

Report

SCCER Accompanying Research 2017–2019

Module 3b: “Networking and (interdisciplinary) collaboration”



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collaboration”

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List of Abbreviations

BIOSWEET	Biomass for Swiss Energy Future (SCCER)
CEDA	Coherent Energy Demonstrator (JA)
CORE	Commission fédérale pour la recherche énergétique
CREST	Competence Center for Research in Energy, Society and Transition (SCCER)
CREST-Mob	The Evolution of Mobility: A Socioeconomic Analysis (JA)
CREST-SoE	Integrated Development Processes for Hydropower and Deep Geothermal Projects: Regulatory, Political and Participatory Perspectives (JA)
CTI	Commission for Technology and Innovation
EIP	Efficiency of Industrial Processes (SCCER)
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt
EPFL	École polytechnique fédérale de Lausanne
ETHD	Domain of Eidgenössische Technische Hochschule
FEED&D	Future Energy Efficient Buildings & Districts (SCCER)
FOS	Fields of Science and Technology
FURIES	Future Swiss Electrical Infrastructure (SCCER)
HEI	Higher education institution
HSLU	Hochschule Luzern
JA	Joint Activity
MOBILITY	Efficient Technologies and Systems for Mobility (SCCER)
OECD	Organisation for Economic Cooperation and Development
P2X	White Paper on the Perspectives of P2X Technology in Switzerland (JA)
RED	Socioeconomic and Technical Planning of Multi-Energy Systems (JA)
SaM	Scenario and Modelling (JA)

SCCER	Swiss Competence Center for Energy Research
SoE	Supply of Electricity (SCCER)
STORAGE / HaE	Heat Electricity Storage (SCCER)
UAS	University of Applied Sciences
UNI	University
VSE	Verband Schweizerischer Elektrizitätsunternehmen
WP	Work Package
ZHAW	Zürcher Hochschule für Angewandte Wissenschaften

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- Prognos (2016) SCCER Accompanying Research Module 2: Interdisciplinary collaboration. Basel.

Summary

Collaboration in the SCCERs took place in two phases. Phase I, from 2013 to 2016, can be described as “finding each other & getting to know each other”. The ongoing Phase II can be described by the keywords “consolidation” and “the impact of collaboration”. Collaboration has also evolved between the two phases. The first phase helped the partners to establish mutual understanding, learning and trust. These important aspects constituted a basis for the more focused, more technical research activities during the second phase. The second phase has been marked by broader and deeper collaboration among institutes and across disciplines, as well as collaboration among different types of higher education institution (HEI). UASs in particular have benefitted within this partnership of equals. UASs are now perceived as independent partners with individual profiles and capabilities for research and development. Additionally, they contribute by spurring on current efforts and broadening the scope of research. The incorporation of the UASs can therefore be seen as a significant benefit of the SCCER funding scheme for developing an energy research community that could incorporate all types of HEI. The development of this collaboration has been harnessed to the maturing of developed applications: as technologies come closer to being deployed outside the lab, the need to collaborate across different scientific disciplines increases. Even at first glance, this applies to natural and technological sciences. However, socio-economic sciences are also becoming more important. Collaborative work and projects are taking a more systemic perspective, thus supporting Switzerland’s “Energy Strategy 2050”.

In sum, SCCERs have provided a framework that supports collaboration, and they have led to deeper collaboration in energy research. SCCERs have strengthened and intensified collaboration among different disciplines: access to other researchers has become easier, and the funding of common projects has increased; the main result of this has been the establishment of research networks in the field of energy. These networks have often been based on personal contacts and SCCER-funded projects. They shorten the way to finding partners (thus lowering transaction costs) by providing easy and fast access to a significant pool of knowledge; they also give researchers opportunities to work on joint projects, and incentivise them to apply for funding and work together. SCCERs also provide crucial discussion platforms, where researchers from different disciplines and institutes can exchange ideas and learn from each other. In particular, it is important to highlight the fact that SCCERs create more openness to cooperation, especially between researchers from disciplines that were previously considered to be too distant for collaborations. This means new sources of motivation and wider research perspectives. One particularly important aspect is that more and more young researchers are gaining access to these networks. Moreover, the SCCER programmes have facilitated the institutionalisation of networks and collaboration, since access is distributed across multiple heads in different fields of research. This in turn makes it less reliant on personal connections. One necessary condition that has sustained SCCER’s success in collaboration has been to understand collaboration as a state of mind, as an integral part of systemic energy. One way this has happened is through SCCER’s Joint Activities. These take a more inclusive approach to organising work, and can be seen as the “glue” between researchers and institutes. Working on Joint Activities encourages various researchers from highly diverse backgrounds and labs to be more open, to lead more intensive discussions, to more freely exchange their results and data, to combine models more creatively, and to work more often with a common set of terminology and thus on a common understanding.

Nevertheless, the sustainability of collaboration without funding is highly uncertain. Alternative funding for multidisciplinary cooperation is sorely lacking; funding possibilities are largely oriented to work within a single discipline. This means that researcher positions and projects will run out of funding possibilities after SCCER's Phase II. It is widely expected that the cooperation that has been achieved so far will decline or even collapse after SCCER financing dries out. This perception has been reinforced by the knowledge that interdisciplinary work is challenging, but (professional) benefits from it are hard to obtain.

In short, there are two kinds of recommendations to ensure the SCCER benefits continue to flow:

1. Platform for communication and networking.

The network of energy research in Switzerland must be institutionalised by the SCCER participants themselves. Therefore, it is advisable to maintain the SCCER as a common platform for communication and networking. SCCER itself should be active in ensuring and fostering communication among the various institutes. In this case, the driving factor is not funding but the need for expertise or another perspective to solve a problem or to improve research and their impacts. The SCCER participants should emphasise an understanding of energy research in a systemic perspective (thus supporting the Energy Strategy 2050) in their own institutes. Additionally, Innosuisse and other Swiss funding agencies should discuss funding possibilities to support a framework, e.g. conferences to support ongoing maintenance and development of the energy research community as a communication and networking platform/framework.

2. Funding arrangements for interdisciplinary/transdisciplinary collaboration

Funding agencies should discuss new funding schemes to encourage interdisciplinary approaches in research and development, and ways to lower the risks of interdisciplinary collaboration (in terms of time and effort). For example, one requirement to obtain funding could be to demonstrate interdisciplinary cooperation within a project, or additional funding could be set aside for interdisciplinary components and the incorporation of collaboration into research projects. As a given technology comes closer to having widespread utility (which we refer to as “deployability” throughout this text), the need for interdisciplinarity and transdisciplinarity is rising as well. One possible approach could include bringing research institutes and the private sector together to engage with each other, including as a possible additional source of funding.

Zusammenfassung

Die (interdisziplinäre) Zusammenarbeit der SCCER erfolgte in zwei Phasen. Die erste Phase (2013-2016) kann als "Kennenlern-Phase" beschrieben werden. Die daran anschließende zweite Phase lässt sich mit den Schlagwörtern «Konsolidierung» und «Vertiefung» charakterisieren. Zwischen den beiden Phasen hat sich die Zusammenarbeit weiterentwickelt. Während der ersten Phase wurde das gegenseitige Verständnis, Lernen und Vertrauen zwischen den Akteuren aufgebaut. Damit wurde der Grundstein gelegt für die anwendungsorientierten und (themen)fokussierten Forschungsaktivitäten der zweiten Phase. Diese Phase ist durch mehr und vertiefte Zusammenarbeit zwischen den beteiligten Einrichtungen und wissenschaftlichen Disziplinen gekennzeichnet. Dabei wurde die Zusammenarbeit zwischen den unterschiedlichen Typen der Höheren Bildungseinrichtungen (Higher Education Institutions, HEI) gestärkt. Insbesondere trifft dies auf die Fachhochschulen (Universities of Applied Sciences, UAS) zu. Sie haben im Forschungssystem erheblich an Sichtbarkeit gewonnen und werden nun als gleichwertige Partner mit individuellen Profilen für Forschung und Entwicklung wahrgenommen. Entsprechend geben sie neue Impulse bzw. erweitern den Rahmen für FuE-Aktivitäten. Die stärkere Sichtbarkeit und Einbeziehung der UAS kann daher als ein wichtiger Nutzen der SCCER-Förderung zur Entwicklung einer umfassenden, alle HEI-Typen einbeziehenden Energieforschungsgemeinschaft in der Schweiz angesehen werden. Die Entwicklung der Zusammenarbeit steht in engem Zusammenhang mit der zunehmenden Anwendungsreife der Forschungs- und Entwicklungsergebnisse: Mit ihr wächst der Bedarf und die Bedeutung der Zusammenarbeit unterschiedlicher wissenschaftlicher Disziplinen. Auf den ersten Blick betrifft dies insbesondere die Zusammenarbeit von Natur- und Technikwissenschaften. Darüber hinaus wächst aber auch die Bedeutung der sozio-ökonomischen Disziplinen. Insgesamt fördert die Zusammenarbeit damit den Blick auf das System bzw. die Systemperspektive und unterstützt auf diese Weise die Umsetzung der Schweizer Energiestrategie 2050.

Die SCCER haben den Rahmen für die Zusammenarbeit in der Energieforschung geschaffen und zu ihrer Vertiefung beigetragen. Sie stärken und intensivieren die interdisziplinäre Zusammenarbeit. Der Kontakt und Zugang zu anderen Forschern und deren Institutionen wurde vereinfacht und Hürden für kooperative Forschungsprojekte abgebaut sowie die Finanzierung gemeinsamer Projekte erleichtert. Als eine weitere wichtige Wirkung entstanden Energieforschungs-Netzwerke bzw. wurden erweitert. Diese Netzwerke basieren in der Regel auf persönlichen Kontakten und SCCER-geförderten Projekten. Sie verkürzen den Weg, neue und geeignete Kooperationspartner zu finden, senken damit den Transaktionsaufwand durch einen vereinfachten und schnellen Zugang zu einem bedeutsamen Wissens- und Erfahrungs-Reservoir. Für die beteiligten Forscher erweitern sich damit die Möglichkeiten, gemeinsam und aus unterschiedlichen Perspektiven an Fragestellungen zu arbeiten. Darüber hinaus bilden die SCCER Diskussionsplattformen, in denen sich Vertreter unterschiedlicher Disziplinen und Einrichtungen austauschen und voneinander lernen können. Hervorzuheben ist, dass mit den SCCER bei den beteiligten Wissenschaftlern die Offenheit für die Zusammenarbeit unterschiedlicher, vormals als weit voneinander entfernt wahrgenommener wissenschaftlicher Disziplinen geschaffen wurden. Damit wurden neue Impulse gesetzt sowie die disziplinären Perspektiven geöffnet. Die SCCER ermöglichen und stärken zudem insbesondere für Nachwuchswissenschaftler den Zugang zu den Netzwerken. Auch die Institutionalisierung der Netzwerke und Zusammenarbeit wurde durch die Öffnung des Netzwerkzugangs unterstützt, da die Abhängigkeit von einzelnen Personen («Gate Keeper») gesenkt wurde. Eine wichtige Voraussetzung für die Verstetigung der Zusammenarbeit ist das Verständnis von interdisziplinärer Zusammenarbeit als Einstellung («State of Mind») und wesentlicher Bestandteil einer systemisch orientierten Energieforschung. Die Joint Activities stärken die Kooperationserfolge der

SCCER wesentlich. Sie intensivieren die Zusammenarbeit mit umfassenderen Ansätzen und bilden ein Bindemittel («Klebstoff») zwischen Forschern / Einrichtungen. Die Arbeit in den Joint Activities fördert die Offenheit der Forscher aus unterschiedlichen Disziplinen und Einrichtungen für intensive Diskussionen, für den Austausch ihrer Ergebnisse und Daten sowie die gemeinsame Arbeit an Modellen ebenso wie die Entwicklung eines gemeinsamen Verständnisses bzw. einer gemeinsamen Sprache.

Die Aufrechterhaltung der Zusammenarbeit ohne weitere Förderung ist unsicher. Generell wird das Fehlen von Fördermöglichkeiten für multi-disziplinäres Arbeiten angemerkt. Die vorhandenen Förderansätze konzentrieren sich weitgehend auf Projekte aus einzelnen Disziplinen. Mit dem Ende der zweiten SCCER-Förderphase laufen damit in der Regel die Finanzierungsmöglichkeiten für die wissenschaftlichen Mitarbeiter-Stellen sowie die angestossenen Projekte aus. Daher wird erwartet, dass sich die bisher erreichten Kooperationserfolge abschwächen oder sogar verschwinden werden. Unterstützt wird diese Auffassung dadurch, dass interdisziplinäre Zusammenarbeit hohe Anforderungen stellt, aber selten mit der entsprechenden Anerkennung im eigenen wissenschaftlichen Umfeld einher geht.

Zusammenfassend werden zwei Empfehlungen zur Sicherung der SCCER-Erfolge hinsichtlich der interdisziplinären Kooperation ausgesprochen:

1. Kommunikations- und Netzwerkplattform

Das Netzwerk der Schweizer Energieforschung sollte durch die SCCER-Teilnehmer selbst institutionalisiert werden. Die SCCER sollten daher als gemeinsame Kommunikations- und Vernetzungsplattform beibehalten werden. Sie sollten dazu Aktivitäten entwickeln, um die Kommunikation zwischen den beteiligten Einrichtungen zu sichern und auszubauen. Wesentlicher Ansatzpunkt ist dabei die Notwendigkeit, neue bzw. ergänzende Expertise und Perspektiven für die Bearbeitung von Forschungsfragen aufzunehmen. Dies wird dann befördert, wenn Energieforschung aus einer systemischen Perspektive verstanden und damit die Energiestrategie 2050 unterstützt wird. Dieses Verständnis muss aus den beteiligten SCCER selbst entstehen bzw. weitergetragen werden; es ist unabhängig davon, ob bzw. welche Finanzierungsquellen zur Verfügung stehen. Dennoch sollte ergänzend von den Schweizer Förderagenturen diskutiert werden, welche Fördermöglichkeiten zur Unterstützung der Kommunikation und Netzwerkpflge wie zum Beispiel Kongresse bereitgestellt werden können, um die mit der SCCER-Förderung entstandene Gemeinschaft der Energieforschung in der Schweiz als Plattform zu sichern.

2. Förderangebote für inter-/transdisziplinäre Zusammenarbeit

Die Schweizer Förderagenturen sollten darüber hinaus diskutieren, ob und welche Fördermöglichkeiten speziell für interdisziplinäre Ansätze in Forschung und Entwicklung bzw. zur Minderung der damit verbundenen Risiken (namentlich der höhere Zeitbedarf und Aufwand) entwickelt werden können. So könnte zum Beispiel die Förderung zur interdisziplinären Zusammenarbeit verpflichtend oder zusätzliche Fördermittel für interdisziplinäre Arbeiten in Projekten bereitgestellt werden. Zudem steigt mit der Anwendungsreife der Bedarf für inter- und transdisziplinäre Zusammenarbeit. Ein Ansatz könnte die Unterstützung des koordinierten Zusammenkommens von Forschung und Wirtschaft darstellen, um die Wirtschaft an entsprechenden Stellen einzubeziehen und damit unter anderem auch zusätzliche Finanzmittel zugänglich zu machen.

Résumé

La collaboration (interdisciplinaire) des SCCER s'est déroulée en deux phases. La première phase, de 2013 à 2016, a permis de faire connaissance. La phase suivante peut être décrite par les mots-clé « consolidation » et « approfondissement ». Entre ces deux phases, la collaboration a évolué. Pendant la première phase, la compréhension, l'apprentissage et la confiance mutuels ont été établis entre les différents acteurs. Ceux-ci constituent la base des activités de recherche de la seconde phase plus axées sur l'application et focalisées sur des thèmes. Cette seconde phase est caractérisée par une collaboration plus importante et plus approfondie entre les institutions et les disciplines scientifiques. Ce faisant, la collaboration entre les différents types d'établissements d'enseignement supérieur a été renforcée. Cela concerne en particulier les hautes écoles spécialisées (Universities of Applied Sciences, UAS). Celles-ci ont énormément gagné en visibilité au sein du système de recherche et sont à présent considérées comme des partenaires à part entière avec des profils individuels en matière de recherche et de développement. De plus, elles donnent de nouvelles impulsions et élargissent le champ des activités de recherche et de développement. La meilleure visibilité et intégration des hautes écoles spécialisées peut donc être considérée comme un bénéfice important du programme d'encouragement SCCER destiné à développer en Suisse une vaste communauté de recherche dans le domaine de l'énergie, regroupant tous les types d'établissements d'enseignement supérieur. Le développement de la collaboration est étroitement lié à la maturité croissante des applications développées par la recherche. Au fur et à mesure que ces dernières gagnent en maturité, la nécessité et l'importance de la collaboration entre les différentes disciplines scientifiques s'accroissent. Cela concerne en premier lieu particulièrement la collaboration entre les sciences naturelles et techniques. Par ailleurs, les disciplines socio-économiques gagnent également en importance. La collaboration encourage globalement une perspective systémique et soutient de cette manière la mise en œuvre de la Stratégie énergétique suisse 2050.

Les SCCER ont créé un cadre encourageant et ont contribué à l'approfondissement de la collaboration dans le domaine de la recherche énergétique. Ils renforcent et intensifient la collaboration interdisciplinaire. Les contacts et l'accès à d'autres chercheurs ont été rendus plus faciles, des obstacles entravant les projets de recherche coopératifs ont été levés et le financement de projets communs a été facilité. Un effet supplémentaire non négligeable a été la création et l'élargissement de réseaux de recherche dans le domaine énergétique. Ces réseaux reposent en général sur les contacts personnels et les projets financés par les SCCER. Ils raccourcissent les circuits, permettant de trouver plus rapidement des partenaires et réduisant ainsi les « coûts de transaction » en créant un accès rapide et simplifié à un important réservoir de savoir et d'expérience. Ces réseaux donnent aux chercheurs la possibilité de travailler ensemble, chacun d'une perspective différente, à des projets communs. En outre, les SCCER constituent des plateformes de discussion dans lesquelles des représentants de différentes disciplines et institutions peuvent échanger et apprendre les uns des autres. Il faut également souligner que les SCCER renforcent chez les chercheurs y participant un état d'esprit propice à la coopération, en particulier entre des disciplines scientifiques auparavant considérées comme étant très éloignées les unes des autres. Des impulsions ont ainsi été données et les perspectives des disciplines scientifiques ont pu être élargies. Les SCCER facilitent en outre l'accès aux réseaux respectifs, en particulier pour les jeunes chercheurs. Un premier pas vers l'institutionnalisation des réseaux et de la collaboration a également été fait, l'accès aux réseaux étant plus facile et ne dépendant plus d'individus. Une condition nécessaire à la durabilité du succès des SCCER est l'intégration de la collaboration

interdisciplinaire en tant qu'état d'esprit et en tant que partie intégrante d'une recherche énergétique systémique. Les « joint activities » renforcent de manière non négligeable le succès des SCCER dans le domaine de la collaboration interdisciplinaire. Elles intensifient la collaboration grâce à une approche plus globale et forment une sorte de ciment entre les chercheurs et institutions. Le travail au sein des « joint activities » encourage les chercheurs des disciplines les plus diverses à mener des discussions intenses, à échanger leurs résultats et leurs données, à combiner leurs modèles et à développer un langage commun et une compréhension mutuelle.

Cependant, sans poursuite du financement, le maintien de la collaboration est incertain. On constate de manière générale un manque de possibilités de financement de la collaboration interdisciplinaire. Les possibilités de financement existantes se concentrent largement sur des projets mono-disciplinaires. Cela signifie qu'avec la fin de la seconde phase d'encouragement des SCCER, la plupart des possibilités de financement de postes de chercheurs et de projets viennent à expiration. On s'attend donc à ce que les succès obtenus par cette collaboration s'affaiblissent ou disparaissent même. Cette opinion est confortée par le fait que la collaboration interdisciplinaire pose des exigences élevées mais est rarement porteuse de reconnaissance dans le milieu scientifique dans lequel évoluent les chercheurs.

En conclusion, deux types de recommandations sont données pour pérenniser les succès des SCCER sur le plan de la collaboration interdisciplinaire :

1. Plateforme de communication et de réseautage

Il est souhaitable que le réseau de la recherche énergétique suisse soit institutionnalisé par les participants aux SCCER. A ces fins, il est conseillé de conserver les SCCER en tant que plateforme de communication et de réseautage. Les SCCER doivent agir elles-mêmes pour assurer et renforcer la communication entre les institutions participantes. L'élément moteur doit ici être la nécessité de créer une expertise et d'adopter une autre perspective dans la manière d'appréhender les questions de recherche. Pour cela, il est nécessaire que les participants aux SCCER adoptent une perspective systémique dans la recherche énergétique et soutiennent ainsi la Stratégie énergétique 2050. Cette approche doit naître et être transportée par les participants eux-mêmes, indépendamment de l'existence de sources de financement. Cependant, il est souhaitable que les agences de promotion suisses discutent à titre complémentaire des possibilités d'encouragement pouvant être mises à disposition, comme p. ex. l'organisation de congrès, pour soutenir la communication et le réseautage, afin de pérenniser sous forme de plateforme la communauté créée dans la recherche énergétique suisse grâce aux SCCER.

2. Mécanismes de financement pour la collaboration inter- et transdisciplinaire

Il est conseillé aux agences de promotion suisses d'examiner en outre quelles possibilités de financement pourraient être développées pour encourager les approches interdisciplinaires dans la recherche et le développement, mais aussi pour réduire les risques de la collaboration interdisciplinaire (vu le temps et les efforts nécessités). Ainsi, les financements pourraient inclure une obligation de collaboration interdisciplinaire ou des financements supplémentaires pourraient être alloués pour encourager les composantes interdisciplinaires au sein des projets. Avec la maturité croissante des applications, la collaboration inter- et transdisciplinaire devient de plus en plus nécessaire. Une approche pourrait consister à encourager et à organiser des rencontres coordonnées entre les instituts de recherche et l'industrie, afin d'impliquer l'industrie et de trouver des possibilités de financement supplémentaires.

1 Tasks, methods and background

1.1 Tasks and core issues of the study

The following study is the final report of the accompanying Research Module 3b. It is intended to analyse and assess the development of network and interdisciplinary collaboration among energy researchers in various scientific disciplines and within and among SCCERs and Joint Activities (JA). The goal of the study is to evaluate whether SCCERs have led to a deep long-term collaboration and have strengthened the collaboration of higher education institutions (HEIs). In particular, the study investigated four main questions:

1. Has SCCER funding led to deeper and long-term collaboration in energy research?
2. Has collaboration among higher education institutions been strengthened?
3. Do Joint Activities properly support interdisciplinary collaboration?
4. If so, how do Joint Activities support interdisciplinary collaboration, especially collaboration between engineering & technology and the social sciences?

1.2 Data and methods of investigation

The research team applied various sources of data and methods to carry out the accompanying research. The main sources of information and empirical data were:

- Application forms and monitoring lists since 2013 of each SCCER and Joint Activity
- Additional documentation on Joint Activities
- Interviews with the leaders of each Joint Activity (6 interviews during February and March 2018)
- Interviews with participants of each SCCER (14 interviews in autumn 2018)
- Selected questions to SCCER Heads, the Evaluation Panel, the Steering Committee and other experts (interviews led by Infrac, January 2018)

Moreover, the following research methods were used: descriptive statistics, qualitative content analysis, semi-structured interviews, and case studies on Joint Activities.

The study started out by analysing the application forms and monitoring lists, taking a quantitative approach (Section 2.1.1). Additionally, desk research was carried out for qualitative aspects. During the second step, SCCER participants were interviewed on the one hand to gather context-related information, and on the other hand to get a more detailed view on collaboration (Section 2.1.2). This was followed by performing a case study on each Joint Activity. The research team first gathered basic information by analysing the documentation on a given JA, and followed this with interviews with members of JAs in leadership roles (Section 2.2). Next, this information and the results of the previous work steps were consolidated and summarised; the recommendations we derived constitute the last section (Section 3).

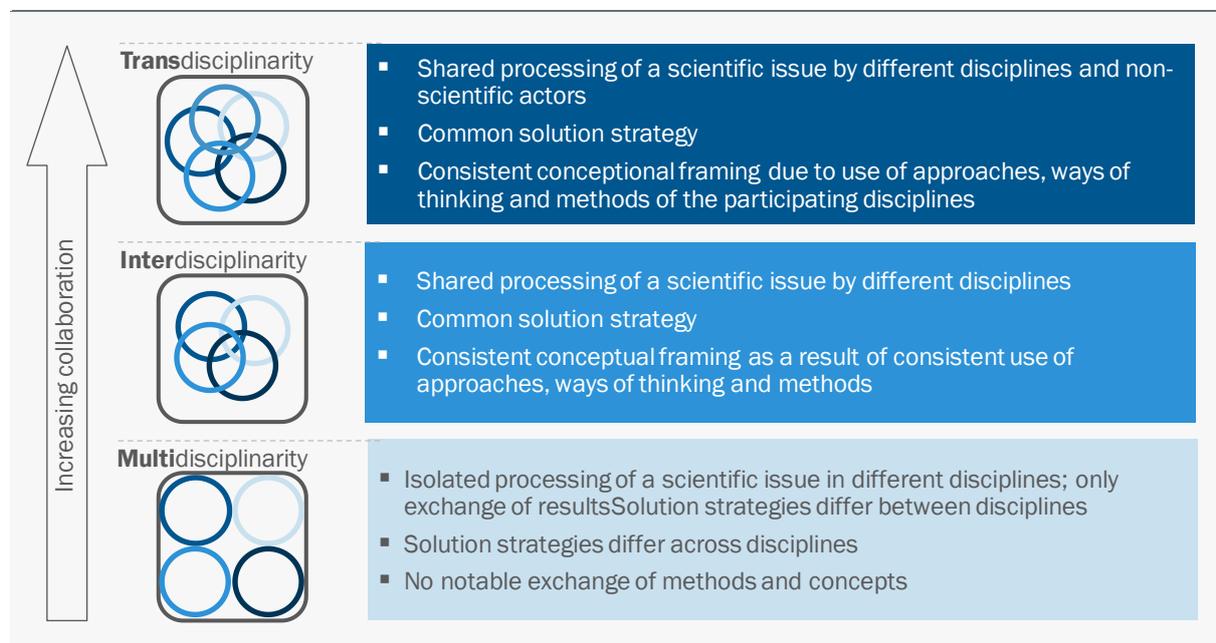
1.3 Background and definitions: interdisciplinarity and innovation

One fundamentally important aspect when analysing collaboration across different scientific disciplines is the understanding and the definition of interdisciplinarity, as well as the classification of the various scientific disciplines and a basic assumption concerning the role of multidisciplinary and interdisciplinarity in the innovation process.

1.3.1 A definition of interdisciplinary collaboration

In a nutshell, interdisciplinary collaboration differs from multidisciplinary collaboration in that the degree of integration is different: while in the case of multidisciplinary collaboration, exchange takes place above all with regard to research results, interdisciplinary collaboration is shaped through the development of a shared approach and a shared effort towards producing results (also interim results). The following figure illustrates the differences (Figure 1). Transdisciplinarity constitutes an even further step of integration. Here, the collaboration extends to encompassing actors outside the system of science. However, such aspects of transdisciplinarity are outside the scope of this report. They are not the object of investigation in the research presented here; nevertheless, this is an interesting topic, especially with regard to the transfer of expertise and research results to business.

Figure 1: Definition of multidisciplinary, interdisciplinarity and transdisciplinarity



1.3.2 Classification of scientific disciplines

One particularly important aspect for the analysis of multidisciplinary or interdisciplinary scientific collaboration is to structure the various sciences into different disciplines. Structuring the different branches of science, which the OECD has harmonised under “Fields of Science and Technology” (OECD 2007), is analogous to structuring industries within an economy. It involves distinguishing among the major fields of science and technology (the first digit in the following “FOS”): the main fields according to the OECD are

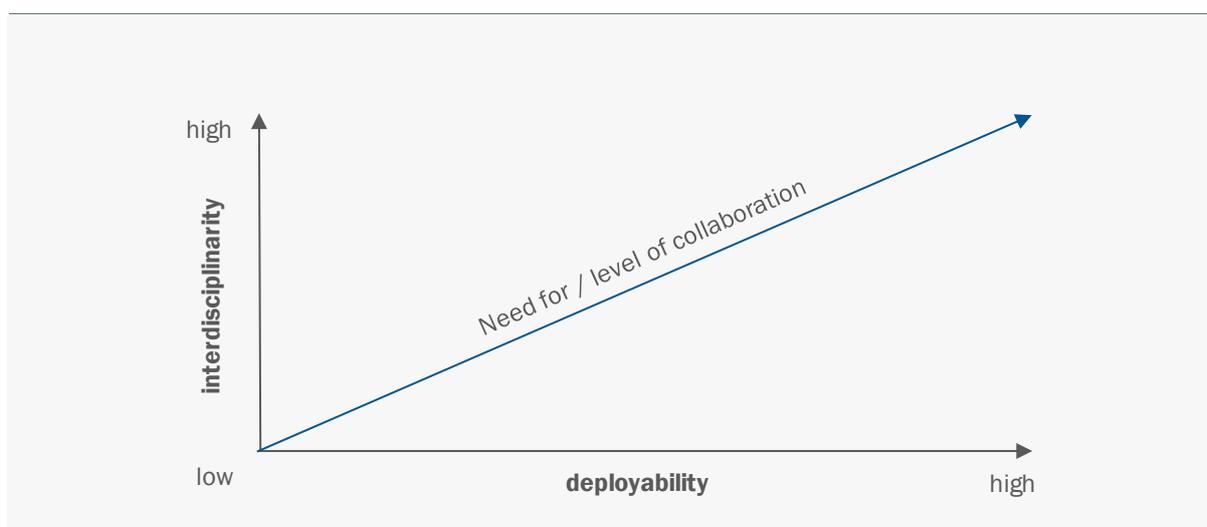
- Natural Sciences
- Engineering and Technology
- Medical and Health Sciences
- Agricultural Sciences
- Social Sciences
- Humanities

These main fields are subsequently grouped into 42 subcategories (the second digit, in the following “Scientific Disciplines”; see Appendix, Table 3). The following step of analysis shows how the institutes participating in SCCERs categorised themselves under different scientific disciplines according to their self-description.

1.3.3 Interdisciplinarity and the innovation process in SCCERs and Joint Activities

To understand the following analysis, it is crucial to note that interdisciplinarity does not *per se* constitute a value. The real significance of collaboration between different disciplines during the innovation process can be seen above all in its correspondence with the stage of the innovation process and the degree of deployability (Figure 2).

Figure 2: Level of collaboration, interdisciplinarity and deployability

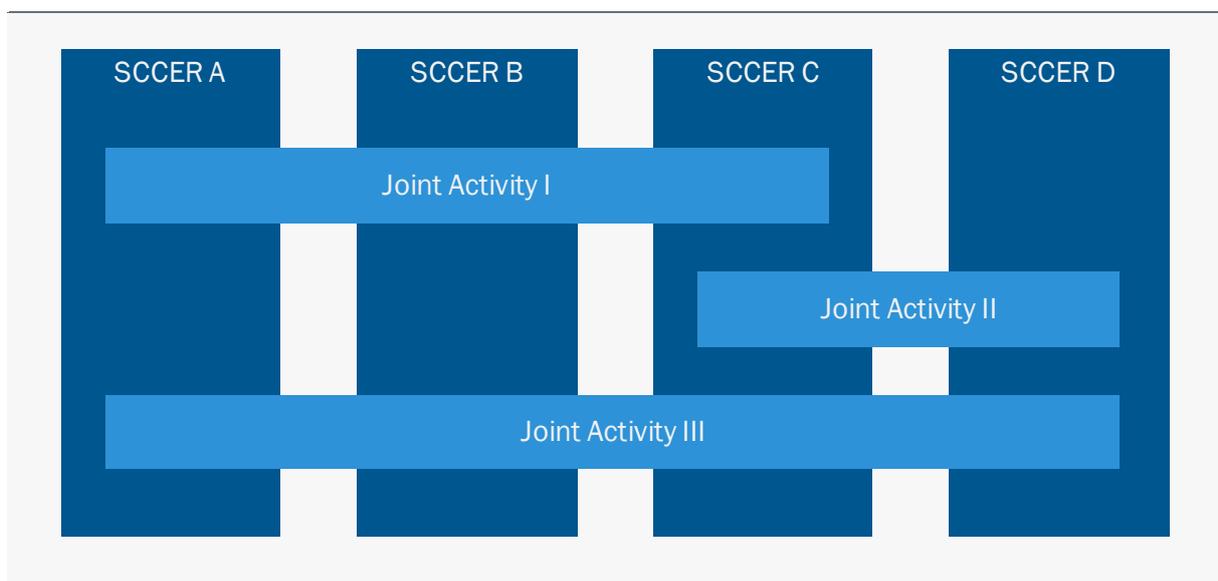


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In light of this, interdisciplinary collaboration does not require all scientific disciplines to be represented in one SCCER. Rather, it is much more important that the most relevant and most important disciplines are involved.

Another important aspect is how collaboration in SCCERs and Joint Activities is set up. Within a SCCER, collaboration mainly occurs in a technological field. Therefore, forms of collaboration are multidisciplinary and interdisciplinary. In Joint Activities, the collaboration occurs in “system perspective”. Interdisciplinarity and transdisciplinarity subsequently increase (Figure 3).

Figure 3: Scheme of collaboration in SCCER and Joint Activities



2 Interdisciplinary scientific collaboration in SCCERs

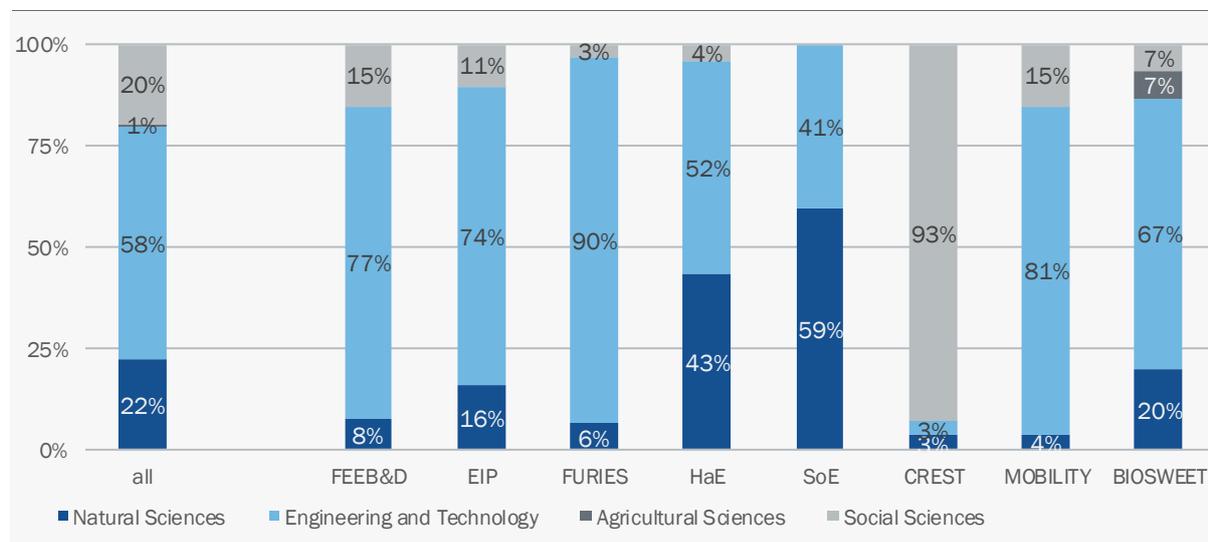
2.1 Collaboration in SCCERs

2.1.1 Quantitative analysis

An interdisciplinary structure

The disciplinary structure of SCCERs is characterised by three fields of sciences (FOSs): natural sciences, engineering and technology, and the social sciences. These three FOSs account for 99% of the disciplines participating in SCCERs. It is hardly surprising that a technology-oriented programme would exhibit such dominance of engineering and technology. Social sciences participate in virtually all the SCCERs; only SoE represents an exception. Natural sciences are likewise represented in all the SCCERs. The interdisciplinary structure establishes a crucial basis for multidisciplinary as well as interdisciplinary collaboration (Figure 4).

Figure 4: The interdisciplinary structure of SCCERs (2017, Phase II)

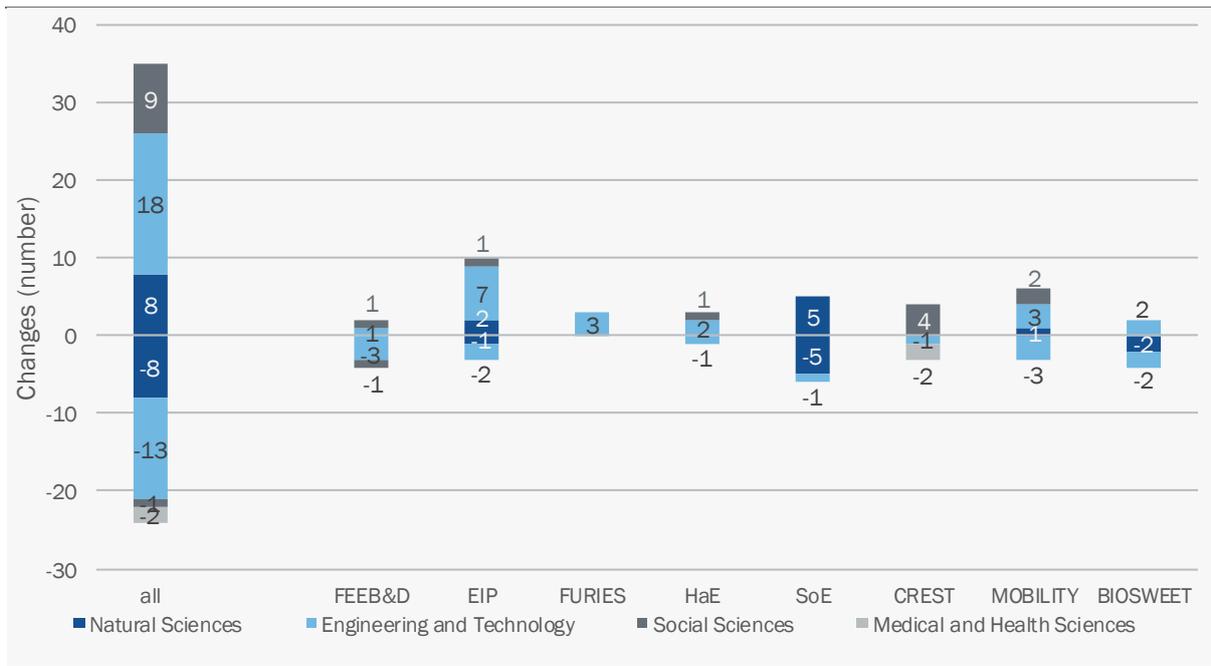


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In Phase II, there was a slight growth of SCCERs and the disciplinary mix within them. The “Engineering & Technology” and “Social Sciences” FOSs increased in importance. This can be taken as

a sign of increasing deployability. The internal differentiation of scientific disciplines changed little in comparison to Phase I (Figure 5):¹

Figure 5: Changes in the interdisciplinary structure of SCCERs (Phase I – Phase II)



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Interdisciplinary work

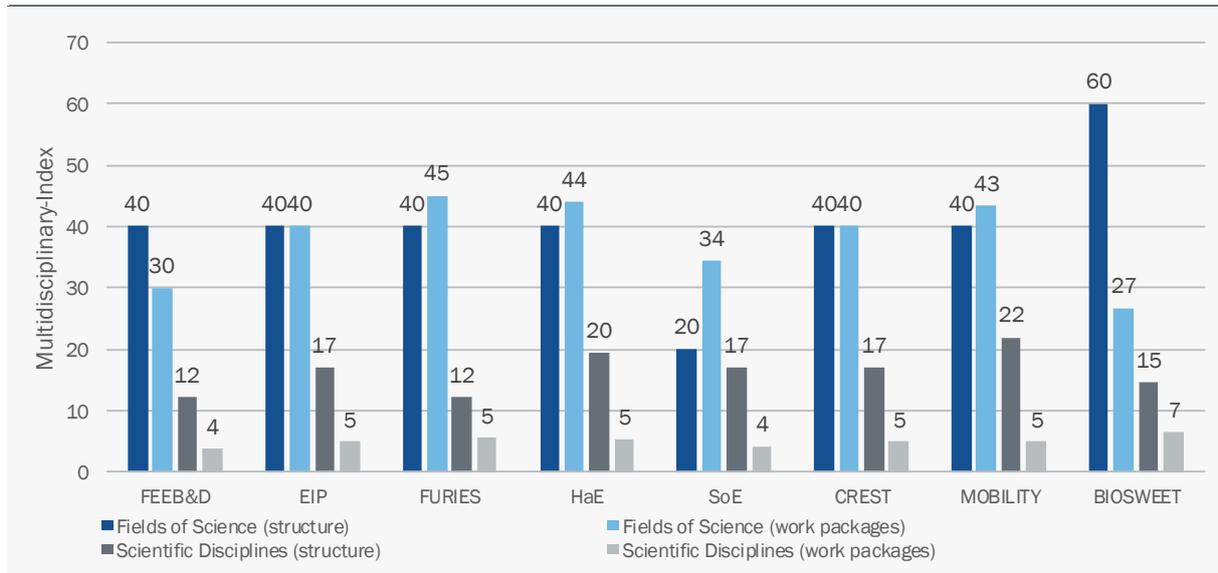
Financial reports formed the basis for compiling a formal index of multidisciplinary (Prognos 2016). The index values describe the formal strength of possibilities for multidisciplinary or interdisciplinary collaboration within a given SCCER. A value of 100, for instance, means that all the disciplines are represented in the SCCER; a value of 0 indicates no collaboration across disciplines.

Analysis of the structural composition (FOS structure and the structure of scientific disciplines; see Appendix) shows the representation of disciplines in the SCCER; analysis of the work packages (FOS WP and scientific disciplines WP) shows the collaborations described in the work packages. Taken together, the index values reveal a clear picture of the multidisciplinary and interdisciplinary foundation of the SCCER: multidisciplinary collaboration has clearly been established

¹ Each column shows the difference in the interdisciplinary structure of each SCCER between Phase I and Phase II. An upward column shows increasing interdisciplinarity; a downward column shows decreasing interdisciplinarity. For example, overall, the presence of the social sciences increased in the SCCERs; nine more disciplines are shown, while just one dropped out. Overall, participation from the social sciences increased by a total of 8 disciplines.

(Figure 6). In comparison to Phase I, it is furthermore clear that multidisciplinary collaboration has been increasing, especially according to the data from the work packages (Figure 7):²

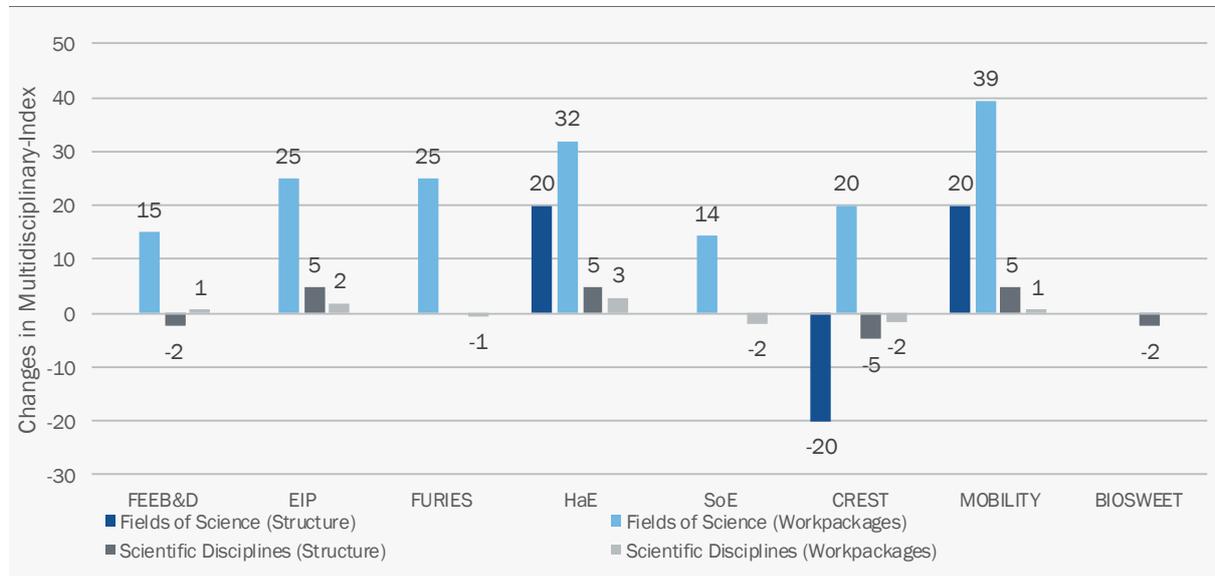
Figure 6: The Multidisciplinary Index (2017, Phase II)



0 = no multidisciplinary; 100 = full multidisciplinary; Structure: disciplinary composition in SCCER, Work packages: disciplinary composition in work packages © Prognos 2019

² Each column shows the difference of the Multidisciplinary Index between Phase I and Phase II. An upward column shows increasing multidisciplinary; a downward column shows decreasing multidisciplinary. For example, the Multidisciplinary Index of FEEB&D's FOS disciplinary composition in work packages increased by a total of 15 points (Phase I = 15, Phase II = 30).

Figure 7: Changes in the Multidisciplinary Index (Phase I – Phase II)



Structure: disciplinary composition in SCCER, Work packages: disciplinary composition in work packages

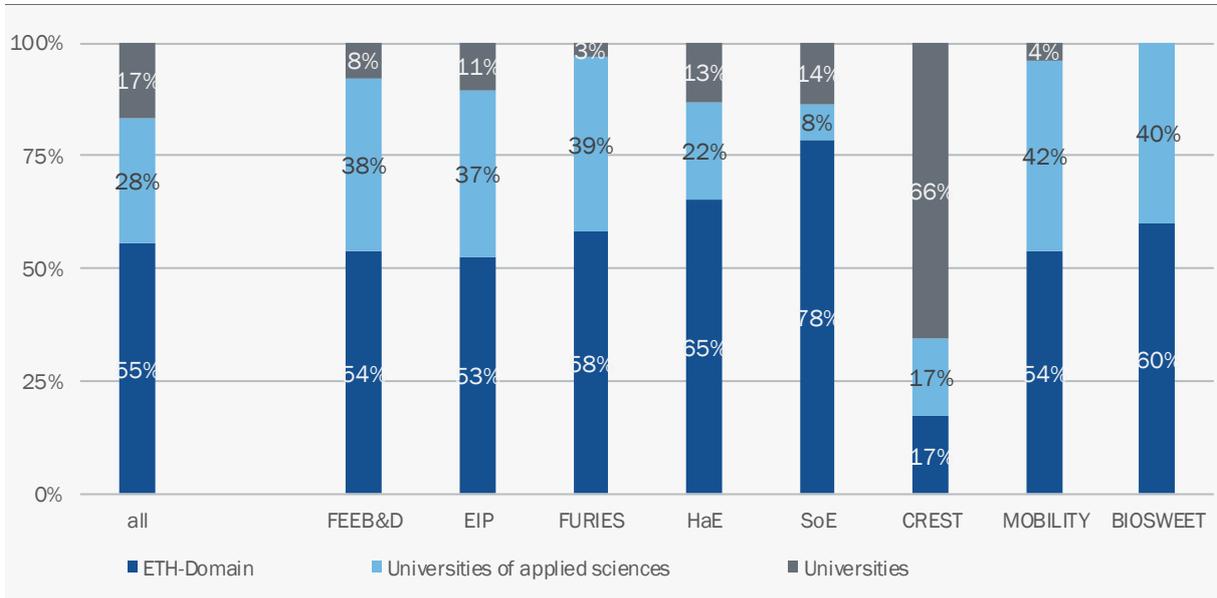
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Collaboration between types of higher education institution

Analysis of the different types of HEI (higher education institutions) revealed that universities of applied sciences (UASs) are especially involved in collaborations with the ETHDs (Domains of the Eidgenössische Technische Hochschule) and clearly play a more significant role than previously thought (Prognos 2016). This also makes the SCCERs’ transfer concepts and proximity to applied practice especially important. In Phase II, participation showed slight growth overall, but especially among UASs (Figure 8 and Figure 9).³ This can be taken as a sign of increasing deployability.

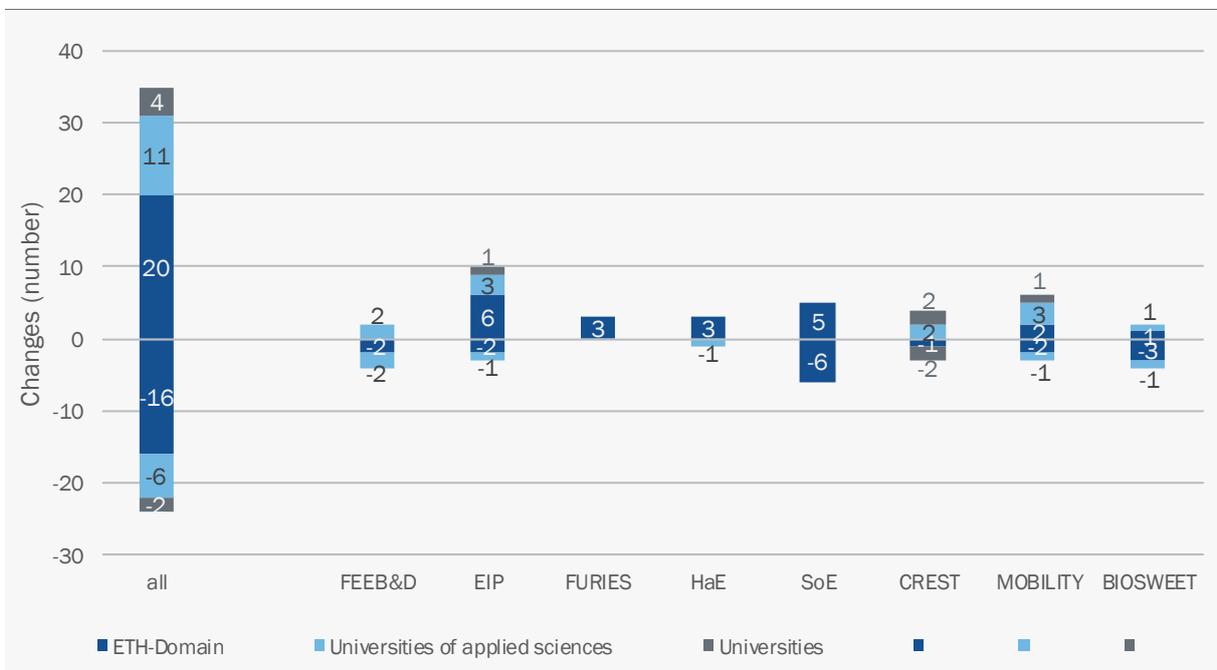
³Each column shows the difference in participation rates by HEIs between Phase I and Phase II. An upward column shows increasing participation; a downward column shows decreasing participation. For example, across all SCCERs, eleven UASs increased their participation; at the same time, six UASs decreased their participation. Overall, the participation by UASs increased by a total of 5.

Figure 8: Participation of higher education institutions (2017, Phase II)



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Figure 9: Changes in the participation of HEIs (2017, Phase I – Phase II)



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2.1.2 Qualitative analysis

Two phases of collaboration development in a SCCER

Funding – and the development of collaboration – took place in two phases. The first phase can be interpreted as a “construction” phase. During this phase, the researchers involved got to know each other, built trust and formed teams. They identified contexts and defined important main questions. At that time, their research activities were rather local and technology-centred. There was relatively little interest in the social sciences (see Prognos 2016).

The second phase can be characterised as a phase of specifying and prioritising research objectives. Users and partners identified their needs more precisely, which led to a selection of research topics from the previous work, and a pivot towards defined objectives. Research activities in Phase II have been directed towards the application or practical implementation of the approaches or technologies developed during Phase I. Work has thus focused on more advanced products, which are more interesting for industrial partners. The need to “transcend borders” and experience “broader horizons” became more relevant and increased the motivation for cooperation. Overall, collaboration became more intense; trust among partners also grew; rigid work package structures dissolved; and work processes became increasingly integrative. Collaboration has also trickled down to the PhD level. Nonetheless, the number of academic partners has decreased due to an expected reduction of programme financing.

The widespread establishment of interdisciplinary collaboration

Deeper analysis using a dozen additional interviews with participants of SCCERs (post-doc or senior researchers) showed that collaboration across different disciplines has generally been established. The SCCERs as a framework have enabled the creation of a community and the establishment of new networks and contacts as a basis for collaboration. Over time – from funding Phase I to Phase II – collaboration has been strengthened.

Nonetheless, there are still noticeable differences regarding the intensity of collaboration. The established work structures of the SCCER and the organisation into work packages have played an important role in this regard. Interdisciplinary collaboration is still structured in this manner. Respective resources are often available in-house, so there is little to no demand for collaboration outside of the SCCER itself or the institutions that comprise it. Nonetheless, depending on the structure of the work packages, collaborations usually employ a multidisciplinary approach. SCCERs, and especially Joint Activities, provide new momentum and contribute to broadening research perspectives. Additionally, the interviews confirmed that the projects’ technological deployability, i.e. their classification as either basic or applied research, had a significant impact on the degree of collaboration. There are signs, however, that SCCERs’ phase of planning and consolidation are over; the rising level of technological deployability of the research projects is apparent. This leads to higher demand for interdisciplinary collaboration, which is seen as increasingly advantageous at higher levels of technological deployability. Respondents often highlighted the infusion of new motivation and the broadening of research perspectives in this regard.

Often, the collaboration between disciplines within the natural sciences, e.g. chemistry, biology, physics, process engineering, etc., is already considered strongly interdisciplinary. Less common is direct cooperation between disciplines from the natural sciences and the social sciences.

Overall, SCCERs have fostered deeper research into individual technologies. At the same time, they have reduced the barriers to finding partners (lowering transaction costs) by providing easy

and fast access to a significant pool of knowledge. In this way, they have provided researchers with the opportunity to work on a common project and have incentivised applying and working together. Also, SCCERs have provided discussion platforms where researchers from different disciplines and institutes have been able to exchange ideas and learn from each other. They have created more openness to cooperation, especially between researchers from disciplines that were previously considered to be too far apart for collaboration (e.g. among social science, economics, and law, or among psychology, economics, and computer science). In this way, SCCERs have even enabled the development of “new” research fields, such as energy law.

New stakeholders, greater access to networks

Cooperation has mainly taken place within a given SCCER. Increasingly, their compositions have gone beyond the main team from the particular institute to incorporate several organisations. The UASs have especially profited from this: their visibility has increased and they have begun to be perceived as independent partners, with individual profiles and capabilities for research and development. Their significance and the appreciation for their work within the SCCER has increased. The incorporation of the UASs therefore can be assessed as a significant benefit of the SCCER funding scheme. Additionally, they contribute by giving new momentum and broadening the research scope.

It is furthermore noticeable that SCCERs have acted as “door openers”. They have facilitated access to existing smaller (especially local) networks and their experts. A trickle-down effect has become apparent: until recently, the contacts were often concentrated among researchers in senior positions. While exchange within and partly across the different SCCERs has intensified, some obstacles still exist regarding contacts from the private business sector. The issue of hierarchy is still sometimes mentioned with regard to contacts in private industry. Specifically, interviewees reported that researchers were not given adequate access to data from private energy supply companies. Generally, the exchange with private actors was thus rated rather heterogeneously; there were also reports of case studies with private planners and building companies where collaboration was fruitful and data could be gathered for analysis. Several work packages also included demonstrator systems that were partly developed with and operated by industrial actors.

With the development of SCCERs over time, more young researchers have gained access to the relevant networks, and senior researchers have given up their role as gatekeepers. This has thus meant a step towards the institutionalisation of networks and collaboration, since access is distributed across multiple heads in different fields of studies. This in turn makes it less reliant on personal connections. Nonetheless, all the interviewees emphasised that personal relationships and camaraderie were still critical factors for successful collaboration.

Hierarchy and information as influential factors

It can be observed that, apart from the type of research (basic research vs. applied science), hierarchical aspects continue to be significant with respect to evaluations of collaboration. People from higher organisational levels usually evaluated the usefulness and need for cooperation with other disciplines more positively than people from lower levels. As the previous report already pointed out, people from this group often fail to grasp the “big picture” relative to the particular SCCER. This group considered the roadmaps to be an important instrument and emphasised the significance of the annual meeting. This is an improvement that could initiate and support deeper collaboration. However, clear communication of goals, the ways the organisation will reach them, and overviews of organisational structures are sometimes lacking. It is in this context that the

Joint Activities were evaluated so heterogeneously. Their work is usually seen as fruitful and scientifically broad beyond the boundaries of the respective discipline. Nonetheless, they are also sometimes viewed sceptically, as a measure imposed from above.

Personal contacts as an influential factor

Apart from scientific research, the activities of the SCCERs provide a framework for networking and meeting stakeholders. Networking activities allow stakeholders to increase the number of personal contacts and open up opportunities to broaden their perspectives and professional expertise. According to the interviewees, this increased the commitment and sense of obligation in both the form of contact as well as during collaboration. Personal contacts help to overcome initial reservations. However, there is always an initial effort necessary that varies with the research topic and/or the project's level of deployability.

The annual meetings were of special significance. Respondents considered them to be extremely useful. The professional and personal exchange was described as very stimulating. Some criticisms included the idea that personal exchange was sometimes shortchanged when the conference schedule was too dense. Interviewees also reported that they sometimes skipped sessions during the annual meeting so as to not interrupt a more spontaneous conversation.

At times, the researchers already knew one another from their student days, so strong personal relationships already existed. One consequence of the SCCERs has been that researchers from “the outside”, whether from a foreign university or from a different discipline, have received the opportunity to gain access to these networks. Respondents noted that personal contact and camaraderie is very important for the development of a common understanding on a given topic, especially when collaborating across different disciplines.

Capacity building as a multilevel effect

Our analysis indicated that the SCCERs have supported capacity building in several ways. First, the SCCERs have contributed to an expansion of academic education and scientific research. Furthermore, they have facilitated significant knowledge gains, with more integrated forms of research leveraging this knowledge to the benefit of the SCCER itself. According to the interviews, the SCCERs have also contributed to reducing competition and selfishness among institutes and institutions. They have provided a framework, where an exchange has been made possible on the meta-level. The willingness to share data and information with the other institutions involved has been much higher due to joint research activities. In this way, the SCCERs have significantly contributed to the reduction of competition between research institutions and the harnessing of synergy potentials. This aspect was often seen as the main benefit of the SCCERs.

SCCERs helped to expose and foster common approaches, goals, and perspectives. Higher degrees of collaboration became especially apparent when discussing resources of the funding system. The various institutes strengthened their cooperation during efforts to obtain funding for common projects. Additionally, collaboration within the SCCERs has facilitated the development of common perspectives and understanding. This repeatedly manifested itself in contextual knowledge during the assessment and interpretation of data and research results. The stakeholders could find a common understanding beyond the boundaries of their respective disciplines. This meant the transmission and utilisation of knowledge and experience across disciplinary boundaries. The joint development and utilisation of data sources, and sometimes even special (partly digital) research tools, was often reported as a benefit of the SCCERs.

The sustainability of SCCER successes

Future financing has consistently been seen as the major challenge in securing the continued preservation of SCCERs' successes. Here, it is a question of how and to what extent it will be possible to finance existing positions without SCCER funding. Interviewees especially brought up the permanence (or lack thereof) of personnel. The respondents also pointed out one structural problem particularly challenging for universities and UASs: Junior and Assistant Researcher positions are rare, so there is a risk that the relevant capacities and knowledge will wander off in the short to medium term. Additionally, the existing networks still heavily rely on individual personal relationships, although progress has been made towards their institutionalisation. In contrast, the framework of the SCCER and its broader interconnectedness prevents the need to rely on a few core individuals. Consequently, it helps decouple the network itself from the individuals that comprise it by intensifying contacts.

Respondents often highlighted that successfully established cooperation would be at the risk of foundering if funding were to run out. Lasting collaboration is usually found where there has been either regional proximity or technical necessity. For these reasons, some cooperation is likely to continue, but not to the same degree. This would be the case not only in terms of diversity with regard to the content of research, but even more so with regard to geographic proximity. The holistic approach taken by the SCCERs is seen as very fruitful and valuable. However, it can probably only be maintained with continued funding.

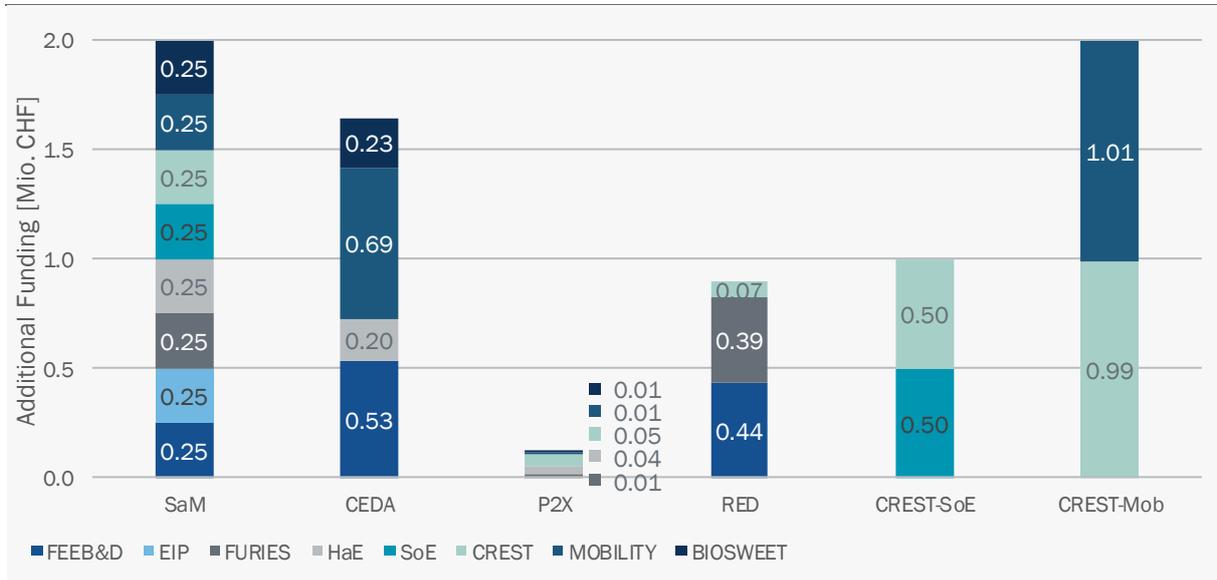
With the prospect of reduced funding and the need to increase third-party financing, it is crucial to identify fields of research, projects and joint activities that provide opportunities for cooperation, and services that are sufficiently attractive for third-party financing. Given the fact that one of the main purposes of the SCCERs is to develop advanced technological solutions for industrial production and dissemination and to deploy these solutions in an advanced energy system, it seems appropriate to evaluate the activities and topics of the SCCERs according to the perspective of further “usability” and possible partners (see the Report on SCCER Accompanying Research Module 2).

2.2 Collaboration in Joint Activities

2.2.1 Overview

In Phase II, the SCCERs set up a number of Joint Activities (JA). The purpose of JAs is to increase cooperation between the SCCERs and exploit existing synergies. They began in 2017, and will continue until 2020. The JAs were submitted to the previous CTI Board in 2016. The CTI has provided CHF 7.7 million of additional funding to support the JAs (Figure 10).

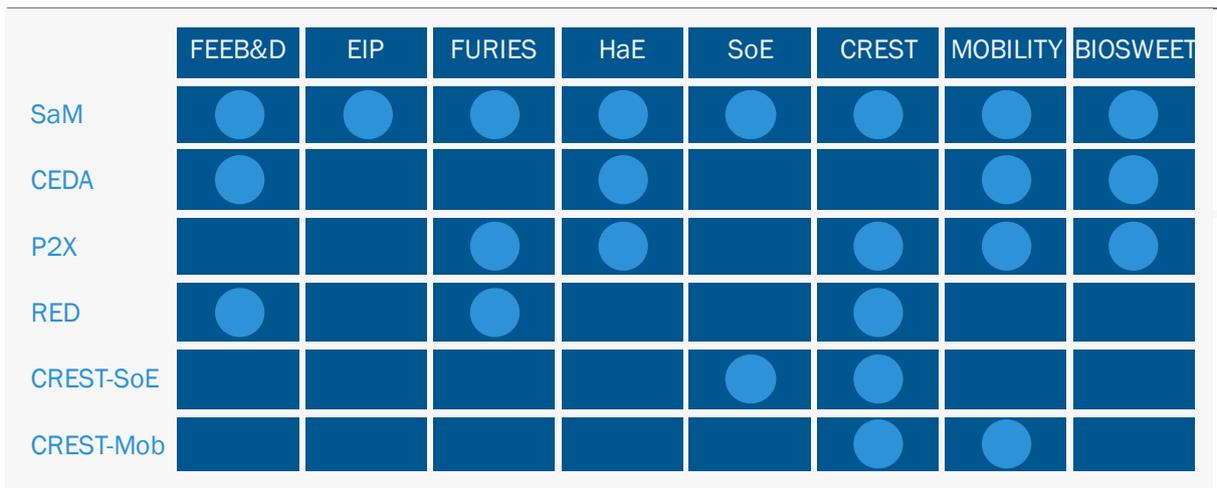
Figure 10: Overview of funding for Joint Activities



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Each SCCER is technology-specific, and this means that each one can only take a system-wide perspective to a limited extent. In contrast, JAs are designed to foster collaboration across SCCERs (and therefore across technologies), as illustrated in Figure 11.

Figure 11: Categorisation of Joint Activities in relation to SCCER



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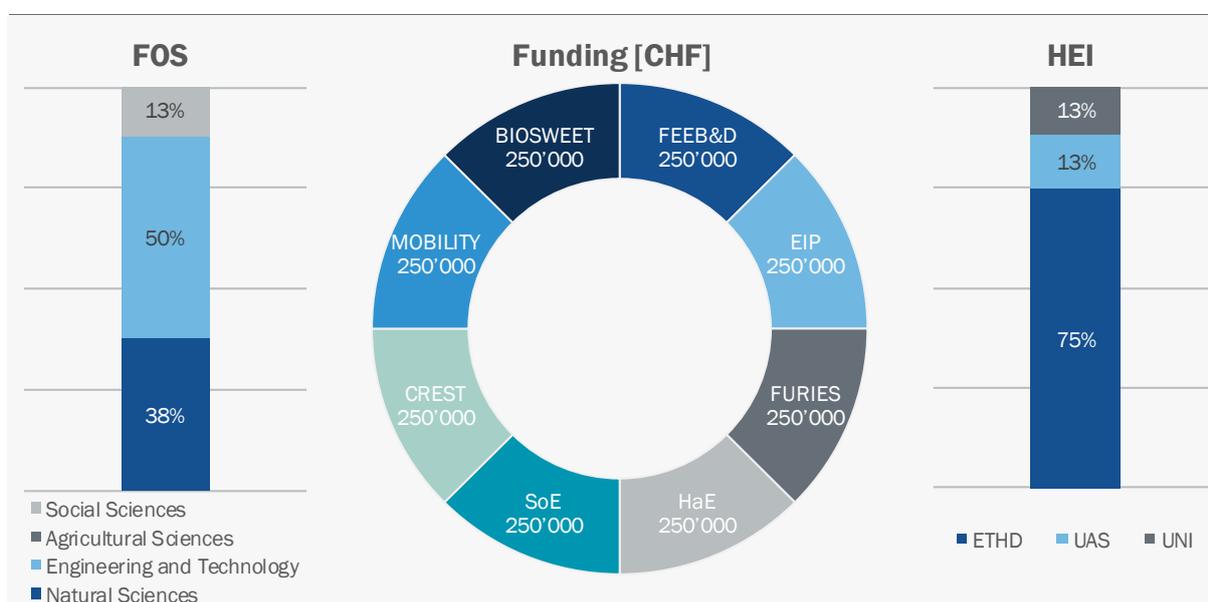
Each JA has unique SCCER, FOS and HEI compositions, as well as objectives and cooperation partners, which are detailed in the following case studies.

2.2.2 Case studies on Joint Activities

Case Study I: SaM

In the SaM (Scenario and Modelling) JA, all SCCERs are equally involved. Funding of SaM amounts to CHF 2 million. The discipline structure is dominated by the Engineering and Technology FOS, followed by the Natural Sciences. The Social Sciences participate to a smaller degree. ETHDs dominate the composition of HEIs (Figure 12). An additional cooperation partner is VSE (Verband Schweizerischer Elektrizitätsunternehmen).

Figure 12: Overview of SaM



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The main objective of SaM is to develop an overarching initiative that will enable researchers to further develop and combine different models, while still preserving the specificity of individual approaches. More specifically, SaM is intended to establish and analyse robust scenarios for the implementation of Switzerland’s Energy Strategy 2050, including what technical elements and market instruments may be required, and the macroeconomic and social impacts that may arise.

SaM is considered the “glue” between researchers/institutes. It enables researchers to consider the energy system as a whole, and not only focus on individual technologies. From the researchers’ point of view, working on SaM is more interdisciplinary than working within the SCCERs. Interviewees acknowledged that social and economic aspects play an important role in the dissemination of technologies. But they also stated that they felt there was a lack of visibility, because most JA personnel are engineers and physicists. Nevertheless, there are intensive discussions between the labs, exchange and comparison of data, and combination of models; these together should lead to synergies.

Some major challenges remain for interdisciplinary cooperation in SaM. The first concerns how the social sciences can be practically incorporated more effectively. Also, respondents indicated that the inevitable ranking of technologies and their role in the Swiss energy transition could lead to some frustration among the cooperating researchers. Second, there is the question of how to preserve knowledge created during the JA and ensure technology transfer. On the one hand, interest within industry is relatively low. On the other hand, the sustainability of collaboration is uncertain, because of the precarious financing situation after 2020.

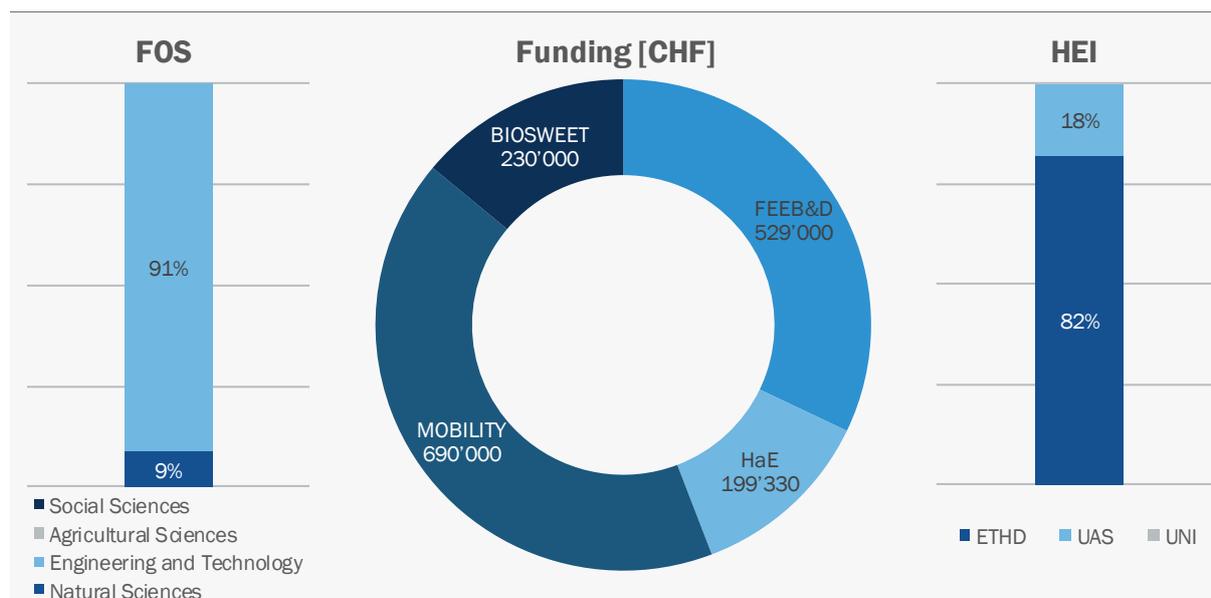
In this JA, the risks stemming from a lack of future third-party financing seem particularly high because the in-depth systemic modelling work is less interesting for industrial partners and their specific needs for technological development and implementation. A considerable amount of resources in time and manpower should be devoted to the exploration of future funding and “business models” in the fields of this JA.

Case Study II: CEDA

In the CEDA (Coherent Energy Demonstrator) JA, four SCCERs are involved. MOBILITY and FEEB&D receive a nearly equal share of funding, followed by BIOSWEET and HaE. Total funding of CEDA amounts to CHF 1.6 million. The discipline structure is dominated by the Engineering and Technology FOS; the Natural Sciences are involved to a small degree. ETHDs dominate the composition of HEIs (Figure 13). There are four additional cooperation partners:

- St. Gallisch-Appenzellische Kraftwerke AG
- Beckhoff Automation
- Holdigaz SA
- Swisspower Services AG

Figure 13: Overview of CEDA



The main objective of CEDA is to provide a common basis to assess various storage and conversion technologies at the system level by investigating four demonstrator groups. These demonstrator groups include the “power-to-gas” group (three projects: Power-to-gas Pilot, ESI Platform, and Move); the “buildings” group (NEST); the “energy flows for mobility, housing and services” group (Ehub); and one project (Grid to Mobility) working on a combined hydrogen and electricity service station and a hydrogen refilling station.

CEDA is mainly a technical project. Socioeconomic aspects are not covered in this JA, although the importance of behavioural and acceptance issues is slowly being recognised. These will be dealt with after the technical aspects. In general, research activities are more focused than in a SCCER alone, and require more collaboration; the inclusion of partners from industry allows for a more practice-oriented approach. One notable aspect is that the wide range of partners come from very diverse backgrounds, yet they work towards a common terminology and thus towards a common understanding. This makes this JA ripe for leveraging potential synergies.

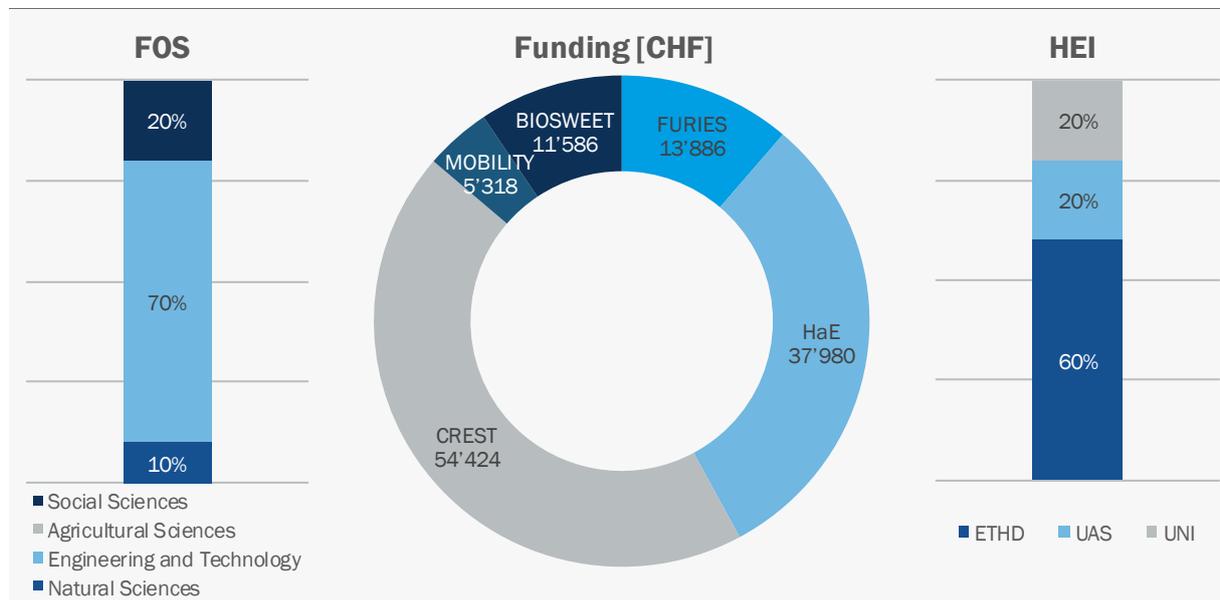
One major challenge for CEDA is to find a common set of terms to convey the specific approaches of the demonstrators and researchers with different backgrounds to each other. This requires time, and research questions must be defined precisely. There is a broad scope of work (modelling, simulation and assessment of various case studies) and researchers must painstakingly analyse how individual results can be used for designs and options of the future Swiss energy system (either by increasing the scope of WP 3 or by adding an additional dedicated WP). As previous case studies have indicated, sustaining collaboration under CEDA will be uncertain without financing after 2020.

Case Study III: P2X

In the P2X (White Paper on the Perspectives of P2X Technology in Switzerland) JA, five SCCERs are involved.⁴ Funding of P2X amounts to CHF 0.12 million. Nearly 75% of this amount has been allocated to HaE and CREST. The discipline structure is dominated by the Engineering and Technology FOS, followed by the Social Sciences. Scientists from the Natural Sciences participate to a minor extent. Once again, the HEI structure is mainly composed of ETHDs, with a few participants from UASs and UNIs (Figure 14). Additional funding has been allocated by the BFE (Bundesamt für Energie).

⁴ Power-to-X (P2X) refers to conversion technologies that allow for innovative technological options of the use of power from the electricity sector in other sectors (such as transport, heating or chemicals).

Figure 14: Overview of P2X



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The main objective of P2X was to gather the major existing P2X knowledge. P2X was designed to provide a synthesis and evaluation for the Swiss energy market and was to include technical, economic and environmental assessments of P2X in the energy system itself, in the gas market, in the transport sector and in the electricity market. Market and systems integration aspects, including legal and regulatory ones, were also to be analysed.

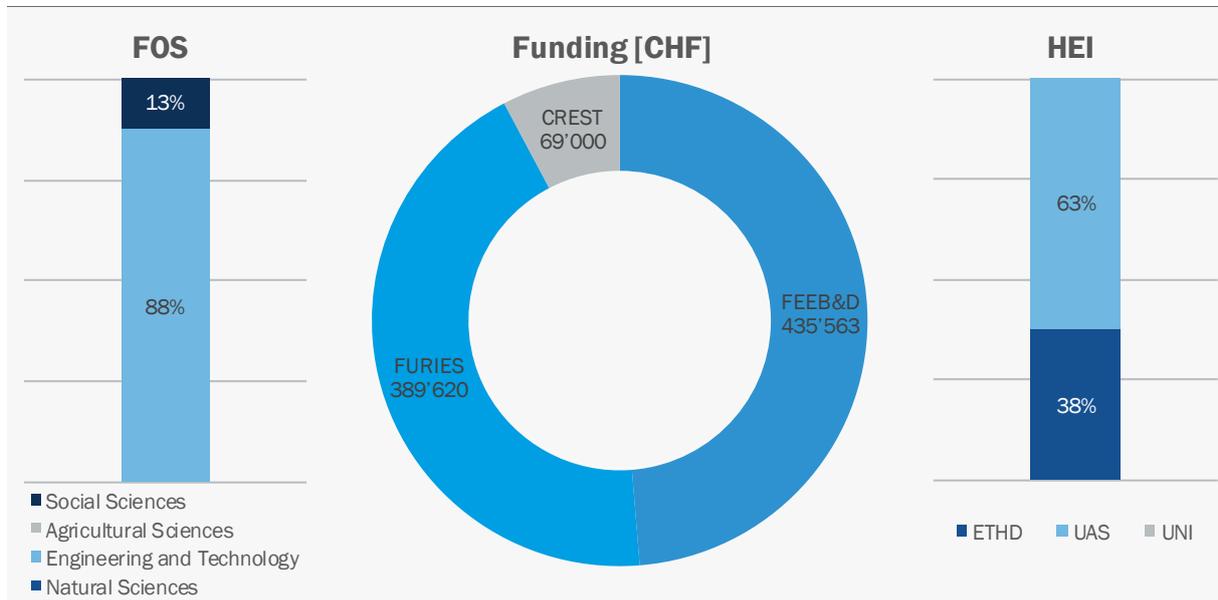
In comparison to SCCERs, P2X's team members emphasised collaboration to a greater extent. Over and above desk research, regular meetings were important. During these meetings, participants discussed consistency in the approach, as well as what aspects overlapped. From the researchers' point of view, the main benefit of collaboration was the broad range of technical, socio-economic and legal aspects that were covered in this JA. The outline of the white paper was rich and coherent, with contributions from many researchers specialising in different disciplines, from many HEIs and many SCCERs. This indicates that the cooperation had been intense up to this point.

The lifetime of P2X was limited to the end of 2018; collaboration afterwards continues to be uncertain. However, one joint publication (by two researchers) after the end of the JA is still expected.

Case Study IV: RED

The RED (Socioeconomic and Technical Planning of Multi-Energy Systems) JA brings together three SCCERs. Funding of RED amounts to CHF 0.9 million, mainly going to FEEB&D and FURIES. The discipline structure is dominated by the Engineering and Technology FOS, followed by the Social Sciences to a lesser extent. In this JA, UASs compose the majority of HEIs (Figure 15). Additional cooperation partners are Romande Energie SA and Siemens AG.

Figure 15: Overview of RED



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RED’s main objective is to explore the technical aspects of multi-energy systems, which couple the electrical grid to other energy-carrier grids, such as heat and gas. It also deals with business models and socioeconomic aspects related to the implementation of multi-energy systems and smart grid solutions, including legal and regulatory matters.

In comparison to SCCER work, RED’s approach is broader, and more stakeholders and scientific disciplines are involved. While work in the SCCERs is more focused on technology and its potential, in RED, economic, behavioural and political aspects (incentives) are a key part of the research. In this way, CREST functions as a “reality check”. One main aspect of collaboration in this JA is the exchange of data and cross-demonstrator analysis. The project has a clear orientation toward real-world applications and customer needs; for this reason, work has focused on more developed products, and on increasing contacts with industry. This in itself has fostered long-term interest and participation by the private sector, which is a positive sign in extending collaboration into the long term.

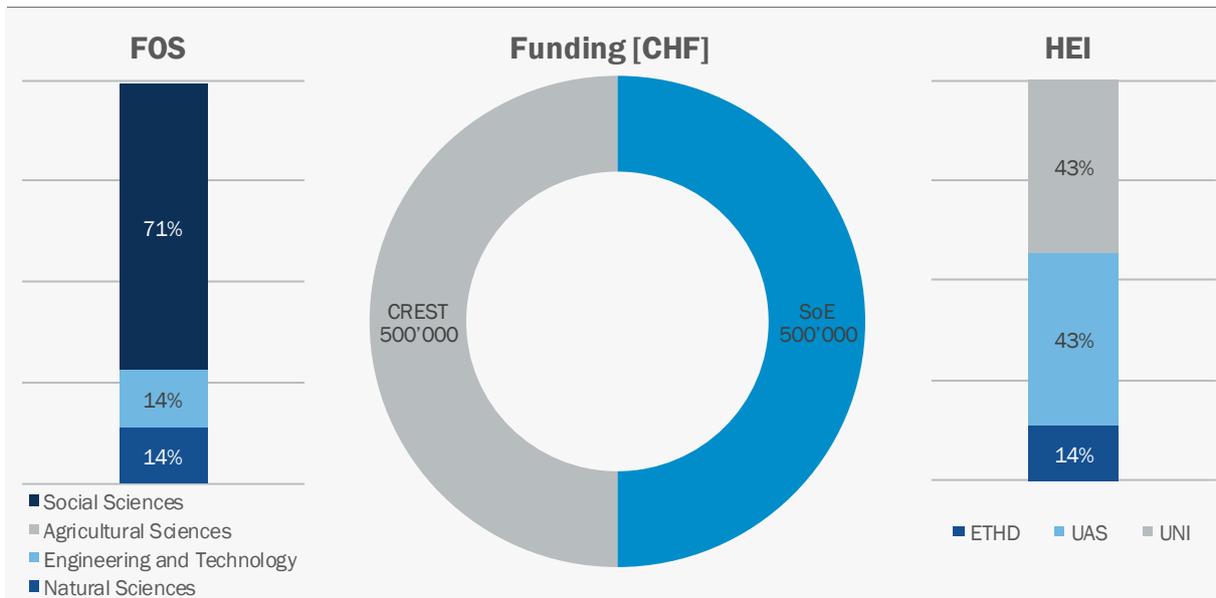
Challenges lie mainly in technical aspects; for example, it is not yet clear if specific models are suitable for RED’s purpose: for this reason, the TREE model (CREST) is about multi-energy systems (not just electricity and PV), and it would be interesting to consider new energy players in addition to Romande Energie and its customers.

Case Study V: CREST-SoE

Only SoE and CREST are involved (each 50%) in the CREST-SoE (Integrated Development Processes for Hydropower and Deep Geothermal Projects) JA. Funding of CREST-SoE amounts to CHF 1 million. The disciplinary structure is dominated by the Social Sciences FOS, followed by Engineering and Technology as well as the Natural Sciences to a lesser extent. UASs and UNIs are the main participants with respect to HEI structure, with both types of institutions participating

equally. ETHDs are involved to a minor degree (Figure 16). There are no additional external partners.

Figure 16: Overview of CREST-SoE



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The main objective of CREST-SoE is to analyse regulatory, political and participatory perspectives of integrated development processes for hydropower and deep geothermal projects. The JA is supposed to provide recommendations about how project development processes, the legislative framework and the governance structure could all be enhanced to facilitate the resolution of conflicts among stakeholders and thus increase investments in hydropower and deep geothermal energy. This means analysing the set of stakeholders and their interests, the governance structure and planning procedures necessary for such energy projects, and the impacts of “Heimfall” regulations on hydropower.

The majority of the researchers belong to a small set of the social sciences, even though they are affiliated with the SoE. The type of collaboration is considered to be multidisciplinary. Work in CREST-SoE has been based on individual desk research and regular meetings with intense discussions. Overall, the JA facilitated cooperation between the social sciences and the natural sciences (geothermal, hydropower), which indeed broadened the perspectives of research in this area (new ideas, innovative approaches). The JA has also helped to generate legal expertise on energy matters. The topic would otherwise be too complex, specific and demanding to be investigated in this depth.

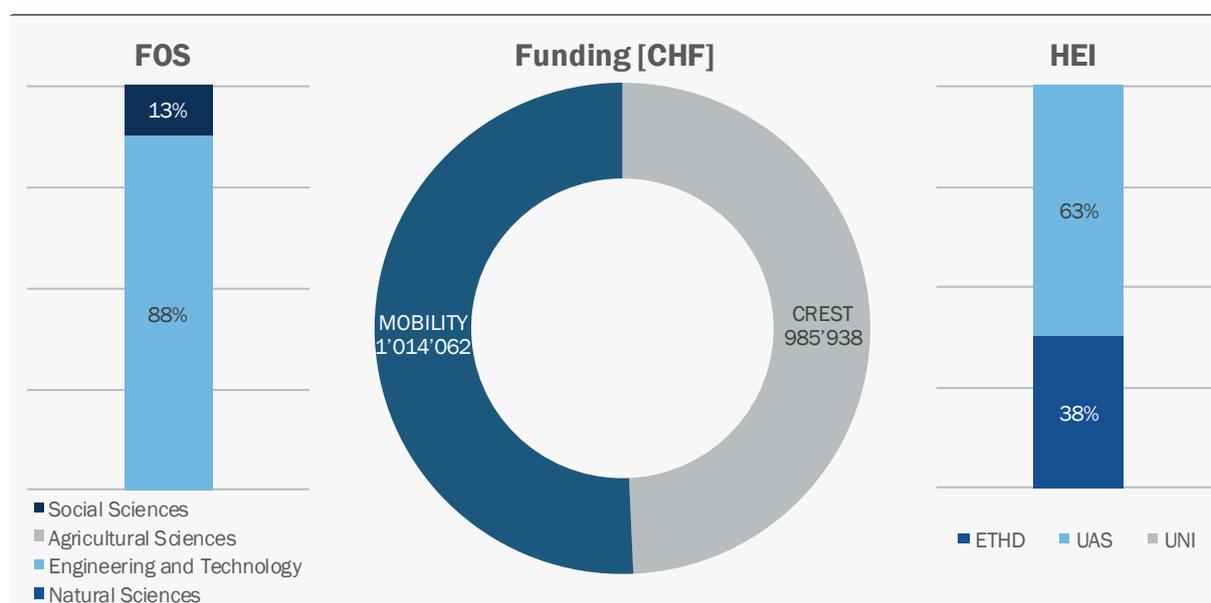
Interdisciplinarity has been difficult, because researchers have considered the inputs of other disciplines, but have continued to use their usual approach. For example, economic aspects often outweighed social and regulatory aspects regarding planned activities and overall approaches. In other words, research questions concerning social aspects and law are prioritised less than those of economic issues. This means there is less staffing and funding provided for these aspects as

well as the methodologies these fields usually employ. Additionally, it is difficult to find matching funds, especially for “smaller” universities.

Case Study VI: CREST-Mobility

In the CREST-Mobility (The Evolution of Mobility: A Socioeconomic Analysis) JA, only MOBILITY and CREST are involved; both have nearly equal levels of involvement. Funding of CREST-Mobility amounts to CHF 2 million. The disciplinary structure is dominated by the Engineering and Technology FOS, followed by the Social Sciences to a smaller degree. The HEI structure is mainly composed of UASs, ETHDs are involved to a lesser degree (Figure 17). There is one additional external partner, SBB CFF FFS.

Figure 17: Overview of CREST-Mobility



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The main objective of CREST-Mobility is to develop ways to reduce transport-related household energy demand, including incentive-based approaches, analyses of social determinants, and information-based measures. This means analysing comprehensive scenarios for a future Swiss transport system, including assessments regarding the energy and CO2 impact of such scenarios. Another object of analysis is information about which policy measures would be required to increase the likelihood of a given scenario. Field experiments will be undertaken to test the impact of programmes that use “soft measures” (information/awareness campaigns), policy measures and environmental impact studies.

Collaboration in CREST-Mobility is structured according to a work plan called a “workstream”. This means coordinators have developed a long-term plan about how results can be exchanged among them to promote and assist in each other’s work. One workshop explicitly focused on bringing the different teams of the workstreams together and fostering the exchange of results and discussions. This process allows the JA to enable researchers to investigate the topic of

transport more thoroughly, considering all the determinants – not just the technical ones. It has also fostered cooperation within the social sciences (economists, psychologists) and with the natural sciences (engineers, computer scientists).

Because of the workstream approach, cooperation requires a great deal of time to develop, especially in light of the four different models. Further work depends on additional funding, for example for the planned field experiment. This is a particular challenge for smaller institutions. The situation is also further aggravated by the characteristics of the theme “mobility” as a sensitive political topic with only a few players: it is difficult to find partners and funding. Therefore, maintaining cooperation is uncertain, and made more difficult because other funding possibilities tend to be oriented towards monodisciplinary work.

2.2.3 Collaboration in Joint Activities

Types of collaboration

Collaboration does not happen naturally or on its own. In fact, it requires effort, time and motivation. Sometimes, researchers do not know at the beginning exactly how they can collaborate effectively, how synergies can be created, and what form collaboration might take. It is necessary to have a process involving intense discussions and exchange of information. Nevertheless, the Joint Activities have helped researchers to collaborate in a variety of ways, which are described in the following table.⁵

⁵ The following analysis is based on the aforementioned case studies (Section 2.2.2). For analytical reasons and clarity, case studies and analysis have been separated.

Table 1: Overview of collaboration in Joint Activities

Joint Activity	Characterisation of the collaboration
SaM	Collaboration based on collection and comparison of data and models; discussions about scenarios
CEDA	Various partners with highly diverse backgrounds work on a common set of terms and thus on a common understanding
P2X	Collaboration based on desk research work and regular meetings, during which participants discuss the consistency of the approach, as well as what aspects overlap
RED	The researchers of the network write joint reports including all the demonstrator programmes in their analyses (demonstrators are no longer developed independently from each other). This leads to knowledge aggregation, comparisons, joint learning and result transmission. For cross-demonstrator analysis, a common technical terminology is necessary.
CREST-SoE	Collaboration based on individual desk research and regular meetings with intense discussions
CREST-Mobility	Workshops explicitly focused on bringing the different teams of the workstreams together and fostering the exchange of results and discussions. Workstream coordinators have developed a long-term plan for how results can be exchanged among them to promote and assist in each other's work

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Three general types of collaboration can be identified in the Joint Activities, depending on the research project:

- Collaboration based on individual desk research and regular meetings with intense discussions (P2X, CREST-SoE).
- Collaboration based on the integration of different demonstrators. This implies field work, and finding a common set of terminology for a cross-demonstrator evaluation (RED, CEDA).
- Collaboration based on joint scenario development. This implies exchanging data, combining complementary models, creating interfaces, and developing common databases (SaM, CREST-Mobility).

The types of collaboration identified here are not always straightforward. The share of individual work and group work varies greatly according to the project's needs and its design. The frequency of meetings and exchanges, as well as the nature and depth of these exchanges, are other variables specific to the project and the team.

Intensity of collaboration

JAs are designed to foster collaboration among researchers from different disciplines. Prognos carried out initial evaluations of the multidisciplinary/interdisciplinarity of each JA by analysing the composition of the team and institutes (see case studies). Another analysis was based on descriptions of the work packages (content, team) and the evaluation reports, as well as on interviews. A summary of the main findings can be found in Table 2.

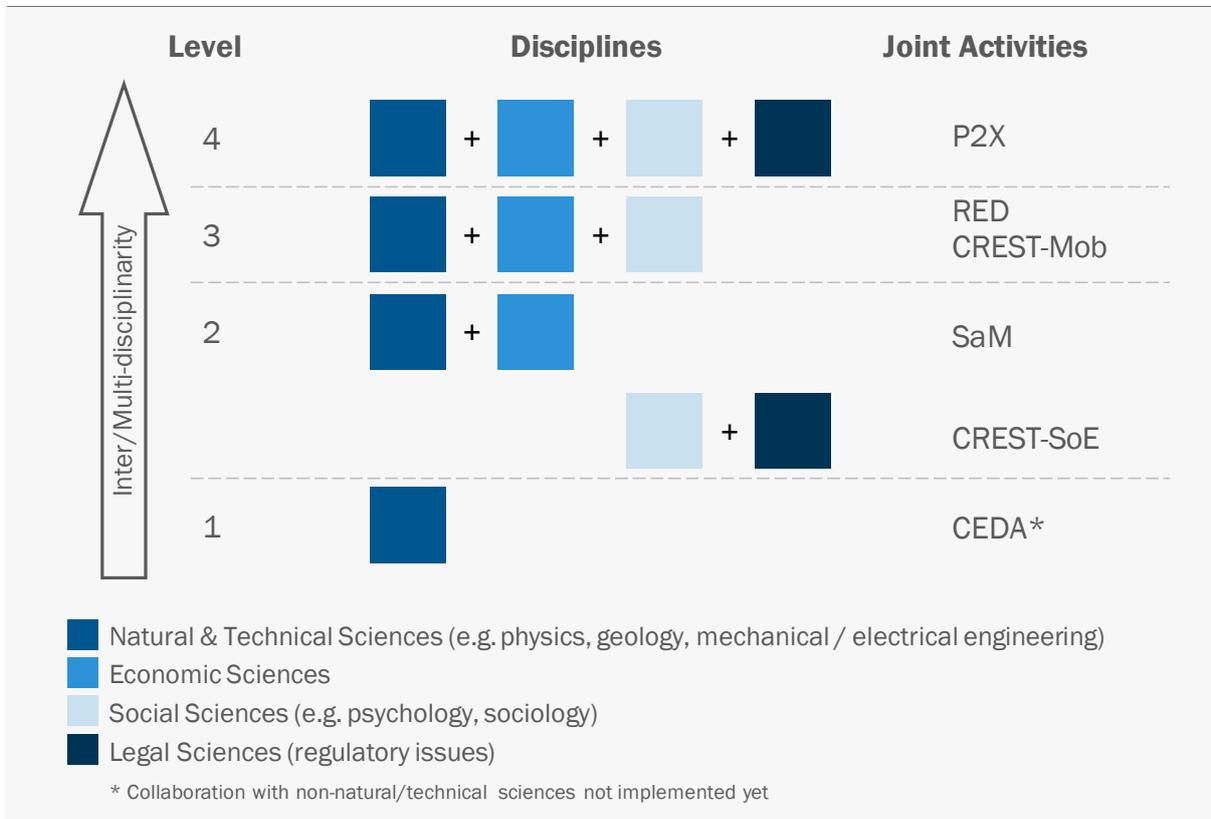
Table 2: Interdisciplinarity in Joint Activities

Joint Activity	Characterisation of the interdisciplinarity
SaM	<p>Intense collaboration among the labs from the 7 HEIs involved.</p> <p>Social and economic aspects are acknowledged to play an important role in the dissemination of technologies (e.g. behavioural change, car ownership). However, most of the JA personnel are still engineers and physicists, and collaboration between CREST and SoE is not yet optimal.</p>
CEDA	<p>Mainly technical project. Socioeconomic aspects are not covered in this JA, although the importance of behavioural and acceptance issues is slowly being recognised. These aspects are to be dealt with after the technical aspects.</p> <p>The inclusion of partners from industry allows for a more practice-oriented approach.</p>
P2X	<p>Technical, socioeconomic and legal aspects are covered in this JA.</p> <p>Contributions by many researchers from many HEIs, many disciplines and nearly all SCCERs. No private sector partner: the white paper should remain neutral about specific technologies.</p> <p>However, there is a risk that the white paper will simply end up being a juxtaposition of contributions.</p>
RED	<p>Institutes from ETHDs (EPFL, EMPA) have been collaborating with UASs (HSLU, ZHAW)</p> <p>Participants from the social sciences serve as a reality check. Part of the project should be focused on socioeconomic aspects related to the implementation of multi-energy systems, including legal and regulatory matters.</p> <p>However, it is not clear if CREST’s existing TREE model is suitable for the purpose of the project.</p>
CREST-SoE	<p>Collaboration was evaluated to be multidisciplinary, not interdisciplinary (which is seen as an overly ambitious goal). The majority of researchers belong to a small set of the social sciences, even though they are affiliated with SoE.</p> <p>No partner: the evaluation should be unbiased.</p>
CREST-Mobility	<p>There is significant potential for interdisciplinarity: part of the project aims are to develop approaches to reduce transport-related household energy demand, including incentive-based approaches, analyses of social determinants, and information-based measures. Technical and social approaches should be combined through the use of 1 or 2 field experiments to test the impact of programmes that use “soft measures” (information/awareness campaigns), policy measures and environmental impact studies</p>

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Based on the findings illustrated in Table 2, Figure 18 depicts a categorisation of JAs according to their level of multidisciplinary or interdisciplinarity (Figure 18).

Figure 18: Categorising JAs according to their level of multidisciplinary/inter-disciplinarity



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The importance or role of particular disciplines varies according to the projects. Generally, engineering and the natural sciences are always part of the research activities. In some projects, research activities include economic aspects (the profitability of a given technology, economic impacts). Social aspects (e.g. how behaviour can influence technology diffusion) plays a significant role only in a handful of projects. Legal and regulatory aspects are rarely investigated. Of all the JAs, CEDA seems to be most focused on technical aspects. Socioeconomic aspects are also considered to be important, but are only expected to be dealt with at a later stage of development. The P2X JA displays the most diversified research aspects, although only five out of eight SCCERs have taken part in the projects in this JA.

Collaboration in Joint Activities as a “real added value”

As the previous pages have shown, JA teams are always a mix of researchers from various disciplines (social sciences, engineering sciences, natural sciences), and various institutions (UASs, ETHDs and UNIs). The proportion of disciplines and institutions varies according to the JA, although engineering sciences dominate many JA. Moreover, most of the JAs incorporate technical as well as socioeconomic aspects into the project. Several implementation partners are involved in each of the Joint Activities along with two or more SCCERs. When looking at the composition of research teams and work packages, it becomes clear that the JAs enable collaboration among institutes and across disciplines, as well as with the private sector. CEDA is an exception: it is

heavily focused on technical aspects. It is also the only JA that does not involve CREST researchers.

In practice, JAs are managed as specific projects within SCCERs, which get much more funding and have a “programme” status. JAs have been described as a necessary complement to SCCERs, delivering several positive results:

- JAs are often seen as the “glue” between researchers/institutes working within SCCERs. They encourage various researchers from highly diverse backgrounds and labs to be more open, to lead more intensive discussions, to more freely exchange their results and data, to combine models more creatively, and to work more often within a common set of terms and thus on a common understanding. Potential synergies could be exploited.
- JAs focus on the energy system as a whole, thus supporting research on complex issues. JAs have a broader approach than the SCCERs individually. They encompass a broader geographic area, include more stakeholders, or investigate from a more systemic perspective. They foster inquiry into topics that have been dealt with intermittently or not at all, and that are too fragmented, complicated, or time-consuming to be researched using the usual funding sources. For example, JAs have enabled the investigation of practical technical issues related to the functioning of multi-technology systems through demonstrator projects, the enhancement of legal expertise on energy matters, and elaboration on the topic of transport that takes into consideration important determining factors other than just technical ones.
- JAs are more interdisciplinary than SCCERs. JAs have enabled cooperation between the social sciences (including economists, psychologists) and the engineering sciences (including computer scientists, geothermal or hydropower engineers), which in turn has broadened perspectives on research in the area of energy (new ideas, innovative approaches). The role of CREST researchers was widely recognised in interviews as important in the sense that they have provided a “reality check” on technological developments. This is especially true regarding the ways and conditions that technologies are adopted and diffused in markets and societies. However, most SCCER and JA staff are technical engineers, and social scientists are still in the minority.
- JAs are more application-oriented than SCCERs. They often aim to implement or refine the work undertaken by SCCERs. This also means they have more specific goals and a more practical focus. While technology itself and the potential springing from it was the focus of SCCERs (Phase I), socioeconomic aspects (social behaviour, political incentives, economic profitability) have played a more prominent role in JAs. Industrial partners are often involved. The long-term interest and involvement of the private sector is a positive sign for sustaining collaboration.

In summary, there is a real added value in Joint Activities. JAs provide the proper incentives for researchers from various backgrounds to work together on projects that are more systemic and complex in their nature than those found in SCCERs – and that they would not have investigated otherwise.

2.2.4 Challenges to fostering collaboration

Nevertheless, the JAs continue to suffer from several obstacles hindering interdisciplinary collaboration.

Lack of motivation/purpose

While researchers are generally used to exchanging their results and taking into account input from other researchers, incorporating other disciplines' point of view is still difficult. The main cause is a reliance on existing methods and approaches in a given discipline. Researchers tend to use methods common in their disciplines, while a change of perspectives or the incorporation of approaches from other disciplines is less common. There is no clear methodology for interdisciplinary collaboration in practice, especially for disciplines as different as legal and natural sciences.

Obstacles arise even in cases when a group of scientists from different disciplines have identified the need for collaboration and are willing to find ways to work together. Above all, a hierarchical ranking of disciplines and technologies poses challenges. For example, there have been instances where economic aspects have outweighed social and regulatory aspects in terms of staff, financing and importance. A ranking of technologies according to their suitability for the Swiss energy transition will inevitably take place, which could lead to some frustration for researchers working on technologies that are ranked lowest. Overall, researchers felt there was a discrepancy between Innosuisse's idea of cooperation, which they deemed too ambitious, and the reality of scientific practice.

Time-consuming process

Collaboration requires a lot of time, patience and effort. Beforehand, researchers need to pro-actively make contacts, understand each other's work, and convince others about the need for collaboration. Besides the time needed for proper coordination between institutes, a great deal of effort is usually focused on finding a common language, agreeing on terminology that can be understood by all partners. The terminology used in each discipline is different. Sometimes the same word has a different meaning, depending on the discipline. Moreover, the fields of science have different approaches and ways of thinking, which complicates the work. Overall, the development of cooperation is time-consuming and challenging.

Uncertainty about maintaining collaboration in the long term

In terms of the number of people collaborating, cooperation reached a plateau. The researchers interviewed expected that cooperation would collapse after financing dried out. Without financial resources, only a few researchers claim that they will still be actively involved in the networks. Projects focusing on demonstrators have better outlooks: these projects are of a longer-term nature and enjoy a deeper involvement from industry, so collaboration is likely to continue. Also, cooperation between institutes with complementary competences is likely to survive the reduction of funding. However, outside of these two groups, the continuation of cooperation after financing is cut is highly uncertain.

One of the obstacles respondents mentioned is the lack of alternative funding for multidisciplinary cooperation, or the lack of attention alternative funding gives to multidisciplinary projects; most other funding possibilities are largely oriented towards mono-disciplinary work.

It is also uncertain whether the personal networks that have been created through the programme will be formally institutionalised. Since cooperation is based largely on trust (the professional stakes for those involved in the cooperation are high) and thus on personal relationships, it is important for any cooperation to be transferred to the institutional level. In this way, the possibilities for future cooperation can be extended to all members of the cooperating institutes.

In the face of such uncertainties, some researchers stressed the importance of maintaining the skills they developed and preserving the knowledge they created during the JAs, as well as ensuring technology transfer.

3 Conclusions and recommendations

Main Question 1: Has SCCER funding led to deeper and more long-term oriented collaboration in energy research?

Overall, SCCER funding has led to deeper collaboration in energy research. The long-term nature of the collaboration (i.e. its sustainability) is uncertain.

Collaboration in the SCCERs took place in two phases. Phase I, from 2013 to 2016, can be described as “finding each other & getting to know each other”. The ongoing Phase II can be described by the keywords “consolidation” and “the impact of collaboration”. Collaboration has also evolved between the two phases. The first phase helped the partners to establish mutual understanding, learning and trust. These important aspects constituted a basis for the more focused, more application-oriented research activities during the second phase. The second phase has been marked by broader and deeper collaboration among institutes and across disciplines. A (frequently personal) network among researchers and across institutes developed. The transfer and exchange of knowledge and data has also been supported.

The development of this collaboration has been harnessed to the maturing of developed applications: as technologies come closer to being deployed outside the lab, the need to collaborate across different scientific disciplines increases. Even at first glance, this applies to natural and technological sciences. However, socioeconomic sciences are also becoming more important. They enable a “reality-check” and provide important aspects for the development of diffusion strategies for technologies or new models for energy and mobility use. Collaborative work and projects are taking a more systemic perspective, thus supporting Switzerland’s “Energy Strategy 2050”.

In sum, it is clear that SCCERs have provided a crucial framework to support collaboration. Access to other researchers has become easier, funding of common projects has been facilitated and the main result of this has been the establishment of research networks in the field of energy. These networks have often been based on personal contacts and SCCER-funded projects. They shorten the way to finding partners (thus lowering transaction costs) by providing easy and fast access to a significant pool of knowledge; they also give researchers opportunities to work on joint projects, and incentivise them to apply for projects and work together. SCCERs also provide crucial discussion platforms, where researchers from different disciplines and institutes can exchange ideas and learn from each other.

Overall, SCCERs have strengthened and intensified the collaboration of different disciplines. Nevertheless, the sustainability of collaboration without funding is highly uncertain. Alternative funding for multidisciplinary cooperation is sorely lacking; funding possibilities are largely oriented to work within a single discipline. This means that researcher positions and projects will run out of funding possibilities after SCCER’s Phase II. Regional proximity or a reliance on a particular technology will continue to support collaboration to a certain degree, but surely not at the current level, or with the same degree of diversity.

One necessary condition to sustain collaboration is to understand it as a state of mind, as an integral part of systemic energy research, rather than as a necessary evil. The increasing level of multidisciplinary within work packages is a sign of this development. In particular, our qualitative analysis has pointed out that SCCERs create more openness to cooperation, especially between researchers from disciplines that were previously considered to be too distant for collaboration. Frequently highlighted aspects in this regard included the addition of new momentum and the broadening of research perspectives. One particularly important aspect to continue to bear in mind would be for more and more young researchers to gain access to the relevant networks, rather than senior researchers occupying roles as gatekeepers. This would be a step towards the institutionalisation of networks and collaboration, because access would be distributed across multiple heads in different fields of research. This in turn would make it less reliant on personal connections.

Main Question 2: Has collaboration among higher education institutions been strengthened?

Collaboration between different types of HEI has flourished. UASs in particular have benefited as a partnership of equals.

When comparing Phase I to Phase II, it is clear that collaboration among different types of HEI has been strengthened. Universities of applied sciences (UASs) are now heavily involved in collaborative projects with the ETHDs and have clearly played a more significant role than previously thought. It must be pointed out that the visibility of their particular capabilities increased and compellingly demonstrated the benefits of collaboration. UASs are now perceived as independent partners, with individual profiles and capabilities for research and development. Additionally, they have contributed by injecting new momentum and broadening the scope of research. The incorporation of the UASs can therefore be seen as a significant benefit of the SCCER funding scheme for forming an energy research community including all types of HEI.

On the one hand, this is a sign of a strengthening of the systemic perspective of energy research. On the other hand, the growing deployability of technologies and projects support – but also require – collaboration, not only across disciplines, but among different types of HEI. This also makes the SCCERs' transfer concepts and proximity to applied practice especially important.

There are still some hurdles to overcome. Organisation of projects into work packages is one important aspect. The respective resources for this are often available in-house, so that there is little to no demand for collaboration outside the SCCER or its institutions. Nonetheless, SCCERs also help to reduce competition between institutes and institutional selfishness. In light of this, SCCER funding has strengthened collaboration among higher education institutions.

Main Question 3: Do Joint Activities support interdisciplinary collaboration properly?

Joint Activities support multidisciplinary and interdisciplinary collaboration: they are used as platforms for intensive dialogue; they facilitate the exchange of approaches, data, and research results; and they allow for deeper integration of these results. Joint Activities have brought together institutes and researchers from different disciplines, working on a tangible and focused task. In other words, they are taking the SCCER approach, yet refining it in a more concrete and focused way. The transfer and exchange of knowledge and data can be undertaken in an increasingly sophisticated way. A shift from multidisciplinary to interdisciplinarity is possible, and in some cases has already materialised. Particularly prominent aspects in this regard have been the infusion of new momentum and the broadening of research perspectives.

Main Question 4: How do Joint Activities support interdisciplinary collaboration, especially collaboration between engineering & technology and the social sciences?

Joint Activities imply more multidisciplinary and interdisciplinary collaboration than SCCERs alone, thus incorporating researchers from different disciplines in one team. As described above, by cultivating contacts and looking at collaboration as a state of mind, Joint Activities function as a way to bind teammates together. They organise work into a more inclusive approach and can be seen as the “glue” between researchers/institutes. Working on Joint Activities encourages various researchers from highly diverse backgrounds and labs to be more open, to lead more intensive discussions, to more freely exchange their results and data, to combine models more creatively, and to work more often with a common set of terminology and thus on a common understanding. They also facilitate mutual learning including in the development of topics that have been dealt with either infrequently or not at all, and that are too fragmented, complicated and/or time-consuming to be researched using the usual funding sources.

The main challenges to fostering the sustainability of collaboration

There are various obstacles and challenges to fostering the sustainability of collaboration. The first worth mentioning is the lack of funding opportunities for interdisciplinary research and work, especially if SCCER funding runs out. It is widely expected that the cooperation that has been achieved so far will decline or even collapse after SCCER financing dries out. Without financial resources, only a few researchers will still be actively involved in the networks. Researchers will have to leave their institutes or – for funding reasons – define their research topics according to other thematic approaches. Junior and Assistant Researcher positions are particularly rare, so there is a risk of the relevant capacities and knowledge wandering off in the short to medium term. Additionally, the existing networks rely heavily on individual, personal relationships, although progress has been made towards their institutionalisation.

The second obstacle to mention is the flip side of the lack of funding: interdisciplinarity is rarely rewarded by existing funding schemes and the organisation of academia according to discipline. Therefore, it is hard to motivate researchers to engage in interdisciplinary collaboration. Success in scientific disciplines often depends on using common methods and approaches in a discipline – “new ways are risky”. There is no clear methodology for interdisciplinary collaboration in practice, just as the benefits of interdisciplinary approaches and collaboration are difficult to measure. Above all, this includes a hierarchical ranking of disciplines and technologies. Altogether, this means interdisciplinary collaboration is a time-consuming process: different fields of science have different approaches and ways of thinking, right down to the terminology their practitioners use; this further complicates the work. Overall, the development of cooperation is time-consuming and challenging. In short: not only is interdisciplinary work particularly challenging, but (professional) benefits from it are hard to obtain.

Recommendations to strengthen the sustainability of collaboration

The following supplemental measures could support the sustainability of collaboration, in particular, the existence of a framework within which institutes can still carry out collaborative projects. Funding is also crucial, because research needs a continuous flow of funding, particularly long-term projects.

1. Platform for communication and networking

One supplemental measure involves the SCCER participants formalising the network they have built at the personal level during their time at SCCER, so that entire institutions can benefit from it. Therefore, it is advisable to maintain the SCCER as a common platform for communication and networking. This could be supported in more than one way:

- SCCER itself should be active to ensure and foster communication among institutes. It is important that collaboration becomes a “state of mind”. This means that the motivation to collaborate comes from the awareness that successful and innovative approaches require cooperation. In this case, the driving factor is not funding but the need for expertise or another perspective to solve a problem or to improve one’s own research and its impact. This means the SCCER participants should emphasise an understanding of energy research in a systemic perspective in their own institutes, thus supporting Switzerland’s Energy Strategy 2050.
- Additionally, Innosuisse and other Swiss funding agencies should discuss other funding possibilities to support such a framework. For example, conferences could be set up as framework – e.g. a “SWISS energy research day” – to support ongoing maintenance and development of the energy research community as a communication and networking platform/framework. In other words, the corresponding activities regarding communication and networking should continue to be funded in order to provide broad access for researchers.

2. Funding schemes for interdisciplinary and transdisciplinary collaboration

Regarding funding, funding agencies should discuss new funding programmes that would encourage interdisciplinary approaches and research and development, as well as reduce the costs (time, effort) of interdisciplinary collaboration. For example, funding could include an obligation for interdisciplinary cooperation as a funding criterion, or interdisciplinary components and the incorporation of collaboration in research projects could be funded from supplementary sources.

In the case of the SCCERs, projects are focused on applied research or experimental development. The increased deployability of applications is accompanied by a growing need for interdisciplinary and possibly transdisciplinary collaboration. In this context, for example, awakening industry interest is crucial for the future development of projects. Research results and their ongoing development is already sufficiently interesting for third-party financing; however, to arouse the interest and involvement of industry, it is necessary for such partners to have knowledge about these research activities and results. A coordinated approach, including organising meetings between research institutes and the private sector, could help get them involved. This in turn would possibly free up additional funding possibilities – from industry.

Appendix

Table 3: Fields of science and technology (OECD 2007)

Field of science	Scientific discipline
1. Natural Sciences	101. Mathematics
	102. Computer and information sciences
	103. Physical sciences
	104. Chemical sciences
	105. Earth and related environmental sciences
	106. Biological sciences
	107. Other natural sciences
2. Engineering and Technology	201. Civil engineering
	202. Electrical engineering, electronic engineering, information engineering
	203. Mechanical engineering
	204. Chemical engineering
	205. Materials engineering
	206. Medical engineering
	207. Environmental engineering
	208. Environmental biotechnology
	209. Industrial Biotechnology
	210. Nanotechnology
	211. Other engineering and technologies

3. Medical and Health Sciences

301. Basic medicine

302. Clinical medicine

303. Health sciences

304. Health biotechnology

305. Other medical sciences

4. Agricultural Sciences

401. Agriculture, forestry, and fisheries

402. Animal and dairy science

403. Veterinary science

404. Agricultural biotechnology

405. Other agricultural sciences

5. Social Sciences

501. Psychology

502. Economics and business

503. Educational sciences

504. Sociology

505. Law

506. Political Science

507. Social and economic geography

508. Media and communications

509. Other social sciences

6. Humanities

601. History and archaeology

602. Languages and literature

603. Philosophy, ethics and religion

604. Art (arts, history of arts, performing arts, music)

605. Other humanities

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