Innosuisse – Swiss Innovation Agency

SCCER Accompanying Research 2017–2019

Synthesis

Zurich, 7 August 2019

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Module 4: Analysis of the collected set of indicators (INFRAS, in cooperation with EBP)

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Summary

1. Introduction

With its Energy Funding Programme, the federal government aims to promote energy research, and thereby support the implementation of the Energy Strategy 2050. A central element of the Programme is the establishment of eight networked inter-university centers of research excellence, known as 'Swiss Competence Centers for Energy Research' (SCCERs). The Programme also includes additional funding for innovation projects in the energy sector. While the focus of the first funding period (2013–2016) was on establishing the SCCERs, the second funding period (2017–2020) should see the SCCERs, and collaboration, consolidated and strengthened. The Energy Funding Programme is scheduled to run until 2020. However, the SCCER concept (including the capacity that has been established, coordination, and collaboration in energy research) is intended to be continued in the long term and contribute to the fullest extent possible to the objectives of the Energy Strategy 2050.

The SCCER Accompanying Research 2017–2019 examined the following areas, and drew up the corresponding recommendations for action: (1) networking and (interdisciplinary) collaboration, (2) implementation of scientific results, (3) preparations for the permanent establishment of the SCCER concept, and (4) analysis of the collected set of indicators. In each case, the research questions were answered by means of an analysis of relevant documents, qualitative interviews, and an online survey among implementation partners (regarding the implementation of scientific results). The following findings and recommendations are based on the reports on the four areas.

2. Findings

Networking and (interdisciplinary) collaboration

Compared with the first funding period (2013–2016), collaboration in energy research and between different types of higher education institution (HEI) became closer still during the second funding period (2017–2020):

- The SCCERs supported the establishment and maintenance of networks, which are based largely on personal contacts and joint research projects. These networks and joint projects resulted in closer cooperation between research institutes and academic disciplines – including socio-economic disciplines, in particular. The Energy Funding Programme has also led to universities of applied sciences becoming more heavily involved in energy research. More and more, these universities are being viewed as important partners with an independent set of skills and capabilities, and they are also increasingly working with the ETH domain.

- Joint Activities[1] step up dialogue and knowledge-sharing between the different institutes and disciplines, thereby strengthening multidisciplinary and interdisciplinary collaboration.

In the future, there will be a lack of funding options for interdisciplinary collaboration, especially after the Energy Funding Programme ends. This casts doubt over the sustainability of cooperation on energy research. To maintain and strengthen collaboration, higher education institutions should continue and expand existing networks as best they can. They might be supported in this by grants for communications and networking platforms. Meanwhile, new financial incentives and/or frameworks for supporting interdisciplinary cooperation should be discussed at the federal level, also with a view to involving private enterprise even more closely.

Implementation of scientific results

The increasing number of contacts and collaborative ventures between higher education institutions and implementation partners[2], and the growth in the number of prototypes and P+D plants, indicate a further increase in knowledge and technology transfer. Most implementation partners attach great importance to cooperation with higher education institutions in achieving progress in the innovation process, especially in the early stages of innovation. The SCCERs (researchers and knowledge and technology transfer (KTT) officers) are actively committed to seeking out cooperation partners and to developing collaborative projects. All in all, they have succeeded in involving the right implementation partners to the right degree. Knowledge and technology transfer are supported above all by a focus on practice-oriented problems and the development of products and P+D plants at an advanced stage of technological readiness, combined with personal commitment and small teams. Hindering factors for joint innovation projects are difficult market conditions in some areas, technologies that are far from being competitive, and a general lack of flexibility to adapt projects under the Energy Funding Programme.

Approximately one fifth of the supported projects are thought to have reached the market to date. It should be taken into account that the implementation of research findings in the market takes time. Some of the projects have helped to raise awareness about, and the visibility of, new technologies. Approximately one sixth of the implementation partners state that the projects have achieved an impact on the concrete level of energy being saved or renewable energy being installed. In general, most stakeholders think it unreasonable to expect a large quantitative impact of the Programme after such a short time.

[1] Joint Activities are special collaborative projects between several SCCERs, aimed at achieving additional added value or a significant contribution to the objectives of the Energy Strategy 2050. They attract additional funding from Innosuisse.
[2] Implementation partners include private enterprise and associations, as well as federal agencies, cantons and communes.

To improve knowledge and technology transfer, Innosuisse should intensify efforts to communicate findings to relevant stakeholders and policy makers, as well as to the broader public. If a similar funding programme is planned in the future, funding criteria should be brought more closely into line with the energy research that is to be supported, and the flexibility afforded by the Programme should be increased. At the same time, the qualitative aspects of cooperation between higher education institutions and implementation partners should be improved, in particular where expectations are concerned.

Preparations for the permanent establishment of the SCCER concept

The SCCER concept offers added value in terms of additional capacity, coordination, and closer collaboration in energy research, and also makes a positive contribution to the achievement of Energy Strategy 2050 objectives. However, what little preparatory work that the SCCERs have done or planned (as at the first half of 2018) towards their permanent establishment is not sufficient to continue the SCCER concept beyond 2020.

If less funding is available for energy research after 2020, it is highly likely that the research capacity and activities of the SCCERs will decrease. Specifically, with the exception of successful, well-established partnerships, the result will be significant contraction in the networks and in collaboration in energy research.

Intensified, coordinated energy research should continue to be pursued in the interests of maximising its contribution to the objectives of the Energy Strategy 2050. Higher education institutions and SCCERs should be more engaged and active in preparing the permanent establishment of the SCCER concept. Furthermore, since the long-term survival of strengthened energy research will also depend in the future on financial support from the federal government, the federal administration (State Secretariat for Education, Research and Innovation SERI, Swiss Federal Office of Energy SFOE, Innosuisse, etc.) should develop the corresponding funding framework, based on a long-term strategy. This funding instrument should include a certain degree of support for networking efforts and collaboration, as well as project-related financing.

Collected set of indicators

The indicators collected from the SCCERs provide an important basis on which to evaluate the degree to which targets are being achieved, to manage the Energy Funding Programme, and to conduct an impact analysis. However, no indicators are gathered which relate to the effects of the supported projects on market actors (outcomes), or on the related energy aspects (impacts).

If the federal government continues to support energy research with an Energy Funding Programme post-2020, it should back up the set of indicators with a periodic impact analysis.

3. Conclusions and recommendations

The findings on the four areas of the Accompanying Research lead to the following conclusions:

- The Energy Funding Programme has generated further progress in collaboration between research institutes and academic disciplines, including socio-economic energy research. Universities of applied sciences have also become significantly more involved in energy research.
- Knowledge and technology transfer in energy research has improved, driven in particular by collaboration between higher education institutions and implementation partners on specific research projects. However, there is still further room for improvement in both knowledge and technology transfer, and collaboration on energy research.
- The Energy Funding Programme has created added value in energy research: it has expanded research capacity and the scope of energy research; research is now more coordinated; and networks have been established and (interdisciplinary) collaboration strengthened.
- If the federal government decides to stop funding strengthened energy research beyond 2020, research capacity in the energy sector and the networks that have been established will contract, and there will be a decline in collaboration on energy research, as well as between higher education institutions and implementation partners.
- If energy research is continue making the maximum contribution to the objectives of the Energy Strategy 2050 beyond 2020, the capacity that has been established should be pursued, and coordination and collaboration in energy research should be strengthened post-2020. In addition to the higher education institutions' own efforts in terms of furthering energy research and collaboration, there is a need for a federal government funding framework that is based on a long-term strategy and includes all relevant actors.

While considering that the Accompanying Research focused on four specific areas, and did not undertake any comprehensive evaluation of the output, effects and cost/benefit relationships of the energy research supported by the Energy Research Programme, the following recommendations for the post-2020 phase may be formulated:

1. In the interests of maximising the contribution of energy research to the objectives of the Energy Strategy 2050, the higher education institutions participating in the SCCERs, and the federal government, should commit to maintaining research capacity and strengthening coordination and collaboration in energy research in the long term.

2. The higher education institutions participating in the SCCERs should attach greater importance to energy research, draw up the corresponding strategies, and as far as possible maintain the research capacity that has been established.
3. The higher education institutions and professorships participating in the SCCERs should make the most of their opportunities to work with other research institutes and implementation partners to maintain, extend, deepen and perpetuate the networks, exchange platforms and cooperation projects that have been established.
4. The higher education institutions and professorships participating in the SCCERs should step up their efforts to launch further research projects with implementation partners, especially private enterprise. In addition to more intensive networking, they should respond specifically to their partners' research needs.
5. Irrespective of any future funding instrument, the federal administration should support higher education institutions and professorships with the maintenance and expansion of networks and cooperation projects with implementation partners. At the same time, the administration should demand more preparatory activities on the part of HEIs in the interests of maintaining capacity, coordination, and collaboration in energy research. In addition, it is worth looking in to how the allocation of 'regular' funding in the energy sector (e.g. SFOE, Innosuisse, SNSF) might be adjusted to support the added value generated by the Energy Funding Programme more effectively.
6. The federal government should draw up a long-term strategy to provide additional support for energy research. Drawing on the objectives of the Energy Strategy 2050, this strategy should define the additional need for energy research (including the underlying conditions and knowledge and technology transfer), as well as principles for the funding. It should combine competition-based project funding with support for networking, including communications. Over time it should be possible to reduce funding provided by the federal government and increase the resources supplied by the higher education institutions and implementation partners themselves.
7. Based on the long-term strategy, the federal administration should develop a funding instrument that sets out support for networking (and communications), and competition-based project funding in greater detail in terms of research focus, requirements, available resources, etc. This should be updated periodically. Monitoring should be backed up by periodic impact analyses to manage funding, and for communication purposes.

Zusammenfassung

1. Einleitung

Der Bund will mit dem Förderprogramm Energie die Energieforschung stärken und damit die Umsetzung der Energiestrategie 2050 unterstützen. Ein zentraler Bestandteil des Förderprogramms ist der Aufbau von acht interuniversitär vernetzter Forschungskompetenzzentren, den «Swiss Competence Centers for Energy Research» (SCCERs). Das Förderprogramm umfasst zudem zusätzliche finanzielle Mittel für Innovationsprojekte im Energiebereich. Während der Schwerpunkte der ersten Förderperiode (2013–2016) auf dem Aufbau der SCCERs lag, sollen die SCCERs und die Zusammenarbeit in der zweiten Förderperiode (2017–2020) konsolidiert und gestärkt werden. Das Förderprogramm Energie ist bis 2020 befristet. Das SCCER-Konzept (inkl. den aufgebauten Kapazitäten, der Koordination und der Zusammenarbeit in der Energieforschung) soll längerfristig weitergeführt und einen möglichst grossen Beitrag an die Ziele der Energiestrategie 2050 leisten.

Die Begleitforschung der SCCERs 2017–2019 untersuchte folgende Themenfelder und erarbeitete entsprechenden Handlungsempfehlungen: (1) Vernetzung und (interdisziplinäre) Zusammenarbeit, (2) Umsetzung wissenschaftlicher Erkenntnisse, (3) Vorbereitungen zur längerfristigen Weiterführung des SCCER-Konzepts und (4) Analyse des erhobenen Indikatoren-Sets. Die jeweiligen Forschungsfragen wurden anhand der Analyse relevanter Dokumente, qualitativer Interviews und einer Online-Befragung von Umsetzungspartnern (zur Umsetzung der wissenschaftlichen Erkenntnisse) beantwortet. Nachfolgende Ergebnisse und Empfehlungen basieren auf den Berichten zu den vier Themenfeldern.

2. Ergebnisse

Vernetzung und (interdisziplinäre) Zusammenarbeit

Im Vergleich zur ersten Förderperiode (2013–2016) hat sich die Zusammenarbeit in der Energieforschung und die Zusammenarbeit zwischen verschiedenen Hochschultypen in der zweiten Förderperiode (2017–2020) weiter verstärkt:

- Die SCCERs unterstützen den Aufbau und die Pflege von Netzwerken, die grösstenteils auf persönlichen Kontakten und gemeinsamen Forschungsprojekten basieren. Die Netzwerke und die Durchführung gemeinsamer Projekte haben zu einer verstärkten Zusammenarbeit zwischen den Forschungsinstituten und den Wissenschaftsdisziplinen (insbesondere auch zu den sozio-ökonomischen Disziplinen) geführt. Das Förderprogramm Energie hat zu einer stärkeren Einbindung der Fachhochschulen (FHS) in die Energieforschung geführt. Die FHS

werden vermehrt als wichtige Partner mit eigenständigen Kompetenzen wahrgenommen und arbeiten vermehrt mit dem ETH-Bereich zusammen.

- Die «Joint Activities»[3] intensivieren den Dialog und den Wissensaustausch zwischen verschiedenen Instituten und Disziplinen. Dadurch verstärken sie die multi- und die interdisziplinäre Zusammenarbeit.

Aufgrund der zukünftig ungenügenden Möglichkeiten zur Finanzierung der interdisziplinären Zusammenarbeit (v.a. nach Beendigung des Förderprogramms Energie) ist die Nachhaltigkeit der Zusammenarbeit in der Energieforschung nicht sichergestellt. Zur Weiterführung und zur Verstärkung der Zusammenarbeit sollten die Hochschulen erstens die aufgebauten Netzwerke nach Möglichkeit weiterführen und ausbauen. Dabei könnten sie durch finanzielle Beiträge für Kommunikations- und Networking-Plattformen unterstützt werden. Zweitens sollten auf Bundesebene neue finanzielle Anreize und/oder Vorgaben zur Unterstützung der interdisziplinären Zusammenarbeit diskutiert werden. Dabei sollte auch darauf hingearbeitet werden, die Unternehmen noch stärker einzubinden.

Umsetzung wissenschaftlicher Erkenntnisse

Die zunehmende Anzahl an Kontakten und Zusammenarbeiten zwischen Hochschulen und «Umsetzungspartnern»[4] sowie die Zunahme der Anzahl Prototypen und P+D-Anlagen weisen darauf hin, dass sich der Wissens- und Technologietransfer weiter verstärkt hat. Die meisten Umsetzungspartner messen der Zusammenarbeit mit Hochschulen eine grosse Bedeutung für die im Innovationsprozess erzielten Fortschritte bei, insbesondere in den frühen Interventionsphasen. Die SCCERs (Forschende und WTT-Verantwortliche) engagieren sich aktiv bei der Suche nach Kooperationspartnern und der Entwicklung von Kooperationen. Insgesamt ist es ihnen gelungen, die richtigen Umsetzungspartner adäquat zu involvieren. Der Wissens- und Technologietransfer wird vor allem durch praxisorientierte Aufgabestellungen, die Entwicklung von in Bezug auf den Innovationsprozesse fortgeschrittenen Produkten und P+D-Anlagen, kombiniert mit persönlichem Engagement und kleinen Teams begünstigt. Hemmende Faktoren für gemeinsame Innovationsprojekte sind in einigen Gebieten schwierige Marktbedingungen, Technologien, die weit davon weg sind, wettbewerblich zu sein, und generell die fehlende Flexibilität für Projektanpassungen im Förderprogramm Energie.

Ungefähr ein Fünftel der unterstützten Projekte sind bisher im Markt umgesetzt worden. Zu berücksichtigen ist, dass die Umsetzung von Forschungserkenntnissen im Markt Zeit benö-

[3] Joint Activities sind spezielle Zusammenarbeitsprojekte zwischen verschiedenen SCCERs, die einen zusätzlichen Mehrwert bzw. einen bedeutenden Beitrag hinsichtlich der Ziele der Energiestrategie 2050 leisten sollen. Joint Activities werden von Innosuisse zusätzlich gefördert.

[4] Die «Umsetzungspartner» umfassen private Unternehmen und Verbände sowie Bundesämter, Kantone und Gemeinden.

tigt. Einige Projekte haben zu einer Sensibilisierung und stärkeren Sichtbarkeit von neuen Technologien geführt. Etwa ein Sechstel der befragten Umsetzungspartner gibt an, dass durch die Projekte konkrete Energieeinsparungen oder ein Zuwachs an erneuerbaren Energien erzielt werden konnten. Gemäss den meisten Akteuren ist es verfrüht, nach so kurzer Zeit eine grosse quantitative Wirkung des Programms (in kWh) zu erwarten.

Zur Verbesserung des Wissens- und Technologietransfers sollte Innosuisse die Kommunikation der Erkenntnisse an relevante «Stakeholders», politische Entscheidungsträger und die Bevölkerung intensivieren. Bei einem allfälligen zukünftigen Förderprogramm sollten zum einen die Förderbedingungen besser an die zu unterstützende Energieforschung angepasst werden (inkl. Erhöhung der Flexibilität des Programms). Zum anderen sollte die Zusammenarbeit zwischen Hochschulen und Umsetzungspartnern in qualitativer Hinsicht (v.a. betreffend Erwartungen) verbessert werden.

Vorbereitungen zur längerfristigen Weiterführung des SCCER-Konzepts

Durch die zusätzlichen Kapazitäten, die Koordination und die verstärkte Zusammenarbeit in der Energieforschung stellt das SCCER-Konzept einen Mehrwert dar und trägt positiv zu den Zielen der Energiestrategie 2050 bei. Die wenigen von den SCCERs umgesetzten oder geplanten Vorbereitungsarbeiten zur längerfristigen Weiterführung (Stand erste Hälfte 2018) genügen jedoch nicht, um das SCCER-Konzept nach 2020 weiterzuführen.

Falls nach dem Jahr 2020 weniger finanzielle Mittel für die Energieforschung zur Verfügung stehen, werden sich die Forschungskapazitäten und die Aktivitäten der SCCERs mit grosser Wahrscheinlichkeit reduzieren. Insbesondere werden sich mit Ausnahme von gut etablierten und erfolgreichen Partnerschaften die Netzwerke und die Zusammenarbeit in der Energieforschung deutlich verringern.

Im Hinblick auf einen möglichst grossen Beitrag an die Ziele der Energiestrategie 2050 sollte der Weg einer intensivierten und koordinierten Energieforschung weiterverfolgt werden. Die Hochschulen und die SCCERs sollten sich im Hinblick auf eine nachhaltige Etablierung des SCCER-Konzepts aktiver und stärker engagieren. Da die längerfristige Weiterführung einer verstärkten Energieforschung auch zukünftig von einer finanziellen Förderung des Bundes abhängt, sollten die Bundesbehörden (Staatssekretariat für Bildung, Forschung und Innovation (SBFI), Bundesamt für Energie (BFE), Innosuisse, etc.) ein entsprechendes Förderinstrument erarbeiten, das auf einem langfristigen Konzept basiert. Das Förderinstrument sollte eine gewisse Unterstützung der Anstrengungen in der Netzwerkarbeit und der Zusammenarbeit sowie eine projektbezogene finanzielle Förderung beinhalten.

Erhobenes Indikatoren-Set

Die bei den SCCER erhobenen Indikatoren sind eine wichtige Grundlage zur Beurteilung der Zielerreichung, zur Steuerung und im Hinblick auf eine Wirkungsanalyse des Förderprogramms Energie dar. Es werden jedoch keine Indikatoren erhoben, dies sich auf die Wirkungen der unterstützten Projekte auf die Marktakteure («Outcomes») und die entsprechenden energetischen Auswirkungen («Impacts») beziehen.

Falls der Bund die Energieforschung auch nach 2020 durch ein Förderprogramm Energie unterstützt, sollte er das Indikatoren-Set durch eine periodisch durchzuführende Wirkungsanalyse ergänzen.

3. Folgerungen und Empfehlungen

Aufgrund der Ergebnisse zu den vier Themenfeldern ergeben sich folgende Folgerungen:

- Das Förderprogramm Energie hat zu weiteren Fortschritten bei der Zusammenarbeit zwischen Forschungsinstituten und wissenschaftlichen Disziplinen (u.a. auch mit der sozio-ökonomischen Energieforschung) geführt. Die Fachhochschulen konnten bedeutend stärker in die Energieforschung eingebunden werden.
- Der Wissens- und Technologietransfer in der Energieforschung hat sich verstärkt. Zentraler Pfeiler des Wissens- und Technologietransfers ist die Zusammenarbeit von Hochschulen und Umsetzungspartnern in konkreten Forschungsprojekten. Bei der Zusammenarbeit in der Energieforschung und dem Wissens- und Technologietransfer bestehen weitere Verbesserungspotenziale.
- Das Förderprogramm Energie hat zu einem Mehrwert in der Energieforschung geführt: Ausbau der Forschungskapazitäten und des Umfangs der Energieforschung; verstärkte Koordination der Energieforschung; Aufbau von Netzwerken und Verstärkung der (interdisziplinären) Zusammenarbeit.
- Verzichtet der Bund auf eine Förderung einer intensivierten und koordinierten Energieforschung über das Jahr 2020 hinaus, reduzieren sich die Forschungskapazitäten im Energiebereich, die aufgebauten Netzwerke sowie die Zusammenarbeit in der Energieforschung und zwischen den Hochschulen und den Umsetzungspartnern.
- Wenn die Energieforschung auch nach 2020 einen möglichst grossen Beitrag an die Ziele der Energiestrategie 2050 leisten soll, sollten die aufgebauten Forschungskapazitäten erhalten und die Koordination sowie die Zusammenarbeit in der Energieforschung auch nach 2020 weiter gestärkt werden. In Ergänzungen zu eigenen Anstrengungen der Hochschulen (Verstärkung der Energieforschung und der Zusammenarbeit) ist dazu ein Förderinstrument des Bundes erforderlich, das auf einem langfristigen Konzept basieren und alle relevanten Akteure einbeziehen sollte.

Unter Berücksichtigung, dass sich die Begleitforschung auf vier Themenfelder fokussierte und keine umfassende Beurteilung der Leistungen, der Wirkungen und des Kosten-Nutzen-Verhältnisses der durch das Förderprogramm Energie unterstützten Energieforschung vornahm, ergeben sich im Hinblick auf die Phase nach 2020 folgende Empfehlungen:

1. Im Hinblick auf einen möglichst grossen Beitrag der Energieforschung an die Ziele der Energiestrategie 2050 sollten sich die an den SCCER beteiligten Hochschulen und der Bund zu einer längerfristigen Weiterführung der Forschungskapazitäten sowie zur weiteren Verstärkung der Koordination und der Zusammenarbeit in der Energieforschung verpflichten.
2. Die an den SCCERs beteiligten Hochschulen sollten der Energieforschung ein grösseres Gewicht beimessen, entsprechende Strategien erarbeiten und die aufgebauten Forschungskapazitäten möglichst erhalten
3. Die an den SCCERs beteiligten Hochschulen und ProfessorInnen sollten ihre Möglichkeiten ausschöpfen, um die aufgebauten Netzwerke, Austauschplattformen und Kooperationen mit anderen Forschungsinstituten und Umsetzungspartnern weiterzuführen, auszubauen, zu vertiefen und zu verstetigen.
4. Die an den SCCERs beteiligten Hochschulen und ProfessorInnen sollen ihre Anstrengungen im Hinblick auf zusätzliche Forschungsprojekte mit Umsetzungspartnern (insbesondere seitens der Wirtschaft) intensivieren. Neben der verstärkten Netzwerkarbeit sollen sie sich gezielt an den Forschungsbedürfnissen der Partner orientieren.
5. Unabhängig von einem zukünftigen Förderinstrument sollte der Bund die Hochschulen und die ProfessorInnen bei der Weiterführung und dem Ausbau der Netzwerke und der Kooperationen mit Umsetzungspartnern unterstützen. Gleichzeitig sollte er die Hochschulen auffordern, die Vorbereitungsarbeiten im Sinne einer längerfristigen Weiterführung der Forschungskapazitäten, der Koordination und der Zusammenarbeit in der Energieforschung zu intensivieren. Zudem sollte geprüft werden, inwiefern die Vergabe von bestehenden «regulären» Fördermittel im Energiebereich (z.B. BFE, Innosuisse, SNF) angepasst werden könnte, um den durch das Förderprogramm erzielte Mehrwert besser zu unterstützen.
6. Der Bund sollte ein langfristiges Konzept zur zusätzlichen Förderung der Energieforschung erarbeiten. Ausgehend von Zielen der Energiestrategie 2050 sollte das Konzept den zusätzlichen Bedarf in der Energieforschung (inkl. Rahmenbedingungen sowie Wissens- und Technologietransfer) und Fördergrundsätze definieren. Dabei sollte eine wettbewerbliche Projektförderung mit der Unterstützung der Netzwerkarbeit (inkl. Kommunikationsaktivitäten) kombiniert werden. Im zeitlichen Verlauf sollten die Fördermittel des Bundes reduziert und die Ressourcen der Hochschulen und der Umsetzungspartner erhöht werden können.
7. Basierend auf dem langfristigen Konzept sollte der Bund ein Förderinstrument erarbeiten, das die Unterstützung der Netzwerkarbeit (inkl. Kommunikation) und die wettbewerbliche

Projektförderung konkretisiert (Fokus der Forschung, Anforderungen, Fördermittel) und periodisch zu aktualisieren ist. Zur Steuerung und zur Kommunikation des Förderinstruments sollte entsprechende Monitoring periodisch durch eine Wirkungsanalyse ergänzt werden.

Résumé

1. Introduction

La Confédération a lancé son Programme d'encouragement Énergie afin de renforcer la recherche énergétique qui, à son tour, est destinée à faciliter la mise en œuvre de la Stratégie énergétique 2050. La mise en place d'un réseau de huit pôles de recherche interuniversitaire (Swiss Competence Centers for Energy Research, SCCER) constitue l'un des piliers de ce programme, qui alloue par ailleurs des aides financières à des projets d'innovation énergétique. Alors que l'accent était mis sur la mise en place des SCCER durant la première période de financement (2013-2016), la deuxième période de financement (2017–2020) vise la consolidation des SCCER et de leurs collaborations. La durée du Programme d'encouragement Énergie est limitée à 2020 ; néanmoins, le système des SCCER, avec ses capacités, ses mesures de coordination et ses collaborations dans la recherche énergétique, a une vocation qui dépasse cet horizon afin de contribuer au mieux à la réalisation des objectifs de la Stratégie énergétique 2050.

L'évaluation scientifique des SCCER 2017–2019 a analysé les champs thématiques ci-après avant d'élaborer les recommandations y relatives : (1) Mise en place des réseaux et de la collaboration (interdisciplinaire), (2) Mise en œuvre des connaissances scientifiques, (3) Mise en place de la poursuite du système des SCCER sur le long terme, (4) Analyse de l'ensemble d'indicateurs saisi. La réponse aux questionnements respectifs s'appuie sur l'analyse des documents pertinents, sur des entretiens qualitatifs et sur un sondage en ligne mené auprès des partenaires de mise en œuvre qui mettent en oeuvre les résultats qui découlent des recherches. Les résultats et recommandations ci-après se fondent sur les résultats obtenus dans chacun des quatre champs thématiques.

2. Les résultats

Réseaux, collaborations (interdisciplinaires)

Les collaborations dans le domaine de la recherche énergétique et les collaborations entre les différents types de hautes écoles se sont encore renforcées durant la deuxième période de financement (2017–2020) :

- Les SCCER soutiennent la mise en place et le suivi des réseaux, ces derniers se basant essentiellement sur des contacts personnels et des projets de recherche communs. Les réseaux et les projets réalisés en commun ont renforcé les collaborations entre les instituts de recherche et les disciplines académiques, notamment en intégrant davantage les disciplines socio-économiques. Le Programme d'encouragement Énergie a aussi permis une meilleure implication des hautes écoles spécialisées (HES) dans le domaine de la recherche énergétique,

assurant aux HES un statut de partenaire de taille, avec des compétences propres, et une multiplication des collaborations avec les EPF.

- Les Joint Activities[5] permettent d'intensifier le dialogue et l'échange de savoirs entre instituts et entre disciplines, renforçant ainsi les collaborations multi- et interdisciplinaires.

Le manque de moyens insuffisants pour financer les collaborations interdisciplinaires qui se profile, en particulier après le bouclement du Programme d'encouragement Énergie, met en danger la durabilité des collaborations dans le domaine de la recherche énergétique. Pour assurer le maintien et le renforcement des collaborations, les hautes écoles sont donc appelées à agir à deux niveaux : d'une part, maintenir et élargir les réseaux qu'elles ont mis en place ; ces démarches peuvent bénéficier de contributions financières, allouées pour des plates-formes de communication et de réseautage. D'autre part, il s'agit de discuter, au niveau fédéral, de nouvelles incitations et/ou conditions pour soutenir la collaboration interdisciplinaire, démarche à laquelle les entreprises doivent être systématiquement associées.

Mise en œuvre des résultats d'études scientifiques

Le transfert de savoir et de technologie a connu un nouveau renforcement ; le nombre croissant de contacts et de collaborations entre hautes écoles et partenaires de mise en œuvre[6] ainsi que le nombre croissant de prototypes et d'installations P+D en sont la preuve. La plupart des partenaires de mise en œuvre estime que la collaboration des hautes écoles a contribué de manière déterminante aux progrès obtenus dans le processus d'innovation, en particulier dans les phases précoces. Les SCCER (chercheuses, chercheurs et responsables du transfert de savoir et de technologie, TST) font preuve d'un grand engagement pour trouver des partenaires de coopération et lors du développement de telles coopérations. On observe que les facteurs clés qui favorisent le TST sont la définition d'objectifs pratiques, le développement de produits et d'installations P+D innovants avancés, associés à un engagement personnel, ainsi que les équipes de petite dimension. Inversement, ce sont les marchés difficiles de certains secteurs, les technologies peu avancées et donc loin d'être compétitives ainsi que, de manière générale, le manque de flexibilité et d'adaptabilité des projets du Programme d'encouragement Énergie qui freinent les projets d'innovation communs.

Un cinquième environ des projets qui ont bénéficié d'un soutien a été mis en œuvre sur le marché à ce jour. Il faut prendre en compte que la mise en œuvre de résultats de recherche sur

[5] Par Joint Activities, on entend des projets de collaboration transversaux entre SCCER qui ont pour vocation spécifique d'apporter une valeur ajoutée ou une contribution significative à la réalisation des objectifs de la Stratégie énergétique 2050. Ces projets transversaux communs bénéficient d'un soutien supplémentaire d'Innosuisse.

[6] Ces partenaires de mise en œuvre comprennent des entreprises et des associations privées ainsi que des offices fédéraux, des cantons et des communes.

le marché nécessite du temps. Certains projets ont eu un effet de sensibilisation et ils ont permis d'accroître la visibilité des nouvelles technologies. Selon environ un sixième des partenaires de mise en œuvre, les projets ont réalisées des concrets économies d'énergie ou une augmentation des énergies renouvelables. La plupart des acteurs estiment qu'il n'est pas raisonnable de s'attendre à un impact grand du programme après une période aussi courte.

Afin d'améliorer le TST, Innosuisse est appelé à redoubler d'efforts pour communiquer les résultats de la recherche aux parties prenantes, aux organes de décision politique et à la population. Un éventuel programme de suivi gagnera d'une part à mieux adapter les conditions d'octroi du soutien à la recherche énergétique qu'il vise à soutenir (y compris par une plus grande flexibilité du programme) et d'autre part à améliorer la collaboration entre hautes écoles et partenaires de mise en œuvre en termes qualitatifs, en particulier en ce qui concerne les attentes.

Préparatifs en vue de la reconduction du système des SCCER à long terme

Renforçant les capacités, la coordination et la collaboration dans le domaine de la recherche énergétique, le système des SCCER représente une valeur ajoutée et contribue ainsi à réaliser les objectifs de la Stratégie énergétique 2050. Toutefois, les préparatifs actuels ou prévus (état au premier semestre 2018) par les SCCER ne suffiront pas à maintenir le système des SCCER à long terme.

Si les ressources financières affectées à la recherche énergétique sont en recul à partir de 2020, il est très probable que les capacités de recherche et les activités des SCCER seront en recul elles aussi. On assistera en particulier au rétrécissement des réseaux et à une réduction sensible du nombre des collaborations dans le domaine de la recherche énergétique, exception faite des partenariats bien établis et qui ont fait leurs preuves.

La maximisation de la contribution à la Stratégie énergétique 2050 passe par le maintien d'une recherche énergétique à la fois intensive et bien coordonnée. Pour y parvenir, les hautes écoles et les SCCER sont appelés à s'engager davantage en faveur de la reconduction durable du système des SCCER. La pérennité de la recherche énergétique étant tributaire d'une reconduction du soutien financier de la Confédération, les autorités fédérales (Secrétariat d'Etat à la formation, à la recherche et à l'innovation, l'Office fédéral de l'énergie, Innosuisse, etc.) devront élaborer un outil d'encouragement basé sur une conception à long terme. Par ailleurs, cet outil devra englober un soutien aux réseaux et à la collaboration ainsi qu'un apport financier aux projets.

Les indicateurs saisis

La brochette d'indicateurs saisis auprès des SCCER constitue une base précieuse pour évaluer si les objectifs définis ont été atteints, pour piloter le processus et pour analyser ultérieurement l'impact du programme de soutien. Aucun indicateur n'a été saisi qui mesure l'effet des projets soutenus sur les acteurs du marché (extrants) et leur impact énergétique.

Si la Confédération continue de soutenir la recherche énergétique au-delà de 2020 au moyen d'un Programme d'encouragement Énergie, elle fait bien de compléter la brochette d'indicateurs existante par une analyse d'impact périodique.

3. Conclusions et recommandations

Les résultats obtenus dans les quatre champs thématiques appellent les conclusions suivantes :

- Le Programme d'encouragement Énergie a effectivement permis de renforcer la collaboration entre instituts de recherche et disciplines scientifiques, notamment avec le volet socio-économique des recherches énergétiques. L'implication des hautes écoles dans la recherche énergétique a été intensifiée.
- Le transfert de savoir et de technologie a été stimulé dans le domaine de la recherche énergétique. La collaboration entre hautes écoles et partenaires de mise en œuvre dans les projets de recherche concrets constitue l'axe principal de ce transfert. Il subsiste néanmoins un potentiel de développement tant au niveau de la collaboration dans la recherche énergétique que du transfert de savoir et de technologie.
- Le Programme d'encouragement Énergie a apporté une valeur ajoutée à la recherche énergétique. On lui doit notamment l'accroissement des capacités et du volume des recherches effectuées dans le domaine de l'énergie, une meilleure coordination de ces recherches ainsi que la mise en place de réseaux et le renforcement des collaborations (interdisciplinaires).
- Si la Confédération renonce à coordonner et à intensifier la recherche énergétique au-delà de 2020, on assistera à une réduction des capacités de recherche, des réseaux constitués et des collaborations entre hautes écoles et partenaires de mise en œuvre le domaine de l'énergie.
- Si la recherche énergétique doit continuer de contribuer le plus efficacement possible à la réalisation des objectifs formulés dans la Stratégie énergétique 2050, il s'agit de maintenir les capacités de recherche mises en place et d'assurer la coordination et les collaborations dans le domaine de la recherche énergétique au-delà de 2020. Un outil d'encouragement de la Confédération, basé sur des objectifs à long terme et intégrant tous les acteurs concernés, devra être créé pour compléter les efforts faits par les hautes écoles (renforcement de la collaboration et de la recherche énergétique).

Les recommandations ci-après en prévision de la phase post-2020 découlent du constat que l'évaluation scientifique s'est concentrée sur quatre champs thématiques et qu'elle n'a pas procédé à l'évaluation complète des prestations, des effets et du rapport coût-utilité de la recherche énergétique soutenue par le programme d'encouragement Énergie :

1. Les hautes écoles, associées aux SCCER, et la Confédération sont appelées à s'engager en faveur de la reconduction et du renforcement des capacités de recherche ainsi que de l'intensification de la coordination et des collaborations dans le domaine de la recherche énergétique afin d'habiliter la recherche énergétique à contribuer au mieux à la réalisation des objectifs de la Stratégie énergétique 2050.
2. Les hautes écoles, associées aux SCCER, sont invitées à accorder davantage d'importance à la recherche énergétique, à élaborer les stratégies qui vont dans ce sens et à tout entreprendre pour conserver les capacités de recherche qui sont en place.
3. Les hautes écoles associées aux SCCER et leurs professeur-e-s sont invité-e-s à tout mettre en œuvre pour reconduire, renforcer, approfondir et pérenniser les réseaux en place, les plates-formes d'échange ainsi que les coopérations avec les instituts de recherche tiers.
4. Les hautes écoles associées aux SCCER et leurs professeur-e-s sont invité-e-s à intensifier leurs démarches pour élaborer de nouveaux projets de recherche avec les partenaires de mise en œuvre, notamment dans le domaine de l'économie. Ils sont également encouragés à renforcer leurs réseaux et à orienter spécifiquement leurs démarches vers les besoins de recherche de leurs partenaires.
5. La Confédération est appelée à soutenir les hautes écoles et les professeur-e-s en vue du maintien et de l'extension des réseaux et des coopérations avec les partenaires de mise en œuvre, indépendamment d'un éventuel futur outil d'encouragement. Parallèlement, la Confédération fait bien d'encourager les travaux qui permettront d'assurer la pérennisation des capacités de recherche, de la coordination et des collaborations dans le domaine de la recherche énergétique. Enfin, il s'agit d'étudier comment adapter l'attribution des soutiens financiers « ordinaires » dans le domaine de l'énergie (p. ex. OFEN, Innosuisse, FNS) pour qu'elle soit mieux à même de soutenir la création de valeur ajoutée obtenue par le programme de recherche.
6. La Confédération est appelée à élaborer une conception à long terme d'encouragement supplémentaire de la recherche énergétique. Cette conception, basée sur les objectifs de la Stratégie énergétique 2050, doit en particulier définir les besoins supplémentaires de recherche du domaine de l'énergie (y c. contexte général et transfert de savoir et de technologie) et décrire les principes qui régissent l'encouragement. Il s'agit notamment d'allier l'encouragement de projets sur la base de concours et le soutien de la gestion des réseaux (avec les activités de communication). Sur la durée, il s'agira de réduire les soutiens

financiers de la Confédération alors que seront augmentées les ressources des hautes écoles et des partenaires de mise en œuvre.

7. Sur la base d'une conception à long terme, la Confédération est invitée à élaborer un outil d'encouragement, à actualiser périodiquement, qui soit apte à concrétiser le travail de gestion des réseaux (qui comprend la communication) ainsi que l'encouragement de projets sur la base de concours (domaine de recherche prioritaire, exigences, soutiens financiers). Enfin, pour faciliter le pilotage et la communication de l'outil d'encouragement, il s'agit de compléter périodiquement le monitorage correspondant par une analyse d'impact.

1. Introduction

1.1. Swiss Competence Centers for Energy Research (SCCERs)

The Federal Council's 'Swiss Coordinated Energy Research' action plan (Federal Council 2012) aims to promote energy research, and thereby support the implementation of the Energy Strategy 2050. A central element of the action plan is the establishment of networked inter-university centres of research excellence, known as 'Swiss Competence Centers for Energy Research' (SCCERs). The focus of the first funding period (2013–2016) was to establish the SCCERs, and the research collaboration. The second funding period (2017–2020) serves to consolidate the SCCERs, including the networks and partnerships that have been set up, and to strengthen collaboration on research. Eight SCCERs have been active in seven priority action areas since mid-2014:

- SCCER Future Energy Efficient Building & Districts (FEEB&D)
- SCCER Efficiency of Industrial Processes (EIP)
- SCCER Future Swiss Electrical Infrastructure (FURIES)
- SCCER Heat and Electricity Storage (HaE)
- SCCER Supply of Energy (SoE)
- SCCER Competence Centre for Research in Energy, Society and Transition (CREST)
- SCCER Efficient Technologies and Systems for Mobility (Mobility)
- SCCER Biomass for Swiss Energy Future (BIOSWEET).

Approximately CHF 120 million in funding is available for the SCCERs (including their 'Joint Activities'[7]) for the period from 2017 to 2020, and also a further CHF 19 million in targeted support for energy innovation projects.[8] This 'Energy Funding Programme' is scheduled to end in 2020. The SCCER concept – encompassing the capacity that has been established, coordination and cooperation – is intended to be continued on a sustainable basis in the long-term (CTI 2016) and to make significant contributions to Energy Strategy 2050 objectives.

The aims of the Energy Funding Programme can be described with a logic model (see Figure 1).

[7] Joint Activities are special collaboration projects between several SCCERs with the aim of achieving high added value, respectively or a significant contribution to the objectives of the Energy Strategy 2050 (CTI 2016).

[8] https://www.innosuisse.ch/inno/de/home/thematische-programme/foerderprogramm-energie.html. During the first period (2013–2016), the Commission for Technology and Innovation (CTI) devoted CHF 72 million to the establishment of the SCCERs and also received a further CHF 46 million in targeted support für energy research and development projects.

Figure 1: Energy Funding Programme: logic model

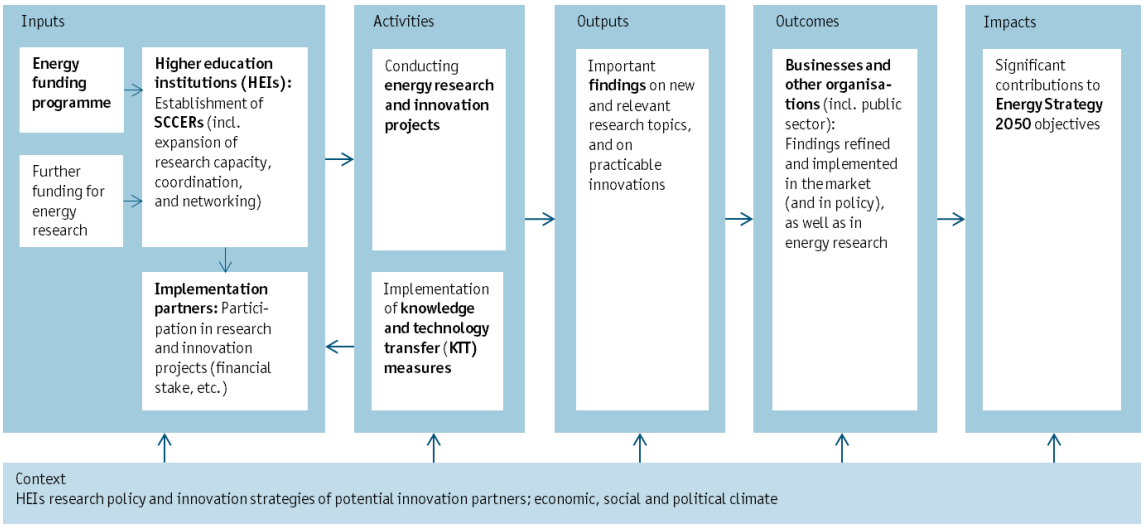

Figure: INFRAS. Source: based on INFRAS and EBP 2018.

The effects that the Energy Funding Programme is intended to have at different levels can be describe as follows:

Table 1: Energy Funding Programme: intended effects

Levels	Intended effects
Inputs	Establishment of SCCERs by higher education institutions (HEIs): ▪ Long-term expansion of research capacity incl. education and training (partly self-funded by HEIs) ▪ SCCERs have a common organisational structure and thematic focus (innovation roadmaps) ▪ Networking between different types of HEI and different disciplines, as well as between the SCCERs and implementation partners ▪ Organisational conditions and a concept for knowledge and technology transfer (KTT)
	Participation of implementation partners (businesses and organisations from the private and public sectors) in energy research and innovation projects by contributing financial resources, technologies, infrastructure, data and models, and expertise
	Acquisition of other third-party funding for research projects (e.g. SNSF, SFOE, EU programmes)
Activities	Conducting energy research and innovation projects that take into account the entire knowledge generation chain, the way in which it translates into practice (from basic research to prototype development and demonstrators), and how it will help to realise the Energy Strategy 2050: ▪ Innovative energy research projects with greater cooperation between different types of HEI and different disciplines ▪ Increase the number of innovation projects with innovation partners on energy issues in the priority action areas
	Successful implementation of KTT programmes (e.g. events, training courses and platforms)

Levels	Intended effects
Outputs	Important findings on new, relevant, and specifically Swiss research topics in the priority research areas (e.g. research publications, theses, data and models, construction of infrastructure and/or pilot plants)
	Implementation-orientated innovations which improve the transfer of research findings to market (e.g. patent registrations, licences, prototypes, spin-offs, pilot plants and demonstrators, and innovative products, processes and services
	Expansion of a young talent pool via joint HEI–business projects
Outcomes	Effects on business and/or organisations from the private and public sectors, as well as on energy research: ▪ New findings from research and innovation projects ▪ Findings refined and implemented in the market (and in policy) ▪ Business competitiveness improved ▪ HEIs and business strengthen and expand energy research in the long term
Impacts	Transformation of the Swiss energy system ▪ Innovations are implemented successfully in the market (and in policy) ▪ Significant contributions to Energy Strategy 2050 objectives
	Harness the economic potential of energy system transformation: the Swiss economy becomes more competitive

Table INFRAS. Source: based on INFRAS and EBP 2018.

The logic model and the effects that the Energy Funding Programme is intended to have (see Section 1.1) are an important basis for the Accompanying Research, especially Module 4 (Analysing the collected set of indicators).

1.2. SCCER Accompanying Research 2017–2019

A Steering Committee defines the strategic boundary conditions of the SCCER's work. The monitoring information collected by the SCCERs, as well as the evaluations and recommendations of an Evaluation Panel, are the cornerstones of managing the Energy Funding Programme. Innosuisse also commissioned the Accompanying Research, which is the subject of this report. This research analysed developments in four specific areas and drew up the corresponding recommendations for action. It is intended to provide an external perspective to help the Steering Committee manage the Energy Funding Programme. The research was conducted between October 2017 and April 2019. While Modules 2, 3a, 3b and 4 examined the four themed areas, Module 1 was responsible for coordinating the research and synthesising the findings (see Table 2).

Table 2: Modules of the SCCER Accompanying Research 2017–2019

Modules	Contents	Contractors
Module 1	Coordination and synthesis	INFRAS, Zurich
Module 2	Implementation of scientific results	EBP, Zollikon Institut de recherches économiques, University of Neuchâtel (IRENE), Neuchâtel
Module 3a	Preparations for the permanent establishment of the SCCERs	INFRAS, Zurich
Module 3b	Networking and (interdisciplinary) collaboration	Prognos, Basel
Module 4	Collected set of indicators	INFRAS, Zurich

Table INFRAS.

The following questions were asked in the four areas covered by the Accompanying Research (see Table 3). The areas are structured with reference to the Energy Funding Programme logic model (see Section 1.1), or according to the time dimension. As Module 4 focuses on specific questions concerning the management of the Programme, we place it last of the four areas.

Table 3: Research questions

Modules	Research questions
Networking and (interdisciplinary) collaboration (Module 3b)	▪ Has SCCER funding led to closer, long-term collaboration in energy research? ▪ Has collaboration between higher education institutions (HEIs) been strengthened? ▪ Do Joint Activities support interdisciplinary collaboration properly? ▪ How do Joint Activities support interdisciplinary collaboration, especially collaboration between engineering and technology and social science?
Implementation of scientific results (Module 2)	▪ Do the SCCERs plan and implement transfer measures in an adequate manner? ▪ Do the SCCERs involve the right transfer partners in an adequate manner? ▪ Which factors support – and hinder – knowledge and technology transfer? ▪ Are the scientific results being implemented in markets, policy and society? ▪ How do the SCCERs contribute to achieving the goals of the Energy Strategy 2050?
Preparations for the permanent establishment of the SCCERs (Module 3a)	▪ Is there a need for the SCCER concept to be established on a permanent basis? What are supporting – and hindering – factors related to the permanent establishment of the SCCER concept? ▪ Are the preparatory activities sufficient to maintain the SCCER concept? ▪ What are the consequences if federal funding for the SCCERs ends after 2020? ▪ What measures are needed to retain the SCCER concept?
Collected set of indicators (Module 4)	▪ Does the current programme of SCCER monitoring collect indicators which permit the achievement of targets to be measured, and the Energy Funding Programme to be managed? ▪ Does the current programme of SCCER monitoring collect indicators that might serve as one of several foundations for a future impact analysis? ▪ Which indicators are less relevant or less informative, and thus no longer need to be collected? Do any additional indicators need to be recorded?

Table: INFRAS.

The research teams used a variety of methods to answer these questions:

- Desk research (all modules), in particular concept documents regarding the establishment of the SCCERs, SCCER monitoring documents (incl. documentation on the indicators that are collected), SCCER evaluation reports, applications made by the SCCERs, SCCER KTT concepts, and documentation on Joint Activities
- Qualitative interviews with various experts (all modules)
- Online survey aimed at implementation partners (Module 2)
- Case studies of collaboration in Joint Activities (Module 3b).

The findings of the modules and corresponding recommendations are summarised below on the basis of the individual reports (Sections 2 to 5). Overarching conclusions are then drawn, and recommendations formulated for the attention of the Steering Committee and Innosuisse.

2. Networking and (interdisciplinary) collaboration

Module 3b analysed interdisciplinary collaboration in SCCERs and in Joint Activities[9]. Based on the report produced by Prognos (2019), the key findings and recommendations are presented below.

2.1. Key findings

SCCER funding has led to closer collaboration in energy research. However, the sustainability of that collaboration is uncertain.

Collaboration in SCCERs has evolved during the two funding periods:

- During the first funding period (2013–2016), mutual understanding, learning and trust were established. They constitute the basis for the more applied and focused research activities of the second phase.
- The second funding period (2017–2020) has been characterised by more targeted and closer collaboration between institutes and disciplines. A network of researchers and institutes has developed. The transfer and exchange of knowledge and data are also supported. Collaboration is increasing in line with the growing maturity of development applications: as technologies become more mature, there is a growing need to for different scientific disciplines to work together. In addition to collaboration between natural and technological sciences, socio-economic sciences are becoming more important. They enable a reality check and provide important input for the development of diffusion strategies for technologies or new models for energy and mobility use. Joint work and projects now take a more systematic approach, thus supporting the Energy Strategy 2050.

Therefore, the SCCERs provide a framework supporting collaboration. Access to other researchers becomes easier, the funding of common projects is facilitated and, as the principal outcome, energy research networks have been established. These networks are often based on personal contacts and SCCER-funded projects. They shorten the pathway to partners by providing fast and easy access to a significant pool of knowledge and researchers, giving them the opportunity to work on a common project, and an incentive to apply and work together.

[9] In the second funding period (2017–2020), Innosuisse is providing CHF 7.7 million to support six Joint Activities: the Scenario & Modelling Initiative, Coherent Energy Demonstrator Assessment (CEDA), a white paper on the outlook for power to product technology in Switzerland, the socio-economic and technical planning of multi energy systems, integrated development processes for hydropower and deep geothermal projects, and the evolution of mobility: a socio-economic analysis (https://www.innosuisse.ch/inno/en/home/thematische-programme/foerderprogramm-energie/joint-activities.html).

In addition, the SCCERs provide discussion platforms where researchers from different disciplines and institutes can share with and learn from each other. In particular, the SCCERs create more openness to cooperation, especially between researchers from disciplines that were previously considered too distant from each other. New impetus is gained and research perspectives widened. More and more young researchers are gaining access to the individual networks. Also, a step towards the institutionalisation of networks and collaboration is achieved, since access is distributed across several heads, and consequently depersonalised.

A necessary condition for the sustainability of the SCCERs' success in collaboration is understanding working together as a state of mind, and an integral part of systemic energy research. The increasing multidisciplinarity of work packages, and the greater institutionalisation of networks and collaboration, are signs of this development. The sustainability of the collaboration that has been achieved is highly uncertain, however:

- The first obstacle is the lack of funding opportunities for interdisciplinary research, and especially the expiry of SCCER funding. It is broadly expected that cooperation will decline after financing of the Energy Funding Programme ends. Without financial resources, only few researchers will still be actively involved in the networks. Researchers will have to leave their institutes or change their research topics for funding reasons. Regional proximity or technical dependency may well support ongoing collaboration, but not the current degree of diversity.
- The second obstacle is that interdisciplinarity is hardly rewarded by existing funding schemes and the discipline-based organisation of science. Funding opportunities are largely oriented towards mono-disciplinary work. Therefore, it is hard to motivate researchers for interdisciplinary collaboration. Overall, developing such partnerships is time-consuming and challenging, and (professional) benefit is hard to gain.

Collaboration between different types of higher education institution (HEI) has been strengthened. Universities of applied sciences, in particular, benefit from a partnership of equals.

Collaboration between different types of HEI has increased since the first funding period. Universities of applied sciences (UAS) are now closely involved in partnerships with the ETH Domain and play a significant role. The visibility of their skills and capacity has increased, demonstrating the benefits of collaboration. UAS are now perceived as independent partners, with individual profiles and research and development capabilities. Additionally, they contribute by lending impetus broadening the research scope. The incorporation of the UAS can therefore be seen as a significant benefit of the Energy Funding Programme in building up an

energy research community including all types of HEI. This is a sign of a greater systemic perspective for energy research.

Nevertheless, there is little to no demand for collaboration across the boundaries of the SCCERs, or their institutes. This is because the research of the SCCERs is organised into work packages, and the respective resources are often available inhouse.

Joint Activities support multidisciplinary and interdisciplinary collaboration.
Joint Activities are used as a platform for intensive dialogue, the exchange of approaches and data, and the integration of research findings. They bring together institutes and researchers from different disciplines to examine a focused task. Therefore, they support multidisciplinary and interdisciplinary collaboration.[10]

Joint Activities deepen the SCCER approach in a more concrete and focused way, offering an increasingly sophisticated means of transferring and sharing knowledge and data. A shift from multidisciplinarity to interdisciplinarity is possible, and has sometimes been realised. Aspects often highlighted in this regard are an injection of new impetus, and the broadening of research perspectives.

Joint Activities imply more multidisciplinary and interdisciplinary collaboration than SCCERs, thus incorporating researchers from different disciplines in one team.
Joint Activities function as an effective conduit, strengthening personal contacts and recognising collaboration as a state of mind. They organise work in a more inclusive approach and can be regarded as forging a bond between researchers and institutes. Working in Joint Activities encourages various researchers from very diverse backgrounds and labs to be more open, to lead intensive discussions, to share their results and data, to combine models, and to work on a common language and thus on a common understanding. Therefore, Joint Activities strengthen the success of SCCERs in collaboration.

2.2. Recommendations

There are two kinds of recommendations to ensure the SCCERs benefit from interdisciplinary collaboration:

[10] Interdisciplinary collaboration differs from multidisciplinary collaboration in the degree of integration: while in the case of multidisciplinary collaboration, exchange takes place above all with regard to the research findings, interdisciplinary collaboration is shaped through the development of a shared approach and a common effort towards producing those findings (Prognos 2019).

1. Platform for communication and networking

The network built at the personal level within the SCCERs and the Joint Activities should be further institutionalised by the participants, so that entire institutes benefit. Therefore, it is advisable to maintain the SCCERs as a common platform for communication and networking:

- The SCCERs themselves should be active in ensuring and fostering communication between the institutes. The motivation to collaborate should come from the awareness that successful and innovative approaches require cooperation. The SCCER participants should understand energy research from a systemic perspective, thus supporting the Energy Strategy 2050.
- Additionally, individual communication and networking activities could be funded in the future in order to provide broad access for researchers.

2. Funding schemes for interdisciplinary/transdisciplinary collaboration

Funding agencies should design funding schemes to encourage interdisciplinary approaches, research and development. One option could be to make interdisciplinary cooperation a selection criterion; another would be to specifically fund interdisciplinary components within research projects.

In view of the growing maturity of development applications, there is a corresponding need for more interdisciplinarity and transdisciplinarity. A coordinated approach, including organising meetings between research institutes and industry, might also help secure the involvement of the private sector as an additional funding possibility.

3. Implementation of scientific results

Module 2 analysed the implementation of scientific results in markets, politics and society. Based on the report produced by EBP and IRENE (2019), the key findings and recommendations are presented below.

3.1. Key findings

In general, the SCCERs plan and implement transfer measures in an adequate manner.

The transfer measures of the SCCERs cover three different aspects of KTT:

- Support with finding and establishing a partnership with relevant implementation partners
- Support for KTT during the project (e.g. help with collaborating effectively, using technical infrastructure or filing patent applications)
- Non-specific KTT measures as one-day courses, papers/publications, workshops, education and training, etc.

Module 2 took the objectives of the SCCERs and KTT concepts as a basis and evaluated whether or not the measures a) correspond to the objectives, and b) are adequately implemented and effective:

- At the general level, the measures instituted by the SCCERs correspond to the objectives of the KTT concepts.[11] Most measures by KTT units focus on the first aspect of KTT, i.e. finding and establishing collaboration. These activities include innovation, thematic and matchmaking workshops, KTT platforms, surveys among industry partners, and market research, for example). The KTT units play only a supporting role in this task. It is mostly the researchers themselves who are approached by partners, or themselves win over partners and establish collaboration.
- An indication of whether or not measures to find and establish collaboration are adequately implemented is how joint endeavours have developed within the SCCERs. The results show that there is an ongoing increase in the number of contacts between researchers and the private sector. Nearly a third of all collaborations have become a long-term relationship. The manner in which researchers and institutes work together has moved slightly forward, towards market implementation. KTT officers and researchers are active in finding

[11] All SCCERs have a KTT concept. However, the objectives of KTT activities are only vaguely formulated. They describe general aims such as maintaining dialogue between research and the private sector, establishing partnerships with new research and implementation partners, the transfer of R&D results into industry, the implementation of P&D plants, and flagship projects. In some concepts, the planned measures are described as a detailed list of activities to be implemented, in others they are only implied in the form of responsibilities of the KTT officer.

implementation partners and establishing cooperation. Judging by the contacts established, as well as by the measures and activities reported, the implementation of transfer measures can be considered adequate.

- Most of the measures have an impact which is difficult to measure. That said, the importance of the SCCERs' networking activities in establishing contacts for collaboration projects, the importance of collaboration for knowledge enrichment for companies and research institutes, and the progress made by industry partners, as a result of SCCER participation have all been confirmed.
- Where the second aspect of KTT is concerned – support for KTT during the project – the SCCERs are not very active. However, this is not as important a factor, as such services are already provided by the higher education institutions, and the ongoing projects already produce relevant progress in innovation phases.
- Non-specific KTT measures were almost impossible to assess in terms of their adequacy and effectiveness, as they cover a wide range of very different measures (publications, workshops, education and training, exchange with authorities, and surveys, etc.) that are not specifically mentioned in the objectives. Nevertheless, there are indications that continuous but non-specific exchange between research and the private sector is considered as important, in particular regarding. a better overview of the research landscape in general, as well as easier access to potential partners among research institutes.

Overall, the SCCERs have involved the right transfer partners in an adequate manner.

KTT officers and researchers are generally satisfied with the involved partners. Some KTT officers pointed out that they would have preferred more large companies with a larger potential impact in the energy sector. However, some of the large companies that were approached were not motivated. Some researchers would have generally liked to find more implementation partners, but this was not possible because of unfavourable market conditions in their fields which made companies reluctant to invest in an innovation project at all. The survey shows that implementation partners mostly see themselves as motivated, having access to market and an impact in the energy sector. However, willingness to invest and take risks is the most critical of the four aspects, and is not always present.

KTT officers are confident that the partners were involved in an adequate manner, as there are different collaboration options to choose from (expertise, financial contribution, with infrastructure and manpower, data and models, technology, or support with communications). Another indication of adequate involvement is that many transfer partners have been cooperating for many years. Only a very small proportion withdrew from the partnership ahead of schedule. Implementation partners are generally satisfied with research collaboration, and

they feel their involvement is adequate. The intensity of collaboration is appropriate, and the allocation of tasks and roles is mostly clear. They also find that research partners understand their needs well or very well.

The most important supporting factors for KTT are practice-oriented problems, products with a high TRL and the implementation of pilot and demonstration (P&D) projects, combined with personal engagement and small teams. The greatest obstacles are unfavourable market conditions, as well as a technology that is far from being competitive, and the lack of flexibility to adapt projects.

The supporting and hindering factors for knowledge and technology transfer can be classified into programme, collaboration, and market factors (see Table 4).

Table 4: Supporting and hindering factors for knowledge and technology transfer

Type of factor	Supporting factors	Hindering factors
Programme factors	▪ Low administrative burden (for project applications and especially monitoring and reporting) for SCCER collaboration projects ▪ Clustering of energy research in SCCERs, as this facilitates access for interested companies	▪ The lack of flexibility for necessary project adaptions along the way (owing to the annual funding allocation cycle) ▪ The administrative burden (for some small/ medium-sized enterprises)
Collaboration factors	▪ Networking and personal contact, as well as a continuous dialogue with the early involvement of industry partners ▪ Personal engagement and small, manageable teams are crucial for implementation and research partners ▪ Practice-oriented problems on a very concrete level are most successful, as well as products with high TRL and the implementation of P&D projects ▪	▪ Cultural differences between academia and enterprises: companies find that researchers are sometimes focused too strongly on publications and not enough on market implementation ▪ Ruptures in the innovation process (e.g. owing to PhD students leaving the research institutes) ▪ Unclear situations about intellectual property ▪ High coordination costs for cooperation if too many partners are involved
Market factors	▪ Favourable regulatory and market conditions, because they are the basis of companies' commercial interest, and thus their motivation to develop and invest in new technologies, products and services	▪ If market conditions are unfavourable and a technology is far from being competitive, companies are not willing to take risks and invest (strong hindering factor) ▪ A general absence of willingness to invest and to take risks and/or lack of ability to pay for R&D (especially in smaller and medium-sized companies)

Table INFRAS. Source: EBP and IRENE 2019.

The number of prototypes and P&D plants is increasing with the progress of the Programme. However, there are only few projects that have already been implemented on the market. Scientific results appear to have little influence on policy and society.

The most frequent outputs of the SCCERs are models and data (57% of overall outputs). The implementation of prototypes and P&D plants comes in second place (27%). Only selected SCCERs applied for patents to push them to market (9%). Outputs that are closer to market implementation, such as innovative processes, products and services, were rarely achieved (together 4%). The creation of spin-offs accounts for about 3%. The number of prototypes and P&D plants has increased with the progress of the Energy Funding Programme. Implementation partners consider research institutes to be important collaboration partners, but mainly for early innovation phases, and not at the market implementation stage.

According to the implementation partners, approximately one fifth of the SCCER collaboration projects have a qualitative impact on the market. In two fifths of the projects the impact is unclear yet. Impact on market includes for example attention from potential customers as well as sensitisation and increasing the visibility of new technologies or concrete energy reduction. Market impact has been achieved through P&D plants, efficiency measures (in buildings, mobility, industry processes, etc.), and the development of tools and IT solutions to optimise process flows. Examples of projects with a direct impact were the Pinch Analyses and recommended measures for companies, and technical optimisations in hydropower plants. Start-ups, as well as education and training in general, are considered important long-term impacts on the market.

Elements that might have had an impact on policy are white papers, greater awareness about first success stories or demonstration plants. Most of the implementation partners consider their political influence to be very small and agree that the ultimate effects are difficult to assess. The impact on society is estimated to be even more difficult to evaluate. Most SCCERs do not see themselves as responsible for having a specific additional impact on society other than what they promise with regard to energy.

To date, the contribution of the projects to the objectives of the Energy Strategy 2050, in terms of energy savings or the installation of renewable energies, has been very small.

According to the implementation partners, approximately 15% of the projects have already had a quantitative impact, and in 30% it is unclear. Quantitative impact in this context means impact on the concrete level of kWh of energy being saved or renewable energy being installed. Most stakeholders think it is unreasonable to expect a major direct impact after such a short time. KTT and market launch both take a long time. To date, specific energy savings have been realised for individual pilot plants and some examples of market launches. Many of the SCCERs'

(KTT) activities are aimed at ensuring that the new technologies and findings are adopted by companies, and can thus unfold their energy-saving potential.

3.2. Recommendations

Up to the end of the second funding period in 2020, Innosuisse should step up its efforts to communicate findings to relevant stakeholders and policy-makers, as well as to the broader public, so that the knowledge gained so far is not lost. This is especially important if no similar follow-up funding programme is planned. Ideas for communication measures include wrap-up events for each SCCER, with research highlights, easy-to-read publications in German and French, and presentations about company success stories to motivate other companies to find out about the research that has been done, and get involved in their own collaboration projects.

The following recommendations refer to the implementation of a possible new funding programme (see Table 5):

Table 5: Recommendations with regard to a possible new funding programme

Area	Recommendations	Explanations
Design funding to fit the type of research	Innosuisse should reduce third-party funding requirements for technologies that are not competitive today but may be important for the future energy system.[12]	In cases where the technology is not competitive today, it is difficult for acquire third-party funds, even if the technology may prove important in the long term.
	Financing from Innosuisse should not only target the development of technologies in Switzerland but also include the implementation of foreign technologies in the Swiss context.	Today, the funding criteria are focused on the development of technology. In some sectors, Switzerland has no or not enough technology-providers (e.g. gasification, lithium batteries), but many technology-implementing partners, who can less easily benefit from SCCERs.
	Innosuisse should consider and examine new support mechanisms for the implementation of new technologies, such as funding insurance for early adopters.	In some sectors the risks of being the first to implement a new technology can be very high (e.g. in the building sector). This means that technology is not applied, or applied much too slowly.
	Innosuisse should permit more flexibility for changes in projects over one programme phase. Adjustments and extensions should be accounted for in the design of the funding scheme.	Many interviewees pointed out that, while it is possible to plan research several years ahead as required in the application phase, it is not realistic that such plans always still make sense a year or two into the research.
Impose funding requirements	Innosuisse should require annual reports to be published in German and French so that they can be more easily read by the target groups.	In one SCCER researchers realised that their white paper was not widely received until they reduced its extent and translated it into other national languages.

[12] Third party funds means non-federal funds, i.e. industry and others (including EU and UN funding, and industry funding for R&D projects).

Area	Recommendations	Explanations
that strengthen KTT	Innosuisse should demand that the type and scope of collaboration, the roles of the involved partners and the outputs and benefits of the cooperation are described in the application.	Several companies reported that they had not understood what was expected from them as implementation partners, and what benefits could be expected from collaborating with an SCCER.
Teaching the essentials of successful collaboration	Innosuisse should draft a manual to be distributed with a call or a positive decision, or alternatively initiate knowledge-sharing sessions in each SCCER together with the KTT officers.	The majority of the supporting and hindering factors mentioned concerned collaboration between partners (e.g. clarification of expectations, etc.).
Increasing qualitative impacts by providing more financial resources for soft factors	At the general level, Innosuisse should increase specific resources for KTT measures and extend them to the SCCER collaboration project level. Thus, a part of the financial contribution for a project would be specifically set aside and could only be used for such measures.	It is difficult to gain funding for soft factors (i.e. efforts needed to develop interdisciplinary cooperation). Thus, such activities are often neglected in the scientific world. This weakens KTT.

Table INFRAS. Source: EBP and IRENE (2019).

4. Preparations for the permanent establishment of the SCCERs

The Energy Funding Programme aims to achieve the long-term expansion of research capacity and the sustainable optimisation of the structures of energy research. The SCCER concept is intended to be continued on a sustainable basis in the long term and to make significant contributions to the Energy Strategy 2050 objectives (see Section 1.1). In our understanding, the continuation of the SCCER concept comprises the following aspects (INFRAS and EBP 2018):

- Capacity: maintaining the research capacity that has been established by the participating higher education Institutions (HEIs), and self-financing for management positions.
- Coordination: the continuation of SCCERs with a common organisational structure and common thematic orientation.
- Cooperation: continued networking and strengthening of cooperation between various types of HEI and disciplines, and with industry.

Module 3a analysed the need for a continued SCCER concept, the preparatory activities by SCCERs, and the additional measures needed to establish the SCCER concept on a permanent basis.

4.1. Key findings

The SCCER concept creates added value and contributes positively to Energy Strategy 2050 objectives. The permanent establishment of the SCCERs is mainly dependent on the federal framework and funding.

Generally, the SCCERs are ascribed a positive overall contribution to the Energy Strategy 2050 objectives. There is broad consensus that the SCCER concept should be retained to preserve its added value. In particular, SCCER activities such as networking and collaboration, as well as the research capacity that has been established, are considered valuable. Today's SCCER structures could be changed, but their activities should be maintained.

The main supporting factors for the permanent establishment of the SCCER concept are continued funding for SCCERs, the commitment of SCCER heads and of HEIs, and successful cooperation. Successful collaborative projects during the first two SCCER funding periods, and the commitment of SCCER heads, support continued cooperation and coordination activities. Furthermore, if HEIs perceive energy research to be important and relevant, then the chances are higher that research capacity and networks will be maintained up to a certain level.

Hindering factors for the permanent establishment of the SCCER concept would be a reduction in energy research funding and the discontinuation of financial support for networks,

coordination and cooperation. A lack of proof of or available information about the added value of SCCER activities is also perceived as a hindering factor.

The preparatory activities on the part of the SCCERs, HEIs, and the federal administration that are ongoing or planned are not sufficient to maintain the SCCERs after 2020.

At the time of the empirical research (first half of 2018) there were only a few preparatory activities ongoing within the SCCERs and the affiliated HEIs. Most SCCERs were awaiting the outcome of the ongoing preparatory activities by CORE and SERI concerning the release of the new framework under the Federal Council's Dispatch on the Promotion of Education, Research and Innovation for the 2021–2024 period. The main activity on the part of the SCCERs was defining relevant topics for future energy research as an input for CORE and SERI. Some SCCERs reported a few other activities. In particular, they were striving to keep coordination and networks running. In addition, the SCCERs' research roadmaps go beyond 2020. Thus – if they are taken seriously – a part of the SCCER concept could be maintained.

The preparatory activities on the part of the SCCERs, HEIs and the federal administration that are ongoing or planned are not sufficient to maintain the SCCER concept after the second financing period. There were no activities reported or planned by SCCERs or HEIs to acquire new funding sources to replace the SCCER funds that may no longer be available. HEIs generally do not feel responsible for preparatory activities, and are consequently inactive. The federal administration has not yet required SCCERs and HEIs to report their plans or to be more proactive. Furthermore, the relatively late process of defining the new framework for energy research funding after 2020 has created uncertainty for SCCERs and HEIs that might impact negatively on the future of the SCCER concept.

If less federal funding for energy research is available after 2020, then research capacity and SCCER activity are expected to decrease.

The HEIs stated their commitment to maintaining the capacity that has been established in the form of letter of intent with their SCCER application in 2013. However, the empirical findings indicate that not all capacity can be kept if the additional federal funding for the SCCERs is no longer available after 2020:

- The established professorships are likely to be maintained. However, the research topics of these professorships could shift over time, depending on the availability of research funds.
- Alongside the professorships, research capacity is highly dependent on federal and third-party funding. Thus, whether or not to retain the research capacity in the medium and long term is not the decision of the HEIs alone. If, overall, less energy research funding is avai-

lable, this will lead to reduced capacity. This in turn will result in a general decline in energy research momentum.

- Furthermore, the empirical findings indicate that it is unlikely that the HEIs will self-finance the management activities of today's SCCERs. Consequently, coordination is expected to diminish, and cooperation will also be reduced without federal funding. However, in view of the added value for research institutes and researchers, well-established and successful partnerships, and a part of the network, are expected to be maintained.

More preparation, a federal framework, and federal funds will be needed to retain the SCCER concept after 2020.

Based on the empirical results three main measures can be identified:

- HEIs, professorships, and SCCERs should become more active to establish the SCCER concept on a permanent basis. HEIs should intensify their efforts to increase the relevance of energy research in their institutions and adopt the SCCER concept into their strategic planning. Furthermore, research projects, following the SCCER roadmaps, should be acquired continuously. The federal administration should require HEIs and SCCERs to step up such preparatory activities.
- To support intensified and better coordinated energy research, the federal administration (incl. SERI, SFOE, Innosuisse, etc.) should draw up a long-term strategy with a time horizon of at least ten years. It should define needs for additional energy research to contribute to the Energy Strategy 2050 objectives, including the direction of research towards technology readiness levels (TRLs). In addition, it should contain the need for and development of additional energy research funds, including a definition of the financing mix. For instance, HEIs should take over a higher share of management costs in the future, and acquire more third-party funds for research projects. Some funding for SCCER activities (at least in the medium term), and particularly project funding, will be needed to maintain the SCCER concept at today's level.
- The long-term strategy must be set out in a research funding instrument that is periodically updated (e.g. at four-year intervals) to redefine the focus of research, and financing parameters. A key point is that the added value of the structures and networks that have been established should be preserved. Therefore, the funding instrument should support the SCCER concept by partially financing the management of networks, and coordination, as well as by means of project funding. The challenge will be to set incentives to continue the SCCER concept, while at the same time reducing funding for SCCER activities (particularly coordination and networking). The allocation of research project funds should be based on a competitive scheme. In a framework like this, HEIs and other research partners should develop research

plans and roadmaps together, and apply for research projects. An important feature of the funding instrument is that it should be open to all potential partners and higher education institutions — including those not yet part of today's SCCERs.

4.2. Recommendations

The following recommendations emerge from the analysis:

- The path of coordinated energy research — i.e. strengthening interdisciplinarity and collaboration between different higher education institutions — should be continued. The SCCER concept creates added value and is contributing to Energy Strategy 2050 objectives.
- HEIs, professorships, and SCCERs should become more active in finding options to maintain coordination, cooperation, and newly created capacity. HEIs should intensify their efforts to increase the relevance of energy research in their institutions and adopt the SCCER concept into their strategic planning. The federal administration should demand more preparatory activities.
- The federal administration should develop a long-term strategy. It should define the needs for and principles of energy research and funding scheme development. This would support the positive development of coordinated energy research, and avoid the disintegration of SCCERs as a result of emerging uncertainties about their future framework. A research funding instrument should be defined, based on the long-term strategy. It should set out support for networks, and project funding in greater detail in terms of research focus, requirements, and available resources.

5. Collected set of indicators

One of the tasks of the Accompanying Research was to analyse whether the indicators recorded as part of the monitoring programme are suitable as a basis on which to evaluate target achievement, and to manage the Programme, with a view to a future impact analysis. One of the keys to assessing the indicators was the Energy Funding Programme logic model (see Section 1.1).

Based on the report from INFRAS and EBP (2018), the key findings and recommendations are as follows.

5.1. Key findings

The indicators gathered from the SCCERs are an important basis on which to evaluate the degree to which targets have been achieved, and to manage the Energy Funding Programme.
The indicators recorded by Innosuisse from the SCCERs provide an important basis for evaluating the degree to which the Energy Funding Programme is achieving its targets, as well as its management, with regard to the inputs, activities, and outputs of energy research. However, the indicators do not cover the effects of the research projects on market participants (outcomes) and the energy system as a whole (impacts).

The indicators gathered about the inputs, activities, and outputs of energy research are largely relevant, informative, and useful. This is particularly true of SCCER funding and capacity-building, R&D projects and their outputs, and communication and KTT work. Further positive points are the overview that the indicators offer of the SCCERs' activities, the fact that they permit the information given by the SCCERs in their monitoring reports and at site visits to be verified, that they encourage reflection, and that they are also of benefit to the SCCERs themselves. Innosuisse's decision to gather a variety of further information on the indicators, thereby aiding their interpretation, analysis and evaluation, is also positive. However, the usefulness of many of the indicators is limited by the fact that they do not directly permit conclusions to be drawn about the achievement of targets, and the impacts of the Programme.

The collected indicators serve as one of several foundations for a future impact analysis. However, the indicators do not cover the outcomes and impacts of the Programme.
The indicators collected from the SCCERs capture relevant effects of the Programme on participating HEIs and implementation partners, as well as on the findings of research and innovation projects. Where an impact analysis is concerned, various aspects of those effects should be investigated alongside the indicators, with a particular focus on cause-and-effect relationships.

However, the SCCER monitoring programme does not collect any indicators which relate to the effects of the supported research projects themselves on market participants (outcomes), or on the energy system in Switzerland and the economy (impacts).

The indicators collected from the SCCERs are sufficient.

The indicators are of differing degrees of relevance and information value in respect of an assessment of target achievement, of management, and as a basis for an impact analysis. Most indicators are nonetheless useful and fit for purpose. There is no real need to continue collecting those indicators that are of comparatively low relevance and information value (number of non-peer-reviewed articles and book chapters, and number of conference proceedings). However, they may still supply information about how the SCCERs are networked, and their transfer activities, within the research community.

The indicators that are collected from the SCCERs to assess target achievement, for management purposes, and as a basis for an impact analysis, are sufficient in our view. We therefore do not believe it is necessary to collect additional indicators. That said, it is worth considering whether or not specific additional information might be collected on a number of indicators, to raise their information value.

Additional indicators could be collected to reflect the effects of research projects on individual economic actors and on energy research (outcomes), as well as on the energy system and the Swiss economy (impacts). However, we do not believe that it makes sense to collect such indicators from the SCCERs on a regular basis. The empirical data required to evaluate outcomes and impacts should thus be gathered and analysed specifically as part of a separate impact analysis.

5.2. Recommendations

In view of the predominantly positive assessment of the indicators that are gathered periodically from the SCCERs, there is no urgent need for major changes to be made. However, the cost-benefit ratio of the indicators, and the foundations for a future impact analysis, might be improved as follows:

- If the time and cost involved in collecting the indicators is to be reduced, Innosuisse might stop gathering those indicators which are less relevant and informative.
- Innosuisse should examine whether or not specific additional information might be collected on a variety of indicators, to raise their information value. It might, for example: record the technology readiness levels (TRL) of research and innovation projects; evaluate the relevance of research and innovation projects to the achievement of the milestones set for the work

packages (or capacity areas); or review whether or not the information on funding for the SCCERs might be linked to the individual work packages (or capacity areas).

- Innosuisse might oblige the SCCERs to continue improving the quality of their indicators. In particular, they might limit them to especially relevant communication and KTT activities, and systematically review the information that the indicators are delivering to avoid overlaps. They might also interpret and analyse in greater depth how the indicators are supporting target achievement.
- Innosuisse could continue to develop and expand the foundations for a future impact analysis. This work should focus on enhancing the programme logic model, formulating indicators for the outcomes and impacts levels, designing the study, and determining the research methods that will be used to collect the empirical source data.
- As part of any future energy research support programme, Innosuisse (or another funding organisation) could essentially limit the annual collection of indicators to those required for the annual status report and management cycle. The remainder, including those on the findings of research and innovation projects, could instead be collected at intervals of several years.

6. Conclusions and recommendations

The primary conclusions and recommendations drawn from the findings of the SCCER Accompanying Research 2017–2019 are set out below.

6.1. Conclusions

The Energy Funding Programme has generated further progress in collaboration on energy research and in knowledge and technology transfer.

Compared with the first funding period (2013–2016), in the second funding period (2017–2020) the Energy Funding Programme generated further progress in collaboration on energy research and in knowledge and technology transfer:

- Exchange and cooperation between disciplines, including the socio-economic sciences, and research institutes has been strengthened further. Collaboration between different types of higher education institution has also been stepped up, with universities of applied sciences, in particular, becoming much more closely involved in energy research. The SCCERs support this collaboration by establishing and maintaining networks, and by providing incentives to work with others on SCCER projects. Multidisciplinary and interdisciplinary cooperation has become even closer through work on Joint Activities.
- Collaboration between higher education institutions (HEIs) and implementation partners[13] is one of the cornerstones of knowledge and technology transfer. Most companies and organisations attach great to very great importance to cooperation in achieving progress in the innovation process, especially in the early stages of innovation. We conclude from the growing number of contacts and collaborative projects, as well as the rise in the number of prototypes and P&D plants, that there has been a further increase in knowledge and technology transfer. The SCCERs (researchers and KTT officers) are actively committed to seeking out cooperation partners and to developing collaborative projects. Networking, personal contacts and continuous dialogue are important in involving private enterprise in this work.

The Energy Funding Programme has generated added value in energy research in terms of maximising its positive contribution to the objectives of the Energy Strategy 2050.

The Energy Funding Programme has generated added value on a number of fronts in terms of maximising the positive contribution of energy research to the achievement of Energy Strategy 2050 objectives.

[13] The implementation partners include private companies and associations as well as federal offices, cantons and municipalities.

- Firstly, Programme and third-party funding have enabled research capacity to be expanded, and have increased the scope of (applied) energy research. Since SCCER research activities follow longer-term strategies known as innovation roadmaps, they are also approached in a coordinated way and can be managed accordingly.
- Secondly, the Programme has resulted in the establishment (or strengthening) of networks between researchers themselves, as well as between researchers and implementation partners. The SCCERs have supported the growth of these networks with appropriate organisational structures, discussion platforms, and opportunities for joint projects. Many respondents judged the establishment and maintenance of the networks to be a key element of the Programme's added value. The networks are based first and foremost on personal contacts, and on joint work on SCCER projects. In some cases, networks have been institutionalised to a certain degree – in other words they have been opened up to a variety of researchers and thus depersonalised. The networks give easier access to a knowledge pool and to potential project partners.
- Thirdly, collaboration in energy research, and between research and implementation partners, has improved. Working together on specific projects results in reciprocal exchange and expansion of knowledge. Joint projects have led primarily to progress in the early stages of the innovation process (the development of ideas and business cases, technologies, prototypes, and P+D plants). Increasingly multidisciplinary and interdisciplinary research, and the greater integration of universities of applied sciences, strengthen the systemic perspective of research and its focus on practical application. This, in turn, supports the contribution that the research makes to the objectives of the Energy Strategy 2050.

However, there is still further room for improvement in both knowledge and technology transfer, and collaboration on energy research.

Strengthening collaboration in energy research and stepping up knowledge and technology transfer are both long-term processes which require time and sufficient incentives. There is still considerable room for improvement in both areas and, with it, the opportunity to maximise the contribution of energy research to the objectives of the Energy Strategy 2050:

- Progress has been made to date on interdisciplinary collaboration (in particular with socio-economic energy research), the institutionalisation of networks, and cooperation between the research institutes participating in the various SCCERs. Collaboration has not yet become a state of mind, regarded as an integral part of energy research. The principal obstacles in this regard are a lack of funding options for interdisciplinary research (especially if and when the Energy Funding Programme ends) and a lack of recognition from a research community

that is organised along mono-disciplinary lines. There is a lack of incentives to motivate institutes and researchers to engage in interdisciplinary collaboration.

- By promoting knowledge and technology transfer at the early stages of the innovation process, the Energy Funding Programme helps considerably to bridge the 'technological valley of death'.[14] There are nonetheless opportunities to improve this aspect of energy research by strengthening supporting factors (such as defining specific, practicable tasks, and personal commitment to collaboration) and eliminating the factors which currently hinder knowledge and technology transfer at these stages of the innovation process (such as a lack of flexibility to adapt projects). Nonetheless, knowledge and technology transfer has (so far) done little to support market implementation or commercialisation (or to overcome the 'commercialisation valley of death'[15]). Firstly, relatively few outputs from the SCCERs relate to innovations in the market. Secondly, knowledge and technology transfer between HEIs and implementation partners appears to be less important as the innovation process nears market readiness. Thirdly, as things stand approximately one fifth of projects are thought to have reached the market. The implementation of findings in the market is of particular importance regarding the realisation of the Energy Strategy 2050. The keys to supporting market implementation are to improve market conditions and to increase companies' willingness to invest. Many firms, particularly SMEs, do not wish to bear the risks associated with development and commercialisation, and thus hold back with investment.

Added value will decline markedly if the federal government decides not to support the expanded capacity, coordination and collaboration in energy research beyond 2020.

Respondents agree that added value will decline markedly if the Energy Funding Programme ends in 2020:

- In the absence of federal government funding for coordinated energy research, research capacity in the energy sector will contract. It cannot be assumed that HEIs will be able to make up the shortfall. Newly created professorships may continue to be financed, but their thematic focus may have to shift depending on the available resources. The research capacity financed by project funding (primarily assistants and doctoral candidates) is likely to shrink considerably. Fewer research projects will be conducted as a result, and fewer young, talented researchers trained on joint projects. Since energy research would no longer follow common, long-term strategies (known as innovation roadmaps), they would also be less coordinated with the Energy Strategy, and less easy to manage.

[14] According to Jenkins and Mansur (2011), the 'technological valley of death' refers to the phase between R&D and the development of a prototype, or proof of concept'.

[15] The 'commercialisation valley of death' refers to the phase between the P&D plant and commercialisation/maturation (Jenkins and Mansur 2011).

- It would be virtually impossible to maintain the networks that have been established. Partnerships rooted in personal relationships that promise mutual benefits would probably continue to be fostered, and would therefore survive. However, there would scarcely be any further regular, broad exchange between researchers, and between researchers and implementation partners. Furthermore, there would be no continued effort to institutionalise networking to establish closer ties with institutes and those implementation partners.
- The lack of research funding for interdisciplinary and applied energy research, as well as smaller networks, would reduce collaboration between disciplines and research institutes, as well as joint projects conducted by research and implementation partners together. A variety of obstacles affecting implementation partners, such as unfavourable market conditions, a lack of financial resources and an unwillingness to take risks, would likely make it difficult to offset a significant proportion of the lost funding for joint projects with additional funding from those implementation partners.

From the Energy Strategy 2050 perspective, the research capacity that has been established as well as coordination and collaboration in energy research should continue to be pursued and strengthened after 2020. In addition to the higher education institutions' own efforts, there is a need for a federal government funding framework that is based on a long-term strategy and includes all relevant actors.

In view of the added value it generates, further room for improvement, and the associated opportunity to maximise the contribution of energy research to the objectives of the Energy Strategy 2050, intensified and coordinated energy research should continue to be pursued and strengthened. As far as is possible, the capacity that has been established should be maintained. Coordination activities should also continue, and collaboration in energy research should be broadened and deepened.

HEIs and professorships are called upon to play their part in upholding and strengthening energy research. They should make the most of their scope for action and invest on their own initiative in the continued existence of the SCCERs:

- Firstly, HEIs should attach greater importance to energy research, draw up the corresponding strategies, and as far as possible maintain the research capacity that has been established – or at least the professorships.
- Secondly, HEIs and professorships should continue as far as possible to maintain, expand, anchor and institutionalise the structures, networks and collaborative projects with other HEIs that have already been established. Closer collaboration should be motivated by the recognition of its benefit for successful innovative approaches and solutions. It is particularly important to strengthen the systemic perspective, increase interdisciplinary collaboration,

and boost cooperation between the ETH domain, the universities and the universities of applied sciences.

- Thirdly, HEIs and professorships should step up their efforts to extend joint projects with implementation partners. Greater cooperation with these partners might increase financial and other resources, result in additional applied research projects, and improve knowledge and technology transfer. One thing that HEIs and professorships can do to strengthen cooperation with implementation partners is to maintain and expand the relevant networks, platforms and (personal) contacts. They should also focus on working with implementation partners on the basis of specific, practice-based problems to bring products and solutions with a high TRL, and P+D projects with potential future demand, to market.

The efforts that higher education institutions are able to make to maintain and strengthen energy research will not be sufficient on their own, however. In our view, a federal government funding framework will also be required in the future. It should be based on a long-term strategy:

- Firstly, the federal administration (SFOE, CORE, SERI, Innosuisse, etc.) should develop a long-term strategy to provide additional support for energy research. Based on the objectives of the Energy Strategy, this should begin by establishing the need for additional energy research, taking considerations about the direction of research according to topic and technologies/solutions, technology readiness levels (TRLs) and collaborative projects, in particular, into account. It must also determine the need for research to improve the underlying conditions for energy research, knowledge and technology transfer and, especially, market launch and commercialisation.[16] Furthermore, consideration must be given to how knowledge and technology transfer can be improved. Principles for funding and the necessary financial resources must then be defined on the basis of this needs analysis. Instead of funding research capacity, we would now envisage a project-based approach, since project funding can be structured and managed more flexibly and more specifically. It would also be open to all research institutes, including private-sector research and consulting firms. Funding should taper off as the research projects achieve greater TRL. In addition, HEIs should be supported in their efforts to maintain and expand networks and communications, such as platforms for exchange. The funding in question should be reduced over time. Moreover, it is worth looking in to how the allocation of 'regular' federal government funding in the energy sector (e.g. SFOE, Innosuisse, SNSF) might be adjusted to support the added value generated by the SCCER concept.

[16] In-depth analysis of hindering factors and possible action to improve underlying conditions (e.g. internalising external costs by means of an energy levy, and appropriate support programmes to reduce the risks associated with the market launch of new technologies, such as guarantees).

- Secondly, the long-term strategy should be set out in detail in a funding instrument, to be revised at regular intervals. The funding instrument should include financial support for the management of networks and communication activities in order to promote collaboration in energy research, as well as between HEIs and implementation partners. It should also define project funding, which should be allocated in a competitive process. Possible criteria for project funding might be the focus of research (topics/technologies, TRL or underlying conditions), expectations in terms of cooperation, and requirements for financial involvement on the part of implementation partners. Additional funding (or bonuses) for special achievements in interdisciplinary collaboration and/or knowledge and technology transfer might also be awarded at project level. The funding instrument should be updated on a regular basis with regard to research focus and financial criteria. In the interests of managing funding, and reporting, monitoring based on indicators and other factors should be backed up by a periodic impact analysis.

6.2. Recommendations

While considering that the Accompanying Research focused on four specific areas, and did not undertake any comprehensive evaluation of the output, effects and cost/benefit relationships of the energy research supported by the Energy Research Programme, the following recommendations for the post-2020 phase:

1. In the interests of maximising the contribution of energy research to the objectives of the Energy Strategy 2050, the higher education institutions participating in the SCCERs, and the federal government, should commit to continuing research capacity and strengthening coordination and collaboration in energy research in the long term.
2. The HEIs participating in the SCCERs should attach greater importance to energy research, draw up the corresponding strategies, and as far as possible maintain the research capacity that has been established.
3. The HEIs and professorships participating in the SCCERs should make the most of their opportunities to work with other research institutes and implementation partners to maintain, extend, deepen and perpetuate the networks, exchange platforms and cooperation projects that have been established.
4. The HEIs and professorships participating in the SCCERs should step up their efforts to launch further research projects with implementation partners. In addition to more intensive networking, they should respond specifically to their partners' research needs.
5. Irrespective of any future funding instrument, the federal administration should support HEIs with the continuation and expansion of networks and cooperation projects with implementation partners, for example with targeted grants for structures and activities. At the

same time, the administration should demand more preparatory activities on the part of HEIs in the interests of maintaining capacity, coordination and collaboration in energy research. In addition, it is worth looking in to how the allocation of 'regular' funding in the energy sector (e.g. SFOE, Innosuisse, SNSF) might be adjusted to support the added value generated by the Energy Funding Programme more effectively.

6. The federal government should develop a long-term strategy to provide additional support for energy research. Drawing on the objectives of the Energy Strategy 2050, this strategy should define the additional need for energy research (including the underlying conditions and knowledge and technology transfer), as well as principles for funding. Here, we recommend a combination of competition-based project funding and support for networking, including communications. Over time it should be possible to reduce the funding provided by the federal government and increase the resources supplied by the HEIs and implementation partners themselves.
7. Based on the long-term strategy, the federal administration should draw up a funding instrument that sets out support for networking (and communications), and competition-based project funding in greater detail in terms of research focus, requirements, available resources, etc. This should be updated periodically, e.g. every four years. Monitoring should be backed up by periodic impact analyses to manage the funding, and for communication purposes.

Abbreviations

CORE	Federal Energy Research Commission
HEI	Higher Education Institution
KTT	Knowledge and Technology Transfer
P&D	Pilot and Demonstration
R&D	Research and Development
SCCER	Swiss Competence Centers for Energy Research
SERI	State Secretariat for Education, Research and Innovation
SFOE	Swiss Federal Office of Energy
SNSF	Swiss National Science Foundation
TRL	Technology Readiness Level
UAS	University of Applied Sciences

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