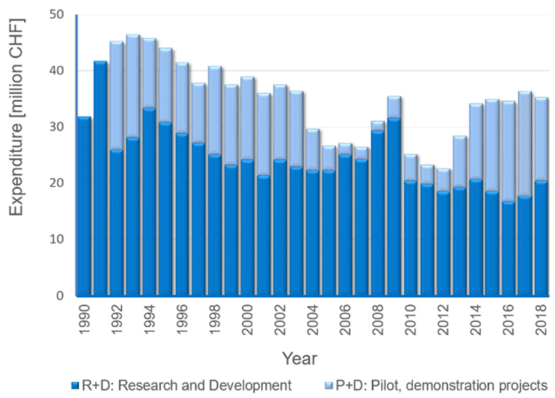

Figure 5 Trend in funding for energy research from the SFOE
(source: SFOE, excluding adjustment for inflation)

4.2 Budgeted Funding for 2021–2024

With respect to the budget planning for 2021 to 2024 the SFOE is assuming that it's funding for research and development will not be reduced versus the 2020 figure.

Table 1 shows the anticipated budgets for the period from 2021 to 2024 for SFOE research, pilot and demonstration projects and the SWEET support programme.

The indicated figures are not set amounts. Each annual budget has to be approved by Parliament.

The allocation of funding to the individual SFOE research programmes will be kept as constant as possible throughout the entire period from 2017 to 2020.

Expenditure for research projects in the areas of ERA-Net (EU) and the bilateral agreements (DACH, IPGT) will be covered by the involved research programmes. The SFOE's pilot and demonstration programme and SwissEnergy participate on a case by case basis in projects within the scope of ERA-Net calls for tenders.

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	2021	*2022*	*2023*	*2024*
Pilot and demonstration projects	28 000 000	28 000 000	28 000 000	28 000 000
Research projects				
Energy efficiency	8 038 000	8 188 600	8 255 000	8 255 000
Renewable energy	6 600 000	6 650 000	6 700 000	6 700 000
Issues relating to social sciences and humanities	1 500 000	1 500 000	1 500 000	1 500 000
Total research	16 138 000	16 338 600	16 455 000	16 455 000
SWEET promotion programme	10 000 000	10 000 000	14 000 000	14 000 000
Coordination[1]				
Research projects[1]	2 208 000	2 208 000	2 208 000	2 208 000
SWEET	1 000 000	1 000 000	1 000 000	1 000 000
Total	57 346 000	57 546 600	61 663 000	61 663 000

Table 1 Budgets anticipated by the SFOE for the period from 2021 to 2024
Basis: 2021–2024 finance plans. Budgets have to be approved by Parliament.
[1] Including expenditure for participation in the research programmes of the International Energy Agency (IEA): mandates for management duties such as operating agents, chairs, vice chairs, etc.

5 Players and interfaces

One of the SFOE's main duties is to network the national players within Switzerland and with the international research community. For this purpose, during the past ten years the SFOE has built up a broad network of contacts, which encompasses the entire higher education sector as well as private research institutions. All research projects supported by the SFOE are accompanied by the heads of the respective SFOE research programmes. This assures an intensive exchange of knowledge with the most important players in Switzerland's research community.

The SFOE represents Switzerland in all committees of the International Energy Agency (IEA) that are of relevance to energy research.

5.1 National players and interfaces

Among private sector organisations, the contacts network encompasses large companies which carry out their own research activities, for example ABB or IBM, as well as numerous innovative small and medium-sized companies such as Meyer Burger or Awtec, and various start-ups and engineering offices. In addition, cooperations exist with various partners which indicate significant multiplication potential, for example Swiss Post, Swiss Federal Railways, and electricity supply companies such as Axpo, BKW and various municipal works. Geographically speaking, the SFOE's research programmes are distributed throughout the entire country.

5.1.1 Interfaces with higher education institutions

Via its research programmes the SFOE has close ties with all research institutes at Swiss higher education institutions that carry out energy research. By attending periodical project meetings, the respective SFOE programme heads are in close contact with research project managers as well as with project partners in the areas of science and industry.

5.1.2 Interfaces with federal offices

Many fields of research are closely tied with various federal authorities, and this is especially the case with respect to energy research. Typical examples include:

- Climate issues: CO_2 emissions from combustion-based processes in the transport, buildings and industry sectors;
- Health issues: particulate matter from wood burners;
- Spatial planning: energy systems in districts and sites; planning of geoenergy or wind energy plants.

In order to utilise synergies associated with similarly oriented research projects, various federal administration units have identified cross-sector research areas (based on the federal «Sustainable Development Strategy») where the extent to which it would be possible to issue joint calls for tenders should be examined.

Here, five main areas were identified which are of high interest for several federal administration units and where there is a need for research at the federal level:

- Sustainable behaviour;
- Sharing society;
- Data security;
- Smart regions;
- Public health and environment.

In the period from 2021 to 2024, coordinated calls for tenders concerning research issues relating to «sharing society» are to be issued within the scope of a pilot project. The focus of interest here is on issues relating to policy formulation, risks and opportunities, rebound effects, data management, changes of behaviour, impacts on the consumption of resources, sustainability and business models.

Based on the findings from this pilot project, the other four cross-sector research topics are to be addressed during the 2021 to 2024 budget period by those federal administration units that have an explicit need for research in order to fulfil their duties.

5.2 International cooperation

International Energy Agency (IEA)

The IEA is a highly important body for the SFOE, which is represented in all the IEA's management committees of relevance to energy research.

The IEA's research projects are implemented within the scope of its Technology Collaboration Programmes (TCP). The SFOE participates in the majority of non-nuclear-related TCP. An up-to-date list of the participants and corresponding contacts is available on the SFOE's energy research website.[2]

European Commission and multilateral cooperation

Switzerland is not a full associate of the European Commission's «Horizon Europe» framework research programme. This means that Switzerland can only participate in the programme's project support as a third country.[13] However, it is able to participate in ERA-Net as before.

European Research Area Networks (ERA-Net)

The objective of ERA-Net is to coordinate national and regional research programmes and strengthen European research as well as certain branches of European industry. The individual networks jointly issue calls for tenders of the involved countries.

The SFOE participates in calls for tenders of relevance to energy research and provides the necessary funding for the participation of Swiss researchers.

CORNET

CORNET[14] stands for Collective Research Networking, i.e. networking of national and regional joint research programmes. Ministries and support bodies from 13 countries and regions are currently involved in CORNET, which organises two calls for tenders each year in which project consortia comprising industry and business associations and research institutions from at least two participating countries or regions may submit applications for joint projects. The award of funding is based on the existing national/regional rules. As part of its promotion mandate, the SFOE supports CORNET partners from Switzerland.

[13] Swiss researchers can continue to participate in calls for tenders, though Switzerland cannot be included in the required minimum of three countries. Researchers therefore have to secure the necessary funding themselves.

[14] www.cornet.online

«DACH» cooperation

«DACH» refers to a cooperation agreement between Germany (D), Austria (A) and Switzerland (CH). In the field of energy research it encompasses two memoranda of understanding concerning smart grids and smart cities and communities.

Cooperation takes the form of exchanges of information and knowledge, and coordination of support policy measures. The focus here is on initiating, financing and implementing specific projects. Switzerland's participation in the «DACH» cooperation programme is secured by the SFOE.

International Partnership for Geothermal Technology

Switzerland has been a member of the International Partnership for Geothermal Technology (IPGT)[15] since 2010. This is a forum comprised of representatives of government and industry from the USA, Iceland, Australia, New Zealand and Switzerland. The IPGT focuses on issues relating to the fostering of geothermal energy systems. In addition to supporting joint research, development and demonstration projects, its activities include making recommendations for multilateral cooperation in specific areas of development of geothermal energy technologies. The IPGT is thus able to make a significant contribution towards intensified cooperation between Swiss and foreign researchers, and to initiate know-how transfer from the findings of large-scale research projects.

15 http://internationalgeothermal.org

6 Scientific Support Commissions and Quality Assurance

The SFOE covers practically the entire spectrum of energy research. It does not limit its involvement to providing funding, but rather it closely accompanies individual research projects and actively represents its research programmes in national and international bodies. The necessary expertise is either available within the SFOE or is secured by external providers (mandated programme heads).

6.1 Advisory commissions

The SFOE is able to call on the support of the extraparliamentary Federal Energy Research Commission (CORE), a consulting body for strategic issues. CORE's activities include the publication every four years of its Federal Energy Research Masterplan, which functions as a planning instrument for all promotional bodies within the federal administration. It is also intended to act as an orientation aid for cantonal and municipal bodies that are mandated with the implementation of energy policy guidelines or possess their own support instruments for energy research.

The members of CORE are elected by the Federal Council and represent the leading players in Swiss energy research, including the industry sector, small and medium-sized companies, the Federal Institutes of Technology, universities of applied sciences, universities and cantons. The Federal Office for the Environment (FOEN), the State Secretariat for Education, Research and Innovation (SERI) and the Swiss Innovation Agency (Innosuisse) hold a seat in CORE in their capacity as observers alongside the SFOE. To view the complete and up-to-date list of members of CORE, please refer to the SFOE's energy research website.[2]

The SFOE is responsible for operating the CORE secretariat. As a rule, CORE holds four half-day meetings each year and organises an annual two-day retreat in the summer.

The SFOE's research programmes are supported by specialised groups on a case-by-case basis.

6.2 Quality assurance

The SFOE orients its research promotion on the federal sector research quality assurance guidelines,[16] according to which quality assurance encompasses the areas of research management, reporting and evaluation.

Within the framework of its international control system, the SFOE uses a three-stage procedure for awarding research mandates: at least two specialists examine each submitted application based on a pre-prepared project evaluation form in terms of the project's relevance, its contribution towards the SFOE's research objectives, the scientific quality of the process concerned and the expertise of the research team. Aspects relevant to financing and procurement are subjected to a review procedure within the finance department, followed by a final examination of content to be approved by management with dual signature.

[16] Quality assurance in federal sector research: Sector Research Coordination Committee; https://www.ressortforschung.admin.ch

Research management

The evaluation of applications for support for research and development projects is carried out by the respective programme heads with the inclusion of at least one additional specialist. Applications for support for pilot and demonstration projects are evaluated in specialised ad-hoc groups (with the inclusion of market-oriented specialists from the SFOE).

The SFOE employs 18 internal staff (11 full-time equivalents) and seven mandated specialists (3.5 full-time equivalents) for evaluating and supporting research projects. These specialists cover a broad range of sciences. Most of them hold university degrees and possess a great deal of experience in project management.

The SFOE also offers them the opportunity to participate in the CAS[17] Research Management[18] course (or its individual modules) at the University of Bern, as well as in other further education courses.

Reporting

All research, pilot and demonstration projects in which the SFOE is involved are filed in the publicly accessible federal database, ARAMIS.[19] A selection of pilot and demonstration projects supported by the SFOE is also depicted on the SFOE's Cleantech map.[20] The SFOE's research programmes also organise periodical specialised meetings and conferences at which the findings from research projects supported by the SFOE are presented and discussed. Each year the SFOE also publishes the figures concerning the public expenditure on energy research (www.energieforschung.ch). The SFOE has set up a knowledge and technology transfer unit for the purpose of distributing the findings from energy research (chapter 6.3).

Evaluation of energy research

On the one hand, the Federal Energy Research Commission (CORE) has the task of commenting on the SFOE's energy research. And on the other hand, it carried out external evaluations in the period from 2017 to 2020 of both the pilot and demonstration programme and sector research (in both cases, in 2018)[21].

6.3 Knowledge and Technology Transfer

The SFOE promotes knowledge and technology transfer in the area of energy with the aid of various instruments and measures. The four main focuses of its knowledge and technology transfer programme are as follows: supporting innovation projects, the catalyst effect of the SFOE, coordination and the provision of information.

Knowledge transfer from SFOE research, pilot and demonstration projects is carried out in the form of published articles[22] and information clips[23] that briefly describe the obtained findings and points of reference. These are primarily intended for the attention of companies, municipalities and cities that are able to implement new findings, and are also addressed to science journalists. The articles are formulated in a broadly comprehensible manner and are thus suitable for the general public as well as for specialists. New articles are announced via a Twitter channel[24] that is widely used by science journalists and companies.

The SFOE also promotes knowledge and technology transfer together with innovation communities and with the aid of a start-up competition. Within the framework of innovation communities, it integrates the Knowledge and Technology Transfer programme into specific thematic areas in cooperation with external

[17] CAS: Certificate of Advanced Studies
[18] www.forschungsmanagement.unibe.ch
[19] The ARAMIS information system contains details about research projects and evaluations that are being carried out or (co-)financed by the federal government. www.aramis.admin.ch
[20] www.bfe.admin.ch/geoinformation
[21] www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/evaluationen.html
[22] www.bfe.admin.ch/ct/printmedien
[23] www.bfe.admin.ch/infoclips
[24] www.twitter.com/bfecleantech

partners such as the energie-cluster.ch[25] companies and universities. In this way, new innovation projects can be initiated, best practice with respect to energy aspects can be defined and joint activities and strategies can be developed. For example, there are innovation communities in the fields of high-performance heat insulation, «plus-energy» buildings, comfort ventilation, home automation, heat storage and heat exchangers.

In order to secure coordination between its research and market-related activities and other major Swiss players in the field of energy research (the ETH domain, universities, universities of applied sciences, Innosuisse, SERI, Euresearch), the SFOE organises two meetings a year for the heads of the various research programmes.

Meetings and conferences for specialists are an important instrument for knowledge and technology transfer in the area of research programmes. For the SFOE's research programmes, some established events already exist, including combustion, heat pump and national photovoltaics conferences, a buildings status seminar and a bioenergy conference that is held annually or every two years. All of these events are addressed to scientists and specialists from the industry sector. In order to communicate the findings from the international research programmes of the IEA to Swiss researchers, the SFOE organises conferences on a regular basis relating to the IEA's Technology Collaboration Programmes (TCP). To intensify contacts between Swiss participants in the IEA's research programmes, periodical networking conferences are held at which representatives of thematically grouped TCP are invited to exchange experiences and findings.

In order to communicate the objectives of the federal government in the field of energy research to the broad research community, energy research conferences are held every four years at which the Federal Energy Research Commission (CORE) presents its Federal Energy Research Masterplan for discussion.

25 www.energie-cluster.ch

Glossary

4E	Energy Efficient End Use Equipment TCP
Action plan	Action plan for a coordinates energy research Switzerland
ARAMIS	Federal research project information system
BIM	Building Information Modeling
BioCCS	Bioenergy, Carbon Capture and Storage
BioCCU	Bioenergy, Carbon Capture and Utilisation
BIPV	Building integrated PV
CAS	Certificate of Advanced Studies
CIGS	Copper-Indium-Gallium-(Di)Selenid
CORE	Non parliamentarian federal energy research commission
CORNET	Collective Research Networking
CSP	Concentrated Solar Power
DACH	Cooperation: German (D), Austria (A), Switzerland (CH)
DME	Dimethylether
EPFL	Federal Institute of Technology Lausanne
ERA-Net	European Research Area Networks
ETH	Federal Institute of Technology
EU	European Union
FIFG	Law on promotion of research and innovation
FNSI	Federal Nuclear Safety Commission
FOEN	Federal Office for the Environment
IEA	International Energy Agency
Innosuisse	Swiss Innovation Agency
Horizon2020	Research framework programme oft he EU
HVO	Hydrotreated Vegetable Oils
IBC	Interdigitated back contact
IPGT	International Partnership for Geothermal Technology
Minergie	Swiss building standard for new and modernized buildings
MuKEn	Model regulations of the cantons in the energy sector for buildings
Nagra	National Cooperative for the Disposal of Radioactive Waste
NEA	Nuclear Energy Agency
OME	Polyoxymethylendimethylether
P+D	Pilot and Demonstration
PEFC	Polymer Electrolyte Fuel Cell
PEM	Polymer-Electrolyte-Membrane
PERC	Passivated Emitter and Rear Contact
PSI	Paul-Scherrer-Institut
PV/T	Photovoltaic–thermal
R+D	Research and Development
SERI	State Secretariat for Education, Research and Innovation
SCCER	Swiss Competence Centers for Energy Research
SET-Plan	Strategic Energy Technology Plan
SFOE	Swiss Federal Office of Energy (SFOE)
SNSF	Swiss National Science Foundation
SOFC	Solid Oxide Fuel Cell
SPC	Swiss Plasma Center
SR	Systematic compilation of federal acts
STE	Solar Thermal Electricity
SWEET	Swiss Energy research for the Energy Transition
TCP	Technology Collaboration Programme
TRL	Technology Readiness Level
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home

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