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ENERGY RESEARCH 2020+ in SWITZERLAND – RECOMMENDATIONS FOR FUTURE PROGRAMMATIC FUNDING

Position Paper of the Extended Energy Commission of the Swiss Academies of Arts and Sciences

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Executive Summary

Context:

- The Swiss energy system currently faces a number of big challenges, including climate change mitigation, security of supply, societal acceptance of risks (e.g. waste disposal, electromagnetic impacts), limitation of material resources, economic and social consequences of energy policies. To address these challenges, a large-scale transformation of the energy system is indispensable.
- Recent large-scale energy research programs in Switzerland – mainly SCCERs and NRPs – have ended or will end soon. They have established research networks and generated first outcomes of coordinated research work in specific areas of the energy system. Multidisciplinary and cross-sectoral aspects have so far only partially been a priority though and need to be intensified and expanded in the future.
- The complexity of the energy system with its numerous interactions among different sectors as well as among socioeconomic, environmental and technology aspects makes an overarching systemic and transdisciplinary research approach necessary.

Recommendations for a future energy research concept:

- Rather disciplinary, both fundamental and application-oriented research will be continued by research institutions (ETH, universities, universities of applied sciences) and funded by SNSF, Innosuisse, SFOE, etc., and hopefully also will still be funded by EU research programs as well. Thus, a national program encompassing this type of research is not necessary.
- While established successful networks should be maintained where appropriate, systemic and transdisciplinary research activities with a special focus on field studies should be heavily strengthened in a follow-up coordinated national research program.
- A pure continuation of previous research activities is not sufficient.
- Main requirements of a new longer-term oriented (between about 10 to max. 20 years) national research program include:
  - transparent evaluation criteria for project consortia: highest scientific quality, systemic view, involvement of crucial stakeholders from the beginning, strong cross-institutional collaborative component, and policy as well as implementation relevance
  - transdisciplinary approach, i.e. involvement and interaction of key disciplines (socioeconomical, behavioural, environmental, technological) and important stakeholders in every topic
  - a consideration of necessary time scales along the chain of Readiness Levels of products, technologies, practices, models, services and instruments
- Important aspects of organization:
  - regular calls on priority research areas
  - competitive element among different consortia
  - provision of flexibility to project management for reorientation according to emerging needs (given approval by the strategic board)
  - strengthening of industry/private company/public sector participation
  - explicit consideration of pilot and demonstration activities and well-orchestrated field studies
- Important aspects and instruments of governance:
  - a *Strategic Board* which defines overarching goals (in consultation with CORE, SFOE and other government offices)
  - an *Advisory/Review Board* consisting of independent national and international scientists and implementation experts/practitioners which evaluates and advises consortia, reviews progress and might advise the Strategic Board on overarching issues
  - a full-time *Program Directorate* that supports individual research consortia, prepares and facilitates an integration/synthesis process across them and cares for consistent operational procedures as well as for outreach and communication
  - a clear separation of roles between evaluation and people/institutions receiving funding
- Proposed funding volume:
  - operating contribution for supporting the two boards and program directorate, incl. management/administration/outreach at max. 1 Mio CHF /year
  - several research consortia for periods of 4 to 6 years with around 2 to 4 Mio CHF/year each
  - typically 3 to 5 consortia in parallel, i.e. a total funding volume of about 10-15 Mio CHF/year during a period of 8 to 12 years

1. The future of the Swiss and global energy System – relevance, challenges and knowledge gaps

a) Relevance

The energy system is of paramount importance for our civilization. It provides the means for energy services of all kinds (heating/cooling, mobility/transport, manufacturing, digitalisation and computing etc.) that fuel economic and social development and help to improve the quality of other societal systems like health, agriculture, etc. Customers expect availability of energy on demand at an affordable price. However, various negative effects of the contemporary energy system have become increasingly apparent, such as environmental pollution, impact on landscapes, large scale risks, societal acceptance issues and, in particular, climate change.

b) Key Challenges

A sustainable future energy system must address several big challenges:

- *Climate Change Mitigation*

  Limiting global temperature increase within 1.5°C (2°C; central aim of the Paris agreement) requires the reduction of CO_2 emissions to net zero by about 2050[1] (or shortly thereafter). Given the long lifetime of energy related assets (powerplants, buildings, vehicle fleets, other infrastructure, etc.) of several decades, the complete replacement of oil, gas and gasoline as energy source is a tremendous challenge. For Switzerland, sticking to the Paris Agreement means to eliminate essentially all domestic emissions until 2050 while at the same time phase out nuclear power plants. This will mostly involve step-change developments including the necessity of huge investments in (new) energy infrastructures.

- *Security of Supply*

  The extreme dependence of the global energy system on fossil fuels and the small number of major suppliers lead to geopolitical risks and potential price shocks. Furthermore, the strong temporal variability of renewable energy supply implicates the need of a major reorganisation of the distribution/storage system of electricity. Security of supply is therefore a key global and national challenge in the future, in particular for Switzerland, with its foreign dependence on fossil fuels and the shift from base load nuclear power to decentralized and variable renewables, which challenge the reliable operation of the electricity grid.

- *Local and regional pollution*

  Local and regional air pollution and its human health implications have been reduced considerably during the last three to four decades. However, in many regions of the world pollutant levels continue to be high; in Switzerland in particular NOx and fine particles must be further reduced in urban/congested areas.

- *Risk governance and societal acceptance of large-scale accidents/risks and waste disposal*

  Some of the low-CO_2 emitting powerplants (nuclear, hydro-dams) exhibit risks of rare but fatal accidents at large-scale, which makes careful risk governance and societal acceptance an important issue. In Switzerland, there are also widespread concerns in the population regarding the disposal of waste particularly underground, be it nuclear or in future CO_2 from carbon capture and storage.

- *Limits of material resources*

  The vision of a sustainable future energy system in Switzerland mainly relying on renewable primary energy is expected to demand large quantities of precious materials (mainly mineral resources). The amount of these materials is limited, which might lead to new types of geopolitical conflicts and yield additional negative environmental/health effects, in particular related to extraction/mining in several countries. Correspondingly, there is also an urgent need for the realization of a circular economy also from the point of view of a sustainable future energy system.

- *Efficient use of energy and sufficiency*

  To meet the Paris targets, efficiency and sufficiency measures will be needed in order to reduce the demand for energy in absolute terms, despite the anticipated growth of the economy and probably of the population in the country. Technological progress with regard to efficiency is evident, but adoption rates are slow and knowledge or methods to improve the situation are often lacking. An

[1] See IPCC special report on global warming of 1.5°C: https://www.ipcc.ch/sr15/

additional societal shift towards non-material values seems key to achieve a reduction of energy use. However, the Swiss society is still far from the implementation of corresponding politically and socially accepted pathways to this end.

- *Economic and social consequences of energy policy changes*
  A base level of energy services is very relevant for our economy and overall human well-being. The transformation of the energy system should ensure that energy for the whole population and the economy is available at a price - that does not negatively affect neither people with limited ability to pay nor the international competitiveness of export-oriented industry, despite the need to adequately account for external environmental and social costs, respectively.
- *Uncertainty and the need for adaptive instruments*
  While the complexity of the various systemic interrelations entails many uncertainties already now, social, economic and technological conditions may in addition change fast and sometimes in unexpected ways in the future. This calls for adaptive/flexible policy instruments, while striving for consistency and coherence with regard to the overarching strategic goals.

c) Urgent need for a Systems Perspective

The above considerations make evident that for a large-scale and sustainable transformation of the energy system we need to understand:

- The multi-facetted dimensions of the energy system, including the interfaces between supply and demand sectors and the complex interactions of technology with society, economy and the environment.
- The numerous impacts and trade-offs among economic, social and environmental consequences - including societal acceptance - of energy policies, technology innovations and business models along different transformation paths.
- The possibilities and needs for designing, monitoring and managing "experimenting and learning" actions, which are inevitable in such a complex and uncertain situation.

Consequently, research towards a sustainable Energy System must encompass a large variety of scientific disciplines and be orchestrated based on a **systemic** view of a dynamically evolving transformation process.

2. Coordinated energy research in Switzerland: current state, lessons learned and future needs

Significant efforts have been undertaken in the last 10-15 years to strengthen collaborative energy research in Switzerland beyond the bottom-up activities of individual research groups. A first successful implementation of interinstitutional research on energy has occurred, as for example the competence centers in the ETH domain[2]. These instruments have been phased out a few years ago in view of the creation of the SCCERs on the one hand and the NRPs 70/71 on the other.

Both the SCCERs and the NRPs 70/71 have been quite successful; in particular the SCCERs have led to a fruitful integration and strengthening of energy related research virtually across all academic institutions in the country (universities, universities of applied sciences, ETH domain) with substantial participation of industrial partners. Especially the collaboration between universities, ETH domain and universities of applied sciences has been strengthened with these instruments. Furthermore, numerous international collaborations have been established, especially in the framework of the European Research Programmes like Horizon 2020.

The main achievements in particular of the SCCERs are:

- the build-up of research capacity, creating the critical mass for innovation in larger thematic areas
- establishment of cross-institutional and interdisciplinary networks around a broad portfolio of topics
- collaboration with private companies (industry and services) and the regional and national administrations in a coordinated way

[2] Mainly the Competence Center Energy and Mobility (CCEM), which contributes to the development of a more sustainable energy system, and to a certain extent the Competence Center Environment and Sustainability (CCES) and the Competence Center Citizen Science (CC-CS)

While we can build on these achievements in a follow-up energy research program, even in the SCCERs transdisciplinary and systemic approaches were very limited and cross-sectoral collaboration marginal. Since – as argued above – the complexity of the problem makes inter- and transdisciplinary approaches indispensable, such aspects should be in the focus of a future research program. Furthermore, we should learn from other shortcomings of these instruments (like quite heavy administration load, limited flexibility for adaption to rapidly emerging needs) and fully use corresponding improvement potentials.

In summary the current situation and immediate perspectives of energy research is characterised as follows (see also appendix for current public funding situation):

- The SCCERs are funded until 2020 and the NRPs have essentially terminated around the end of 2018.
- SCCER-like activities will be continued to a certain extent by the involved institutions, but presumably in a much less coordinated manner and with far less financial and human resources.
- While the participation in EU research framework programs is important for energy research, especially with regard to activities in the private sector, the possibilities of future participation of Switzerland in these frameworks is uncertain and depends on the ongoing negotiations with the EU.
- There is and will continue to be energy-related research in the ETH domain, at universities and universities of applied sciences. This research focuses typically on specific research questions, each time in a rather narrow field. This is absolutely necessary but is expected to continue on the existing basis by the institutions themselves and funded by 'regular' instruments like SNSF, Innosuisse (incl. private sector) or SFOE.

In consequence, the following reasons underline the need for a future coordinated research program:

- A systemic and transdisciplinary view on the energy system, including practical relevance and interrelations with society and environment, is still lacking, but is absolutely necessary. Such an overarching perspective will be an important support for decision-making along the envisaged long-term transformation.
- To bring the systemic view and the transdisciplinary approach to the fore, involving all stakeholders, i.e. academics, private sector and administration, a research program, which strongly focuses on the combination of environmental, socioeconomic and technological aspects is needed.
- The Swiss energy research community needs clear signals that systemic, interdisciplinary energy-related research will be supported in the near future, to provide incentives to continue and extend established networks and collaborations.
- Well-orchestrated medium and large-scale field studies testing policy-relevant innovations are still missing.
- The need for support of the implementation of the Swiss energy strategy with explicit consideration of the Paris Agreement, which requires large-scale technology and socioeconomic innovations.

With this background in mind, the creation of a new funding instrument is an excellent opportunity to rethink the content, organization and funding options of collaborative energy research in Switzerland, learning from experience gained so far and taking the chance to design an appropriate framework with a longer time horizon and a much stronger systemic, transdisciplinary and policy-relevant view.

In the following, the Extended Energy Commission of the Swiss Academies of Sciences outlines a number of requirements for a mid- to long-term energy research strategy and funding framework for the years beyond 2020 to ensure a well-coordinated energy research program.

3. Content and Focus Research Areas – A conceptual Framework for Energy Research in Switzerland 2020+

The conceptual framework should provide a "helicopter view" over the whole energy system (see figure 1), encompassing the individual energy demand and supply sectors (transport, buildings, industry, services as well as electricity, heat and fuels generation, distribution and storage) and their interactions as well as their links to the environment, society and economy. As examples among others, the following anticipated developments have to be considered:

- The gradual convergence of the energy sectors, which have so far been mostly looked at "in isolation" from each other, to an integrated system, where low-CO_2-emitting and (at least in the foreseeable future) nuclear-free electricity will directly or indirectly (through long term storage and conversion to synthetic chemical energy carriers) dominate the supply of energy services. One example of such links is storing large quantities of instantaneously "excess" electricity either directly in batteries or indirectly by the production of renewable fuels over seasonal time scales. Should these fuels go beyond hydrogen to synthetic hydrocarbons, synergies with the need to capture and re-use CO_2 would become apparent. An important aspect of this will be that the manufacturing, heating and transport sector would probably compete for such energy carriers but on the other hand they would also provide the necessary scale of demand for stimulating such developments. This "sector coupling" should be steered towards an optimal cost-benefit ratio for the society and the environment over the next decades.
- The foreseeable interdependencies between demand and supply for individual energy services through new business models that will be facilitated by information and communication technologies. It is conceivable that at every step along the chain between the demand for energy services and the supply of primary energy, decisions made by consumers, investors and technology developers will be strongly influenced by energy policy. An example for this is the "Mobility as a Service" concept facilitated by available data and interconnected, shared vehicles and automatic driving.

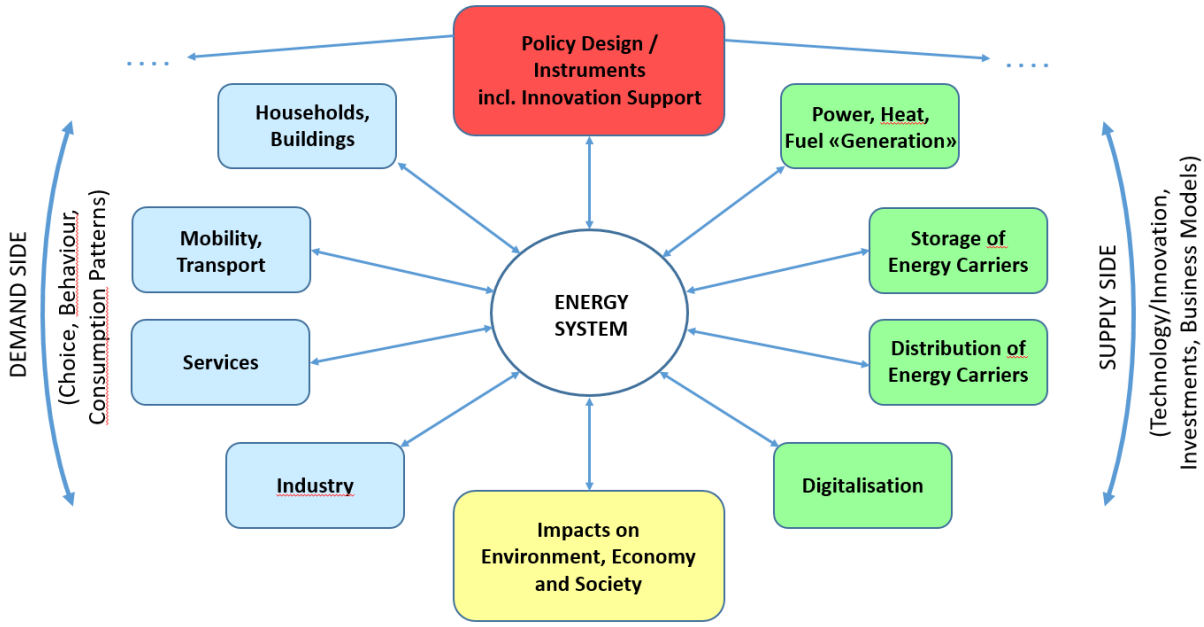

Figure 1: The energy system from a "helicopter" perspective. Exogenous drivers (GDP, demography, population size) and relevant spatial (regional, national, global) and transition time (short-, mid-, long-term) scales are not explicitly shown

Of course, research and innovation on specific topics from a disciplinary perspective will still be necessary, for example to advance new materials for batteries, synthetic fuels, carbon-capture and utilization, design of policy instruments etc., but also to understand and improve behavioural and decision-making processes.

The proposed conceptual framework is therefore based on three pillars:

A. A collaborative national research program (which is the focus of this document), that supports transdisciplinary projects which elaborate an interdisciplinary, systemic view encompassing the interlinkages between different sectors and systems as well as influences on and from socioeconomic actors and the environment.

B. Basic research on science fundamentals that is funded by SNF and research institutions (ETH domain, universities, universities of applied sciences) themselves and has typically a narrow disciplinary character
C. Application-oriented research in collaboration with private companies is supported by EU research programs, SFOE, Innosuisse and industry itself aiming at a specific product development or technology/services improvement. The organizational and financial framework for EU funded research, however, remains largely unclear at the moment. Therefore the Swiss research community will need to stress the importance to ensure participation of the country to the post-2020 European Research programs in the political process.

In the following we concentrate on pillar A, which is a crucial responsibility at a national scale and requires a new program design and funding approach.

Basic concept of a new collaborative national research program

A substantial and fast enough transformation of the energy system in order to fulfil the relevant sustainability criteria requests action and breakthrough developments in all energy sectors. These will be strongly linked to each other as well as to socioeconomic trends and the implementation of relevant policies. Therefore, a coherent but flexible research strategy across technology and socioeconomic disciplines is needed with the following characteristics:

- There has to be sufficient flexibility and adaptive capability in funded projects to respond to unexpected developments in the course of the research, move away from dead ends and to pursue emerging paths. Flexibility refers to the size of funded projects or consortia (depending on the research topic) and the reorientation of funds in case of emerging new insights. A variety of implementation phases should be included in projects, accounting for a broad representation of (technology and socioeconomic) readiness levels.
- Important evaluation criteria of consortia to be funded:
  - alignment with the overarching goals of the energy strategy and the obligations according to the Paris Agreement (policy relevance), that means e.g. have a significant energy savings potential and/or a substantial impact on CO2 emission of a given activity sector in Switzerland
  - convincingly show highest scientific quality
  - demonstrate a systemic view including the awareness of strong interrelations of technology – environment – society – economy – policy
  - credibly involve crucial stakeholders (from business and administration) from the beginning to increase chances for implementation and diffusion of innovations to the market
  - have a strong collaborative/integrative component that transcends the boundaries of individual groups and departments or even (preferably) institutions, thus keeping or extending the important network concept of preceding programs.
  - keep an eye on energy sectors integration and related optimization potentials
  - novel approaches (and not just more of the same) which cannot take place in the “usual” funding channels
  - particularly focus on well-orchestrated medium and large-scale field studies
- The funding scheme should allow different scales and durations of projects and consortia, respectively. Rather than size or number or geographical distribution of participating institutions, criteria should be:
  - composition of participating institutions that best fits the research area
  - inclusion of all competences needed to cover the different aspects of the topic in view of the whole system (i.e. interrelations to other components of the energy system including socioeconomic and environmental aspects within the same consortium)
  - required resources appropriate for the topic or research question
- The necessary time scales for research-based innovation in the energy sector must be properly accounted for and the program should allow for iterating through the implementation phases. A successful national program continuation will be most fruitful if it extends for a period in the order of 8-12 years (“Research Agenda 2030”), including continuous evaluations, which are key to the intended flexibility of the program.

- Work streams and funding instruments must be designed in a way that the whole chain of implementation phases can be included, all relevant partners are involved in the various stages and thus "valleys of death" – usually happening between 'proof of concept' and 'product development' phases - are avoided to the extent possible.
- Often investments of the private sector only start at quite late phases, which misses the opportunity to learn from the implementation process in order to improve the initial concept. Therefore, the possibility of sufficient public funding should encompass pilot, field studies, scale-up and demonstration activities early enough in case that "proof-of-concept" research is successful.

4. Options for Organization, Governance and Funding

The considerations in the chapters above lead to the following general recommendations concerning organizational and financial issues for a possible "Energy Research 2020^{+}" program. We are aware that other stakeholders are working on similar proposals so that a consensus on the basic concept with respect to the overall content must be achieved first before a final definition of these issues.

Organization:

Based on the experience of the administrative treatment in the frame of past funding instruments for collaborative energy research in Switzerland we suggest the following:

- Every project selection and evaluation should be carried out by a committee with a thematically broad view and expertise.
- It is fundamental to carefully define appropriate evaluation metrics/criteria as well as the scale scope and duration of research projects/consortia, which might be different between projects.
- For every call, submission of proposals competing with each other is welcome and encouraged.
- Administration load shall be kept as low as possible, following "best-practices" from the past.
- The management of project consortia is given the flexibility for occasional reorientation of individual activities, including reallocation of funds if rapidly changing circumstances require so
- Private/public sector participation is strengthened, for example by:
  - alignment of the roles of academic and corporate partners along the Readiness Levels cascade
  - close interaction with government offices, since these have valuable know-how and are regularly involved in the decision-making process for policy design and implementation in the energy, environmental, transport and related infrastructure sectors
  - the explicit possibility of funding pilot demonstration and field studies in collaboration with partners of the private sector.
  - the possibility of (limited) financing of corporate partners through the funding scheme in early project stages

Governance:

We envision a concept involving the following boards and instruments for ensuring adequate governance and a competitive, quality-based allocation of funds to research proposals:

- A *Strategic Board* which defines and specifies the overarching goals (with participation of CORE/UVEK/SFOE/Innosuisse, private sector, policy-makers, etc.), approves any substantial consortia reorientation and is responsible for the overall program and its budget vis-à-vis the Federal government.
- An *Advisory/Review Board* of national and international renowned scientists and industry representatives where appropriate, preferably with a broad view and background and certainly independent from funded projects. They shall contribute international and/or outside perspectives to the program with regard to selection and evaluation. The members of the Advisory/Review board shall be chosen by the Strategic Board upon recommendations by the academic and funding institutions in Switzerland. It is important to guarantee a clear separation of roles among the members of the two Boards and the research community receiving funding.
- A full-time and independent (no project involvement) *Program Directorate* (e.g. consisting for example of one Director, two scientific officers and lean administrative support) that supports individual research consortia, cares for consistent operational procedures and takes care of the

integration and synthesis across the consortia. The directorate should closely interact with the Strategic Board to ensure alignment of strategy with bottom-up insights from running projects in order to co-shape subsequent call areas. In this way, the Directorate should serve as interface and integrated communication channel between all consortia on one hand and the Strategic Board and Advisory/Review Board on the other. It should also be responsible for outreach to policy makers and stakeholders from the economy and society, thus representing the Program in a coordinated way as a whole.

Volume of Funding:

Although it is difficult at the current stage to make concrete suggestions with regard to an appropriate funding volume, we recommend funding for the following distinct purposes:

- Support of the two boards and the program directorate including necessary administration staff, evaluation and outreach workshops etc.: ~1 Mio CHF/year
- Finance several research consortia for periods of 4 to 6 years with around 2-4 Mio CHF/year each, allowing for funding typically 10 partners per consortium. Depending on the considered Readiness Level of the proposed implementation, partners outside academic institutions should be eligible for funding. In addition, significant matching funds (in-kind of universities and third-party funds from industry) must be secured.

Typically 3-5 consortia, all with an interdisciplinary, systemic approach to a concrete thematic area could be run in parallel, leading thus to a total funding volume of (around) 10-15 Mio CHF/year.

These numbers are indicative of the appropriate scale for such an effort and need of course to be negotiated in the frame of the political process.

Although the proposed funding volume amounts to less than 5% of the total public spending for energy research in Switzerland (~397 Mio CHF in 2017) it would still make a substantial contribution to the systemic interdisciplinary nature of a Future Energy Research Program, as it is exactly this component that would be lacking otherwise in the period beyond 2020.

Appendix: Current public funding of Energy Research in Switzerland

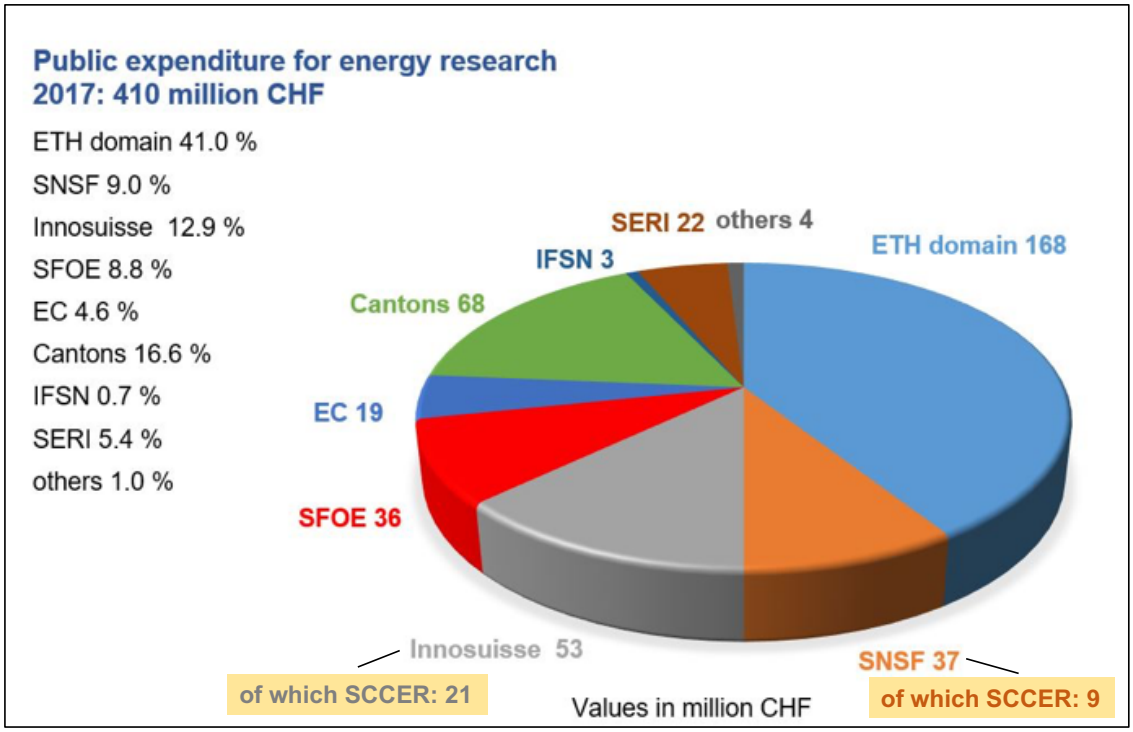

Figure 2: Current public funding of Energy Research. The funding of SCCERs will drop in the end of 2020