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Innosuisse – Swiss Innovation Agency

SCCER Accompanying Research 2017–2019

Module 4: Analysis of the collected set of indicators

Final report
Zurich, 29 August 2018

Stephan Hammer, Alexander Wunderlich, Rolf Iten (INFRAS)
In cooperation with Benjamin Buser (EBP)

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Editorial information

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Introduction

Eight Swiss Competence Centers for Energy Research (SCCER) have been active in seven priority energy-related action areas since mid-2014. The SCCERs are intended to promote new and effective approaches to energy, and to implement them in partnership with the private sector. Approximately CHF 120 million in funding is available for the SCCERs, or rather the 'Energy Funding Programme', for the period from 2017 to 2020.

Innosuisse has commissioned accompanying research on the SCCERs for the 2017 – 2019 period. One of the tasks of this research is to analyse the extent to which the indicators recorded as part of the monitoring programme are suitable as a basis for evaluating the degree to which targets have been achieved, and as a means of management, with a view to a future impact analysis. Here, the indicators are evaluated on the basis of our own analysis, taking into account the assessments supplied by representatives of Innosuisse, the SCCER Steering Committee, the SCCER Evaluation Panel, and the heads of the eight SCCERs.

Findings

The indicators gathered from the SCCERs are an important basis on which to evaluate the degree to which targets have been achieved, and to manage the Energy Funding Programme. They also provide a foundation for analysing the impacts of the Programme in terms of the inputs, activities, and outputs (findings) of energy research. However, no indicators collected track the effects of the supported research projects themselves on market participants and energy research (outcomes). They neither relate to the energy system as a whole in Switzerland, nor the economy (impacts). That said, since it is not appropriate to collect these indicators on a regular basis from the SCCERs as part of the monitoring programme, we view the set of indicators as a whole as effective and fit for purpose.

In our view, taking their methodological limitations into consideration, we believe that the indicators gathered about the inputs, activities and outputs of energy research are relevant, informative and useful in evaluating target achievement, managing the Programme, and permitting an impact analysis. Furthermore, the indicators offer an overview of the SCCERs' activities, encourage reflection, and contribute to an overall picture of the SCCERs' achievements. Innosuisse's decision to gather a variety of further information on the indicators, thereby aiding their interpretation, analysis and evaluation, is also valuable. In our view, Innosuisse is largely making the most of the opportunities offered by the indicators gathered from the SCCERs during regular monitoring. However, the usefulness of many of the indicators is limited by the fact that they do not directly permit conclusions to be drawn about the achievement of

targets and the impacts of the Programme. Rather, they must be interpreted and evaluated at the qualitative level.

In summary, our assessment of the individual indicators is as follows:

- The indicators for funding for the SCCERs and for capacity development are very relevant and informative. They allow target achievement to be measured and management decisions to be made, and also permit effects in these areas to be evaluated.
- A second group of indicators offers relevant and informative data, although it must be interpreted and evaluated before it can be used to assess the corresponding targets and effects. This group includes the indicators relating to the research projects, their deliverables (peer-reviewed articles, innovative products, patent registrations, licences, prototypes and spin-offs, etc.), and to education and further training modules. These indicators provide valuable information for an assessment of the associated targets. They can also be used to some extent for management purposes and provide a foundation for an impact analysis.
- We regard a third group of indicators as someone less relevant and informative. These indicators nonetheless provide interesting information for the assessment of progress towards targets, for management purposes, and as a basis for an impact analysis. In addition, they offer an overview of the SCCERs' activities, encourage reflection, and provide information on the SCCERs' transfer activities. These indicators cover data on cooperation, theses, communications, knowledge and technology transfer (KTT) measures, and events.
- In our view, the indicators for non-peer-reviewed articles and book chapters, as well as conference papers, are less relevant and informative for the purposes of evaluating the scientific quality of research findings and the effects of the Programme, although they may supply information on how research findings are communicated within the research community.

Recommendations

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

1. If the time and cost involved in collecting the indicators is to be reduced, Innosuisse might stop gathering those indicators which are less relevant and informative (such as the number of non-peer-reviewed articles and book chapters, or the number of conference papers).
2. We recommend that Innosuisse examine whether or not specific additional information might be collected on a variety of indicators, to raise their information value. It might, for example: record the technology readiness levels (TRL) of research and innovation projects;

evaluate the relevance of research and innovation projects to the achievement of the milestones set for the work packages (or capacity areas); or review whether or not the information on funding for the SCCERs might be linked to the individual work packages (or capacity areas).

3. Innosuisse might oblige the SCCERs to continue improving the quality of their indicators. In particular, they might limit them to especially relevant communication and KTT activities, and systematically review the information that the indicators are delivering to avoid overlaps. They might also interpret and analyse in greater depth how the indicators are supporting target achievement.
4. We recommend that Innosuisse essentially limit the annual collection of indicators to those required for the annual status report and management cycle. The remainder, including those on the findings of research and innovation projects, could instead be collected at intervals of several years. For practical reasons, however, we would not implement this recommendation within the context of the Energy Funding Programme, which runs only until 2020, but would wait and implement it as part of any future energy research support programme.
5. We recommend that Innosuisse continue to develop and expand the foundations for a future impact analysis. This work should focus on enhancing the programme logic model, formulating impact indicators for the outcomes and impacts levels, designing the study and determining the research methods that will be used to collect the empirical source data, in addition to other preparatory work for the impact analysis, such as developing data collection tools.

Zusammenfassung

Einleitung

Seit Mitte 2014 sind acht Energie-Kompetenzzentren (sog. «Swiss Competence Centers for Energy Research», SCCER) in sieben priorisierten Aktionsfeldern im Energiebereich tätig. Die SCCER sollen neue und wirksame Ansätze fördern und diese gemeinsam mit der Wirtschaft umsetzen. Für die Finanzierung der SCCER (bzw. des Förderprogramms Energie) stehen in den Jahren 2017–2020 rund CHF 120 Mio. zur Verfügung.

Die von Innosuisse in Auftrag gegebenen Begleitforschung SCCER 2017–2019 hat u.a. zu analysieren, inwiefern sich die bei den SCCER im Rahmen des Monitorings erhobenen Indikatoren als Grundlage zur Beurteilung der Zielerreichung, zur Steuerung und im Hinblick auf eine zukünftige Wirkungsanalyse eignen. Die Beurteilung der Indikatoren basiert auf einer eigenen Analyse unter Berücksichtigung der Einschätzungen von Vertretenden von Innosuisse, des SCCER Steering Committee, des SCCER Evaluation Panel sowie den Heads der acht SCCER.

Ergebnisse

Die bei den SCCER erhobenen Indikatoren sind eine wichtige Grundlage zur Beurteilung der Zielerreichung, zur Steuerung sowie im Hinblick auf eine Wirkungsanalyse des Förderprogramms Energie betreffend die Ebenen «Inputs», «Aktivitäten» und «Outputs» (bzw. Ergebnisse) der Energieforschung. Demgegenüber werden jedoch keine Indikatoren erhoben, die sich auf die Auswirkungen der geförderten Forschungsprojekte auf die Marktakteure und die Energieforschung («Outcomes») sowie das Energiesystem Schweiz und die Wirtschaft («Impacts») beziehen. Da es nicht zweckmässig scheint, entsprechende Indikatoren im Rahmen des Monitorings periodisch bei den SCCER zu erheben, beurteilen wir das Indikatoren-Set insgesamt als gut und zweckmässig.

Die auf den Ebenen «Inputs», «Aktivitäten» und «Outputs» der Energieforschung erhobenen Indikatoren beurteilen wir – unter Berücksichtigung ihrer methodischen Möglichkeiten – zur Beurteilung der Zielerreichung, zur Steuerung und im Hinblick auf eine Wirkungsanalyse als relevant, aussagekräftig und nützlich. Zudem ermöglichen die Indikatoren eine Übersicht über die Aktivitäten der SCCER, unterstützen die Reflexion und tragen zu einem Gesamtbild der Leistungen der SCCER bei. Positiv ist, dass Innosuisse zu den Indikatoren verschiedene weitere Informationen erhebt, die deren Interpretation, der Analyse und der Bewertung dienen. Aus unserer Sicht schöpft Innosuisse die Möglichkeiten der im Rahmen des periodischen Monitorings bei den SCCER erhobenen Indikatoren weitgehend aus. Einschränkend ist jedoch zu erwähnen,

dass von vielen Indikatoren nicht direkt auf die Zielerreichung und die Wirkungen des Programms geschlossen werden kann. Die Indikatoren müssen qualitativ interpretiert und bewertet werden.

Die einzelnen Indikatoren beurteilen wir zusammenfassend wie folgt:

- Die Indikatoren zur Finanzierung der SCCER und zur Entwicklung der Kapazitäten sind sehr relevant und aussagekräftig. Anhand dieser Indikatoren können die Zielerreichung gemessen, allfällige Steuerungsentscheide getroffen und die Wirkungen in diesen Bereichen beurteilt werden.
- Eine zweite Gruppe von Indikatoren betrifft relevante und aussagekräftige Informationen, die jedoch im Hinblick auf die Beurteilung der entsprechenden Ziele und Wirkungen interpretiert und bewertet werden müssen. Diese Gruppe umfasst die Indikatoren zu den Forschungsprojekten, zu deren Ergebnissen (wissenschaftlich begutachtete Artikel, innovative Produkte, Patentanmeldungen, Lizenzen, Prototypen, Spin-offs, etc.) und zu den Aus- und Weiterbildungsmodulen. Diese Indikatoren stellen wertvolle Informationen im Hinblick auf die Beurteilung der entsprechenden Ziele dar. Zudem dienen sie teilweise der Steuerung und stellen Grundlagen für eine Wirkungsanalyse bereit.
- Eine dritte Gruppe von Indikatoren beurteilen wir als etwas weniger relevant bzw. aussagekräftig. Die Indikatoren betreffen jedoch für die Beurteilung der Zielerreichung, die Steuerung und als Grundlage für eine Wirkungsanalyse interessante Informationen. Zudem ermöglichen sie eine Übersicht über die Aktivitäten der SCCER, unterstützen die Reflexion und geben Hinweise zu den Transferaktivitäten der SCCER. Diese Indikatoren betreffen die Angaben zu den Kooperationen, den Dissertationen, den Kommunikationsmassnahmen, den WTT-Massnahmen und den Veranstaltungen.
- Die Indikatoren zu den nicht wissenschaftlich begutachteten Artikeln und Buchbeiträgen sowie zu den Konferenzbeiträgen erachten wir zur Beurteilung der wissenschaftlichen Qualität der Forschungsergebnisse und der Wirkungen als weniger relevant und aussagekräftig. Sie können jedoch Hinweise zur Kommunikation der Forschungsergebnisse gegenüber der Forschungs-Community geben.

Empfehlungen

Aufgrund der überwiegend positiven Beurteilung drängen sich keine grossen Veränderungen bei den beiden SCCER periodisch erhobenen Indikatoren auf. Das Kosten-Nutzen-Verhältnis der Indikatoren und die Grundlagen für eine zukünftige Wirkungsanalyse könnten jedoch wie folgt verbessert werden:

1. Falls der mit der Indikatorenerhebung einhergehende Aufwand reduziert werden soll, könnte Innosuisse auf die Erhebung der wenig relevanten und aussagekräftigen Indikatoren

(Anzahl nicht wissenschaftlich begutachtete Artikel und Buchkapitel; Anzahl Konferenzbeiträge) verzichten.

2. Wir empfehlen Innosuisse zu prüfen, ob zu verschiedenen Indikatoren spezifische zusätzliche Informationen erhoben werden können, um deren Aussagekraft zu erhöhen: Erfassung des Technology Readiness Levels (TRL) der Forschungs- und Innovationsprojekte; Bewertung der Relevanz der Forschungs- und Innovationsprojekte zur Erreichung der Milestones der «Work Packages» (bzw. der «Capacity Areas») und Prüfung, ob die Angaben zur Finanzierung der SCCER auf die «Work Packages» (bzw. «Capacity Areas») bezogen werden können.
3. Innosuisse könnte die SCCER verpflichten, die Qualität der Indikatoren weiter zu verbessern (v.a. Beschränkung auf besonders relevante Kommunikations- und WTT-Aktivitäten; systematische Prüfung der Angaben zu den Indikatoren auf Abgrenzungsfragen) und die Indikatoren im Hinblick auf deren Beitrag zur Zielerreichung verstärkt zu interpretieren und zu bewerten.
4. Wir empfehlen Innosuisse, die jährliche Erhebung grundsätzlich auf Indikatoren zu beschränken, die jährlich zur Standortbestimmung und zur Steuerung benötigt werden. Die übrigen Indikatoren (u.a. zu den Ergebnissen der Forschungs- und Innovationsprojekte) könnten in einem mehrjährigen Rhythmus erhoben werden. Aus praktischen Gründen würden wir diese Empfehlung jedoch nicht mehr in dem bis zum Jahr 2020 befristeten Förderprogramm Energie, sondern erst im Rahmen einer allfälligen zukünftigen Förderung der Energieforschung umsetzen.
5. Wir empfehlen Innosuisse, die Grundlagen für eine zukünftige Wirkungsanalyse weiterzuentwickeln und zu ergänzen. Im Vordergrund stehen die Weiterentwicklung des Wirkungsmodells, die Erarbeitung von Wirkungsindikatoren zu den Ebenen outcomes und impacts, die Festlegung des Untersuchungsdesigns und der Forschungsmethoden zur Erhebung der empirischen Grundlagen sowie weitere Vorbereitungsarbeiten für die Wirkungsanalyse (z.B. Erarbeitung von Erhebungsinstrumenten).

Résumé

Introduction

En été 2014, huit centres de compétences (Swiss Competence Centers for Energy Research, SCCER) ont commencé à travailler dans sept champs d'action prioritaires du domaine de l'énergie. Ces SCCER ont pour vocation d'encourager les approches à la fois innovantes et efficaces et de les mettre en œuvre en s'associant aux milieux économiques. Les ressources financières dont sont dotées les SCCER (respectivement le programme d'encouragement Energie) s'élèvent à quelque 120 millions de francs suisses pour la période 2017 à 2020.

La recherche d'accompagnement SCCER 2017–2019 lancé par Innosuisse doit notamment évaluer dans quelle mesure les indicateurs relevés par les SCCER dans le cadre du monitorage sont à même de servir de base pour vérifier si les objectifs visés ont été atteints, de piloter le programme et d'effectuer une future étude d'impact. L'évaluation des indicateurs se base sur une analyse interne, qui tient compte des évaluations faites par les représentant-e-s d'Innosuisse, par le comité de pilotage SCCER, par le groupe d'évaluation SCCER ainsi que par les responsables des huit SCCER.

Les résultats

Les indicateurs relevés dans les SCCER constituent une base significative pour évaluer si les objectifs fixés ont été atteints et pour piloter le programme ; ils constituent également une base significative en prévision d'une future étude d'impact du programme d'encouragement Energie en matière d'inputs, d'activités et d'outputs/résultats dans le domaine de la recherche en matière d'énergie. Aucun indicateur n'a cependant été relevé qui se réfère aux effets des projets de recherche soutenus sur les acteurs du marché, sur la recherche en matière d'énergie (outcomes) ou sur le système énergétique suisse et de l'économie (impacts). Il n'est pas judicieux de relever périodiquement les indicateurs correspondants dans le cadre du monitoring auprès des SCCER ; selon notre appréciation, la brochette d'indicateurs considérée est donc bonne et appropriée dans l'ensemble.

Nous estimons en outre que les indicateurs saisis au niveau des inputs, des activités et des outputs de la recherche matière d'énergie, sont pertinents, significatifs et appropriés pour évaluer si les objectifs fixés ont été atteints, pour piloter le programme et en prévision d'une future étude d'impact, compte tenu des possibilités méthodologiques qu'ils offrent. De plus, ces indicateurs donnent une vue d'ensemble des activités des SCCER, contribuent à la réflexion et contribuent à illustrer les prestations fournies par les SCCER. Nous constatation avec satisfaction qu'Innosuisse relève non seulement les indicateurs, mais encore une série d'informations

supplémentaires qui facilitent leur interprétation, leur analyse et leur évaluation. Nous estimons qu'Innosuisse exploite au mieux les possibilités offertes par les indicateurs relevés dans le cadre du monitorage périodique effectué dans les SCCER. Notre seule réserve : parmi les indicateurs, nombreux sont ceux qui ne permettent pas d'établir directement si les objectifs fixés ont été atteints et si le programme permet de réaliser l'effet escompté. Une interprétation et une évaluation qualitative des indicateurs s'impose.

Notre évaluation des différents indicateurs en bref :

- Les indicateurs relatifs au financement des SCCER et au développement de capacités sont très pertinents et significatifs. Ces indicateurs permettent de savoir dans quelle mesure les objectifs visés ont été atteints, d'intervenir au niveau du pilotage et d'évaluer les effets obtenus dans ces domaines.
- Un deuxième groupe d'indicateurs concerne les informations pertinentes et significatives, qui nécessitent cependant une interprétation et une appréciation avant de pouvoir procéder à l'évaluation des objectifs et des effets visés. Ce groupe comprend les indicateurs relatifs aux projets de recherche, à leurs résultats (articles soumis à un avis scientifique, produits innovants, brevets déposés, licences, prototypes, entreprises dérivées, etc.) ainsi qu'aux modules de formation et de formation continue. Ces indicateurs donnent des informations précieuses pour savoir si les objectifs fixés ont été atteints. Par ailleurs, certains d'entre eux livrent des repères pour le pilotage ainsi que des informations de base pour une étude d'impact.
- Un troisième groupe d'indicateurs est moins pertinent et significatif selon nous. Ils fournissent néanmoins des informations intéressantes pour savoir si les objectifs fixés ont été atteints, pour piloter le programme et en prévision d'une future étude d'impact. Par ailleurs, ils donnent une vue d'ensemble des activités des SCCER, contribuent à la réflexion et renseignent sur les activités de transfert des SCCER. Ces indicateurs informent sur les coopérations, les thèses de doctorat, les activités de communication, les mesures TST (transfert de savoir et de technologie) et les manifestations organisées.
- Le quatrième groupe d'indicateurs concerne les articles et les contributions à des ouvrages qui n'ont pas été expertisées scientifiquement ainsi que les contributions à des conférences ; nous estimons que ces données sont moins pertinentes et significatives pour évaluer la qualité scientifique des résultats et des impacts de la recherche. Néanmoins, ils livrent des indications concernant la communication des résultats de recherche au sein de la communauté scientifique.

Recommandations

Les résultats globalement positifs de l'évaluation montrent que les indicateurs relevés périodiquement dans les SCCER font leurs preuves dans l'ensemble et ne nécessitent pas d'adaptations majeures. Néanmoins, nous estimons que le rapport coût-utilité des indicateurs et le fondement d'une future étude d'impact pourront être améliorés au moyen des mesures suivantes :

1. S'il s'agit de réduire les frais de saisie des indicateurs, Innosuisse pourrait renoncer aux indicateurs les moins pertinents et significatifs (nombre des articles et contributions à des ouvrages qui ne bénéficient d'aucune évaluation scientifique, nombre de contributions à des conférences).
2. Nous recommandons à Innosuisse d'évaluer la possibilité de collecter des informations spécifiques supplémentaires à propos de certains indicateurs afin d'accroître leur pertinence : relever le niveau de maturité technologique (Technology Readiness Levels, TRL) des projets de recherche et d'innovation ; évaluer la pertinence des projets de recherche et d'innovation en vue d'atteindre les jalons des «Work Packages»/ «Capacity Areas»; vérifier si les informations relatives au financement des SCCER peuvent se référer aux «Work Packages»/ «Capacity Areas».
3. Innosuisse pourrait engager les SCCER à poursuivre l'amélioration de la qualité des indicateurs (notamment en se limitant aux activités de communication et de TST prioritaires et en vérifiant systématiquement les informations sur les indicateurs sous l'angle de leur délimitation) et de focaliser l'interprétation et l'évaluation des indicateurs quant à leur aptitude à contribuer à atteindre les objectifs fixés.
4. Nous recommandons à Innosuisse de limiter leur relevé annuel aux indicateurs nécessaires au bilan annuel et au pilotage. La fréquence de saisie des autres indicateurs, notamment ceux qui se rapportent aux résultats des projets de recherche et d'innovation, peut s'effectuer à un rythme pluriannuel. Pour des raisons pratiques, nous suggérons de mettre en œuvre cette recommandation non dans le programme d'encouragement Energie limité à 2020, mais dans le cadre de l'éventuel programme de suivi de recherche sur l'énergie.
5. Nous recommandons à Innosuisse de poursuivre et de compléter le développement des bases d'une future étude d'impact, notamment en développant le modèle d'impact, en élaborant des indicateurs pour les outcomes et les impacts, en déterminant la méthode d'analyse et la méthode de recherche destinées à saisir les bases empiriques ainsi que les autres travaux préparatoires de l'étude d'impact (p. ex. élaboration des instruments de saisie).

1. Introduction

1.1. Background

The Federal Council's 'Swiss Coordinated Energy Research' action plan (Federal Council 2012) aims to promote energy research, and thereby support the implementation of the Energy Strategy 2050. A central element of the action plan is the establishment of networked inter-university centres of research excellence, known as 'Swiss Competence Centers for Energy Research' (SCCERs). Eight SCCERs have been active in seven priority energy-related action areas since mid-2014. These competence centres are intended to promote new and effective approaches to energy, and to implement them in partnership with the private sector. Approximately CHF 120 million in funding is available for the SCCERs (including their 'Joint Activities'), or rather the 'Energy Funding Programme'[1], for the second funding period from 2017 to 2020 (CTI 2016a). Innosuisse funding for the SCCERs is scheduled to end in 2020.

Innosuisse commissioned a working group consisting of INFRAS, EBP, IRENE[2] and Prognos to conduct research accompanying the SCCERs for the 2017–2019 period. This accompanying research is intended to provide an external perspective to help the Steering Committee manage the Energy Funding Programme. It comprises four modules:

- Module 1: Lead and coordination of the accompanying research; drafting the synthesis of results
- Module 2: Analysis of the implementation of scientific findings
- Module 3: Analysis of the long-term future of the SCCERs, divided into
  - Module 3a: Preparations for the permanent establishment of the SCCERs, and
  - Module 3b: Analysis of networking and cooperation
- Module 4: Analysis of the collected set of indicators.

This report contains the findings of the accompanying research conducted for Module 4.

1.2. Remit and research questions

Module 4 is designed to analyse and evaluate the set of indicators collected annually from the SCCERs. The analysis should examine the extent to which the indicators are suitable as a basis of information on which to evaluate the degree to which targets have been achieved, as a means of managing the SCCERs, and as a foundation for a future impact analysis of the Energy

[1] In line with the corresponding implementing provisions issued by Innosuisse (2018), financial support for the SCCERs and their Joint Activities will be referred to collectively as the Energy Funding Programme.
[2] *Institut de recherches économiques de l'Université de Neuchâtel* [Institute of Economic Research at the University of Neuchâtel].

Funding Programme. The findings will then be used to derive potential for improvement, and specific recommendations for the attention of the Steering Committee.

The targets and requirements of the commissioning party give rise to the following research questions:

1. Does the current programme of SCCER monitoring collect indicators which permit the achievement of targets to be measured, and the Energy Funding Programme to be managed?
2. Does the current programme of SCCER monitoring collect indicators, which might serve as one of several foundations for a future impact analysis?
3. Which indicators are less relevant or less informative, and thus no longer need be collected? Do any additional indicators need to be recorded?
4. How are the indicators that are collected from the SCCERs to be evaluated overall? Where is there room for improvement?

In response to the requirements of the commissioning party, Module 4 focuses on evaluating the indicators that are to be used to measure target achievement, and for management purposes. It should also look at the extent to which the indicators collected from the SCCERs are suitable for use in a future impact analysis. Only brief references are expected with regard to any further indicators and foundations for an impact analysis.

1.3. Methodology

Analysis concept

Module 4 examines the indicators that Innosuisse collects annually from the SCCERs. We regard these indicators as a means of observing and describing the changes brought about by the Energy Funding Programme. The objective of Module 4 is to evaluate the extent to which the indicators enable target achievement to be measured, how they contribute to the management of the Programme, and their suitability as a basis for a future impact analysis. There are certain overlaps between these areas because the Programme's objectives are largely effect-focused:

- The aims of the Energy Funding Programme are defined in the Federal Council dispatch of 17 October 2012 on the 'Swiss Coordinated Energy Research' action plan (Federal Council 2012), and in the Innosuisse documents that are based upon it (primarily CTI 2016a) As a basis for our analysis, we first developed a target matrix which classifies targets into different effect levels and a hierarchy (strategic vs. operational) (see Annex A1). In a second step, we then produced a logic model for the Energy Funding Programme which presents the desired

effects within a coherent logical structure (see Section 2). The indicators represent the practical implementation of the targets (or desired effects).

- We assume that Programme management is geared to the Programme targets, and that it focuses on those targets over which the Steering Committee and Innosuisse have as direct an influence as possible.
- A future impact analysis will examine the effects triggered by the Energy Funding Programme at a variety of levels. The effects which the Programme is designed to achieve are already described to some extent in the Programme targets. The indicators overlap to a considerable degree as a means of evaluating target achievement and impact. There are three things to consider with regard to a future impact analysis, however: 1) it may be necessary in some instances to extend the explicitly formulated target impacts with additional, desired effects; 2) unintended impacts should also be factored in as far as is possible; and 3) the impact analysis should investigate specifically the extent to which the changes that have been observed genuinely are the result of the Energy Funding Programme. The expected impacts of the Energy Funding Programme are also shown in the programme logic model.

Before actually conducting our evaluation, we classified the indicators according to their desired effects in line with the programme logic model (see Section 3.3). This classification was made on the basis of our own considerations and the instructions contained in the internal CTI documents (primarily CTI 2017).

In view of their close relationship, we combined the target achievement and management indicators (see Section 4). Three criteria were applied to this evaluation: relevance, information value and cost-benefit ratio:

- The more closely the content of an indicator is related to a specific target, the more relevant it is. Consequently, the more detailed the definition (or practical implementation) of a target, and the closer the indicator reflects the content of that target, the more relevant the indicator. When assessing the relevance of the indicators in management terms, the degree to which the Steering Committee and Innosuisse are able to influence target achievement must also be taken into consideration.
- The information value of the indicators is higher the more suitable they are for evaluating (or measuring) the content of the targets. Thus, information value is particularly high where indicators relate to quantitative and easily measurable targets, or those which can fundamentally be measured in quantitative terms.
- The cost-benefit ratio improves the lower the time and cost involved in collecting the indicators, and the greater their benefit. The evaluation of benefit must consider not only the direct benefit of the indicators in measuring target attainment and in management decision-

making, but also their indirect benefits, such as the overview of the activities and output of the SCCERs that they provide. The time/cost assessment should also factor in the proportion of the overall funding which supports the SCCER.

In consultation with the commissioning party, the SCCER indicators are evaluated as a basis for a future impact analysis in summary form, applying the 'relevance' and 'information value' criteria (see Section 5). We also suggest possible further indicators and data for such an analysis. Our evaluation of the indicators is based on our own analyses, taking into account the appraisals of representatives of Programme management (Innosuisse, Steering Committee and Evaluation Panel) and the SCCERs themselves.

It should be noted that the indicators are just one of several sources of information that the Steering Committee can use to evaluate whether or not the set targets – and what effects – have been achieved. Other particularly important sources are the SCCERs' annual monitoring reports, the Evaluation Panel's evaluation reports, and the impressions gained by the Steering Committee and the Evaluation Panel during their site visits to the SCCERs. With this in mind, the indicators should not be evaluated in isolation, but rather in association with other monitoring instruments.

Empirical basis

As a basis for our own analysis and evaluation of the indicators, we examined relevant documentation, specifically the concept documents, and documentation on the indicators that are collected. We also conducted structured qualitative interviews with the management of the Energy Funding Programme at Innosuisse, five members of the SCCER Steering Committee, seven members of the SCCER Evaluation Panel, one additional subject matter expert, and the heads of the eight SCCERs themselves (on occasion including the programme managers or coordinators). The interviews focused on the indicators' usage, value, limits and optimisation potential.[3]

[3] Further details of the qualitative interviews (and especially the subjects who were interviewed), as well as on the relevant findings, are documented in Annex 2.

1.4. Structure of the report

This report is structured as follows:

- In Section 2, the Energy Funding Programme's logic model is reconstructed on the base of the targets formulated in the concept documents and other considerations of our own.
- Section 3 describes the set of indicators collected from the SCCERs and embeds it in the context of other monitoring instruments. The indicators are also classified according to their desired effects in line with the programme logic model.
- Section 4 evaluates how suitable the indicators collected from the SCCERs are for measuring target achievement and for management purposes. This section also highlights options for improvement.
- Section 5 looks at the suitability of the indicators as a basis for a future impact analysis. It also suggests further data that might be collected as an input to such an analysis.
- In Section 6, we offer an overall assessment which answers the research questions. From this we then derive recommendations on how the indicators might be improved.
- The Annex documents the following supplementary information and findings: Annex A1 sets out the targets that the SCCERs are intended to achieve; Annex A2 contains further details about the interviews that were conducted, and their outcomes.

2. Energy Funding Programme: logic model

The logic model describes the effects that the Energy Funding Programme is intended to have at different levels. It is one of the keys to evaluating the indicators collected from the SCCERs. The indicators should be able to capture the different effects, and track the relevant changes, as effectively as possible.

The logic model distinguishes between the following effect levels (see Figure 1):[4]

- 'Inputs': conceptual and organisational foundations, financial and human resources, and further inputs into energy research (e.g. networking, technology and infrastructure).
- 'Activities': work on research and innovation projects, as well as knowledge and technology transfer (KTT).
- 'Outputs': the results of research and innovation projects.
- 'Outcomes': the effects of the outputs of energy research on businesses and organisations from the private and public sectors, with a particular focus on implementation partners.
- 'Impacts': the effects on Switzerland's energy system and the Swiss economy.

The logic model was produced on the basis of the targets laid down in the concept documents (see Annex A1). Given the emphasis of Module 4 (evaluation of target achievement and management indicators), the model concentrates on the inputs, activities and outputs levels. We do, however, propose how outcomes and impacts are beginning to crystallise. The programme logic model is a working tool that can be refined and extended as necessary.

[4] For examples of how to structure logic models according to these levels, please refer to Funnell and Rogers 2011.

Figure 1: Energy Funding Programme: logic model

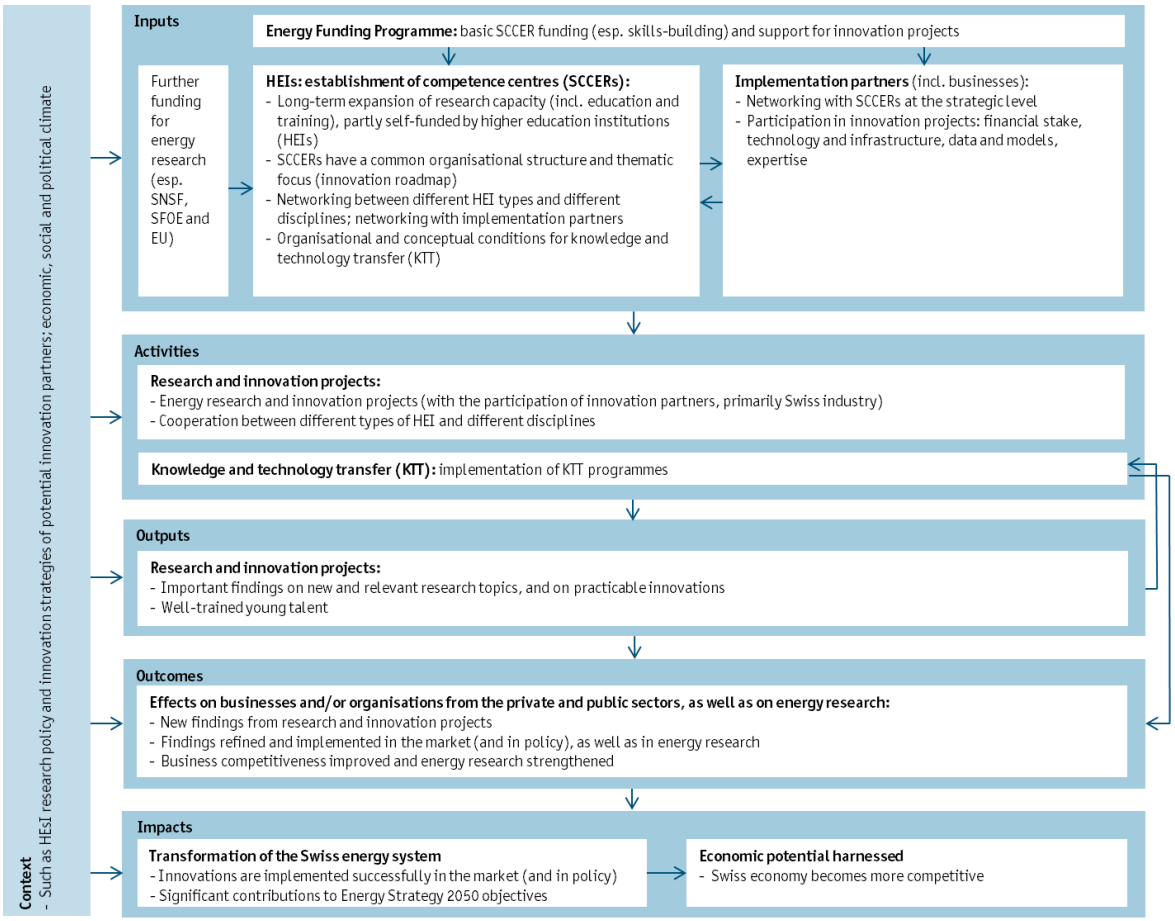

Figure: INFRAS.

The primary aim of the Energy Funding Programme is 'through research and innovation, to contribute significantly to improving the efficiency of the energy system in Switzerland and to meeting electricity needs after nuclear generation capacity is switched off'. (Federal Council 2012). The desired effects at the various levels are described below (see Figure 1):[5]

Inputs

When discussing inputs into energy research, a distinction must be drawn between financial support from the Energy Funding Programme and the energy research grants from higher education institutions (HEIs) and implementation partners (incl. businesses) which are triggered by this Programme funding. Other funding for energy research must also be taken into account:

[5] Any unintended effects are not described here. In our view, it is almost impossible to capture and analyse these effects with indicators that are collected on a periodic basis. Rather, they should be analysed in the context of a snapshot impact analysis or evaluation.

Energy Funding Programme

The Energy Funding Programme is described and substantiated in the corresponding Federal Council dispatch (Federal Council 2012). The dispatch and the documents for the call for proposals which are based on it (CTI 2013 and 2016a) set out the concept of the Energy Funding Programme and its implementation in greater detail. The Programme (i.e. Innosuisse) provides basic funding grants for SCCERs (primarily funding for skills-building, as well as funding for the SCCERs' operating expenses), as well as (competitive) funding for innovation projects.

Establishment of competence centres (SCCER) by HEIs

The Energy Funding Programme is intended to result in an expansion of research capacity, the establishment of competence centres (SCCERs), and to greater networking and cooperation on energy at the higher education level:

- Research capacity is to be expanded by and at the higher education institutions (HEIs, including the ETH domain, universities and universities of applied sciences) which participate in the SCCERs. This expansion is intended to build and retain skills at these HEIs over the long term. The HEIs themselves are expected to contribute their own financial resources to such programmes. Thus, the objective of the Energy Funding Programme is to encourage the HEIs involved to prioritise energy research to some degree when drawing up their budgets. As capacity is expanded, participating HEIs are expected to broaden the associated education and training courses they offer. Both the Federal Council (2012) and the Commission for Technology and Innovation CTI (2016b) have drawn up quantitative targets for the expansion of research capacity (see Annex A1). The proportion of female researchers should also be increased, and two-thirds of the jobs created at the SCCERs should be retained after 2020, spread appropriately across the various functions and levels.
- HEIs should establish competence centres (SCCERs) with a common organisational structure and a common thematic focus and operate these SCCERs for the long term. The SCCERs should align this thematic focus with priority research areas. Research activities should be based on jointly developed innovation roadmaps. These should show which research contribution to Energy Strategy objectives is to be made by each SCCER.
- Networking at the structural level between the different types of HEI and between the different disciplines should be strengthened.

Furthermore, the structural, academic and conceptual foundations of knowledge and technology transfer (KTT) should be improved, in particular by means of KTT strategies, dedicated KTT officers, and the involvement of the technology transfer units at the participating HEIs.

Participation of implementation partners in energy research

The aim of the Energy Funding Programme is for implementation partners – primarily businesses – to take a financial stake in energy research, i.e. innovation projects. The Federal Council and the CTI have set targets for the proportion of SCCER activity funding that the various partners should provide (see Annex A1). Businesses can also take part in projects by contributing their technologies, infrastructure, data and models, and expertise. They usually contribute to the cost of innovation projects on a 'cash and in kind' basis (infrastructure, R&D staff, etc.).

Further funding for energy research

The SCCERs are intended to compete for and win further third-party funding for their energy research projects. Examples here include federal government (SNSF, SFOE) and EU programmes.

Activities

Where activities are concerned, a distinction must be drawn between the conduct of research and innovation projects, and the implementation of KTT programmes:

Research and innovation projects

The Energy Funding Programme is intended to strengthen energy research in the long term to support the implementation of the new energy policy. The academics and researchers at the SCCERs should conduct research and innovation projects that will help to realise the Energy Strategy 2050. These should take into account the entire knowledge generation chain and the way in which it translates into practice – from basic research through to prototype development and demonstrators. There are two main approaches here:

- One is to conduct innovative energy research projects, the aim being for the academics from various types of HEI and various disciplines who are involved in the SCCER to work together more closely.
- The other is to increase the number of innovation projects on energy issues in the priority action areas that involve implementation partners (businesses and/or organisations from both the private and public sectors). This is intended to strengthen application-oriented research.

Knowledge and technology transfer (KTT)

The SCCERs should step up knowledge and technology transfer (KTT) with regard to the outputs of their research and innovation, making such programmes more professional and placing

them on a long-term footing. They should share their findings pro-actively with their partners and other actors. KTT programmes, such as events, training courses and platforms, should be implemented successfully.

Outputs

Research and innovation projects aim to achieve the following outputs:

- Innovative energy research projects should deliver important findings on new, relevant and specifically Swiss research topics in the priority research areas. These findings should also be recognised internationally. Possible outputs include research publications, theses, data and models, and the construction of infrastructure and/or pilot plants.
- Innovation projects conducted with implementation partners (primarily businesses) should develop implementation-oriented innovations which improve the transfer of research findings to market. Potential outputs include patent registrations, licences, prototypes, spin-offs, pilot plants and demonstrators, and innovative products, processes and services (including business cases). The projects should also train young talent.

Outcomes

According to the Federal Council (2012), the innovations resulting from the Energy Funding Programme should be brought successfully to 'future' markets. The concept documents do not provide any further details of the expectations of and possible effects on the individual (market) actors.

We assume that specifically those implementation partners involved in SCCER innovation projects are able to play a significant part in the successful translation of those innovations into everyday life:

- Participating businesses from the private (or public) sector should have gained new findings from the research and innovation projects. Where necessary, they should further develop these findings and/or technologies. It is key that they bring these to market, for example by launching and marketing a product or service until it becomes established, or by putting organisational, process-related and product innovations into practice. This might make the businesses concerned more competitive, in the form of greater innovative drive, access to new markets, a stronger market position or cost savings, etc. – thereby sustainably increasing the business's earning capacity and employment levels.
- Participating government agencies should have created a basis of information (e.g. data and models) and/or gained knowledge that will allow them to optimise their energy policy framework and programmes to achieve the objectives of the Energy Strategy 2050. Where

necessary, they may continue to enhance this source data and these findings. It is also important that they are put into effect in these agencies' specific activities, in improvements to energy policy instruments, for example.

In the case of businesses and/or organisations from the private and public sectors who are not involved in the SCCERS' energy research, knowledge and technology transfer (KTT) might also trigger a learning process and the steps needed to bring the innovations to market or incorporate them into policy. For example, businesses might improve their products and services in response to the findings of innovation projects. The potential effects here are comparable to those felt by the implementation partners themselves.

Furthermore, the impetus generated by the Energy Funding Programme might have a longer-term effect on energy research, with HEIs and businesses prompted by knowledge gains, the corresponding innovations and partnerships, as well as the success of research and innovation, to invest in a greater breadth and depth of research into the field.

Impacts

Transformation of the energy system

According to the Federal Council (2012), the Energy Funding Programme should ultimately be used to support the transformation of Switzerland's energy system. Innovations are to be implemented successfully in the market (and in policy). This should make significant contributions to the achievement of Energy Strategy 2050 objectives. However, the concept documents give no further details of expectations in this regard.

The following effects would be desirable, in our view:

- Innovations, such as new or improved processes, products and services, will become increasingly common and established on both the supply and demand sides of the market.
- Among energy consumers, these innovations will result in efficiency gains (also measurable in kWh) or to products which use a higher proportion of renewable energies. Rebound effects will be avoided as far as possible.
- Successfully bringing innovation to market and embedding it in policy will further strengthen and expand energy research, i.e. it will have a dynamic positive feedback effect. This in turn will be an effective factor in the long-term transformation of the energy system.

Harness the economic potential of energy system transformation

The Federal Council (2012) also wants to harness the economic potential of new energy policies. Specifically, increasingly harnessing the potential of innovation might help to make the

Swiss economy more competitive, in the form of greater innovative drive, access to new markets, a stronger market position or cost savings, for example.

3. The set of indicators

3.1. Collected set of indicators

Innosuisse collects the indicators in connection with the monitoring reports which the SCCERs must produce on an annual basis. They are recorded in two lists: a 'monitoring' list (see CTI 2017b) and a 'financial monitoring report' (see CTI 2017c). A variety of additional information on the individual indicators is also collected. According to Innosuisse, the indicators are drafted in consultation with representatives of the Evaluation Panel, and then approved by the Steering Committee. These indicators, as well as the additional information collected from the SCCERs, is shown below (structured according to the 'monitoring' list).

Table 1: Indicators collected from the SCCERs (incl. additional information)

Themes	Indicators	Additional information
Research and development projects	Number of R&D projects	Per R&D project: title of project, date of approval, total project costs, funding for SCCER research group, main funding agency, research partner(s), implementation partner(s), WP/CA affiliation, international participation
Cooperation	Number of cooperations with the private sector and with the public sector	Per cooperation: name of company/organisation/government agency, implementation partner (yes/no), type of contribution, in-kind contribution, start date, WP/CA affiliation
Training and support	Number of training modules	Per training module: name of module, brief description of module, type of education, type of training, type of higher education institution (HEI), start date, number of graduates, new training module (yes/no)
	Number of completed theses	Number of completed theses within type of HEI: ▪ master's and PhD theses ▪ in total and by women
Performance/ output	Number of patent applications	Per patent application: applicant, inventor, title, priority date, patent exploited, status, validity, brief description
	Number of licences	Per licence: subject, grantor of licence, licence holder, year, contract period, brief description
	Number of spin-offs	Per spin-off: name of spin-off company, former research institution and institute, year of incorporation, town, brief description of the business idea
	Number of prototypes, pilot plants, demonstrators	Per prototype, etc.: type, name, external partner(s), potential client, date of market launch (pilot plants and demonstrators), brief description (including the innovative features)
	Number of innovative products, processes or services	Per product, etc.: brief description, type, innovative process: cost reduction (yes/no), new features, external partner(s), final client, status of market implementation
	Number of developments of models and data collections	Per model and data collection: models, client, brief description,

Themes	Indicators	Additional information
Scientific publications	Number of peer-reviewed articles	Per article: title, authors and year of publication
	Number of non-peer-reviewed articles	Per article: title, authors and year of publication
	Number of reviewed book chapters	Per book chapter: title, authors and year of publication
	Number of non-peer-reviewed book chapters	Per book chapter: title, authors and year of publication
	Conference proceedings	In each case: title, authors and year of conference
Scientific events and technical conferences	Number of scientific events and technical conferences organised by the SCCER	Per event/conference: title, type, date and place, estimated number of participants, target groups, background of participants, purpose of event
	Number of scientific events and technical conferences not organised by the SCCER, at which the SCCER's research findings were presented in a speech	Per event/conference: title, type, date and place, title of speeches given by SCCER, organiser, number of participants from the SCCER, international event (yes/no)
Management of the SCCER	Number of cooperations with other SCCERs	Per cooperation: SCCER work package involved, name of partner SCCER, institute taking part in the SCCER, benefits and expected outputs
Communication	Number of communication measures	Per communication measure: type of contribution, name of medium, target groups, date of publication
Knowledge and technology transfer (KTT)	Number of preparatory KTT measures (e.g. workshops, working groups, innovation groups, exploratory talks)	Per measure: start date, short description of the measure, prospective implementation partner, WP affiliation, outcome of the measure
SCCER staff	Number of positions (in FTE)	
	Number of positions per gender (in FTE)	
	Number of positions per function (in FTE)	
	Number of positions per HEI (ETH, University of Applied Sciences, University)	
Funding sources	Amount of funding per source (CTI, own, competitive funds, third party)	

Table: INFRAS. References: CTI 2017b and CTI 2017c.

3.2. Collection, usage and embedding of the indicators

The indicators are one of several sources of information used to monitor the Energy Funding Programme. According to those who were interviewed, they are collected and used as described below:

SCCERs

According to the SCCERs, the indicators are collected by the SCCER management from the individual research groups. A number of SCCERs stated that the work associated with producing the indicators supports management activities within the SCCER, as well as the planning and implementation of knowledge and technology transfer (KTT). For example, they encourage contact with the research groups, and enable their work to be tracked. Respondents also stated that the indicators refer to a variety of aspects which are important for the SCCER to achieve its targets, such as KTT. Some SCCERs made a point of saying that they do quality and plausibility checks on the information received from the research groups. Particular attention is paid to listing only those activities which have been implemented in connection with the SCCER itself.

Certain SCCERs emphasised that the information that is collected for the indicators provided a good overview of activities within the SCCER, and could also be used for the SCCER's own purposes – primarily for reflection, in management, and for external communications. However, most of the SCCERs regard collecting information for the indicators to be a time-consuming task. While they largely accept the content of the indicators, a number of SCCERs believe that one-year collection intervals are too short for many of the indicators.

The SCCERs must submit a monitoring report to Innosuisse every year. In this report, they must present and evaluate scientific progress, present developments with regard to cooperation with other SCCERs, education and further training, outputs, communication and KTT activities, and demonstrate the value that the SCCER adds in terms of energy research and the transformation of Switzerland's energy system (see CTI 2017c). As a general rule, the reporting period is September to August.[6] The information that is gathered for the indicators forms a direct component of a number of aspects of the monitoring report.[7] Certain SCCERs point out that the indicators provide an important basis for drafting the monitoring report, and for the site visits conducted by members of the Evaluation Panel and Steering Committee.

[6] The indicators for scientific publications are an exception here. Their reporting period runs from January to August.
[7] For example, in the case of training modules, completed theses, scientific publications, the events organised by the SCCERs, communication measures and KTT preparation measures, readers are referred directly to the relevant monitoring list.

Evaluation Panel

The SCCER Evaluation Panel reviews the monitoring reports submitted by the SCCERs, including information for the indicators, and then evaluates the progress that the SCCER has made (see Innosuisse 2018). The first step of this process is for the subject matter experts selected for each SCCER to examine that SCCER's progress independently. In the second step, two members of the Evaluation Panel's core group draw up a consolidated evaluation report for each SCCER (see CTI 2017d).

According to the Evaluation Panel members who were interviewed, the evaluation report is based on the SCCERs' monitoring reports (including indicators), and the findings gained from the site visits. A number of Evaluation Panel members emphasised that the indicators were useful in their work. They said that they looked through the information for the indicators, but were not able to analyse it in any depth. They continued that the indicators give a good overview of the activities and output of the SCCERs, were suitable for evaluating whether or not a variety of targets had been achieved, and also helped to verify the information and assessments given by the individual SCCERs in their monitoring reports. A number of members of the Evaluation Panel stated that, during site visits, they ask specific questions relating to the indicators, in particular about how reported performance is allocated to the SCCER, and the importance of that performance with respect to the targets or milestones defined in the work packages. In addition, individual members of the Evaluation Panel conduct spot checks on the information for the indicators, and/or themselves attempt to link the indicators with the targets laid down in the work packages.

Innosuisse

Innosuisse also reviews the monitoring reports and the information that is given for the indicators. It emphasises that the experts and the Steering Committee use the indicator information to check progress towards targets and, where necessary, to intervene. Furthermore, Innosuisse said, without the indicators there would be no overview of the activities and output of the SCCERs. Information for the indicators also provides an important foundation for communications about the Programme. Innosuisse analyses the quantitative indicators for all SCCERs over time, and has collated the results for 2017 into an overview (see CTI 2017e).

Steering Committee

The members of the SCCER Steering Committee who were interviewed regard the monitoring reports (including information for the indicators) as an important basis on which to evaluate

the achievement of targets and to manage financial support for the SCCERs. They also emphasise that the information for the indicators permits a good overview of the activities and output of the SCCERs.

The members of the Steering Committee state that, when assessing output and the achievement of targets, they draw primarily on the reports of the Evaluation Panel, and the impressions gained during site visits. The Steering Committee conducts only a summary discussion of the indicators, or limits its discussions to a selected few. Steering Committee members nonetheless believe that the indicators help to create an overall picture of the output of the SCCERs, and allow them to look at certain aspects in greater detail. One member of the Steering Committee underlined that certain indicators (such as information on capacity-building and on cooperation with industry) are important primarily in the SCCER's set-up phase, when they are monitored closely. A further member pointed out that, in the initial set-up phase, monitoring and other factors (including information for indicators) had led the Steering Committee to determine that industry was not being sufficiently involved. The Steering Committee then set the SCCER in question a number of tasks, including producing and implementing KTT strategies.

Various members of the Steering Committee nonetheless emphasised that the indicators intended to help manage the content of the Energy Funding Programme were of only limited use. Specifically, the indicators did not permit an assessment of research findings and how they contribute to the Energy Strategy 2050.

3.3. Classification of indicators according to their desired effects

In this Section, the indicators collected from the SCCERs are classified according to their desired effects, in line with the programme logic model (see Table 2). These desired effects specifically cover both the explicitly stated target effects (see also Annex 1), and those effects which are implicitly desired. Indicators were classified according to our own considerations, taking into account the instructions contained in internal CTI documents (CTI 2017). The classification shows that the indicators relate to the inputs, activities and outputs levels. No indicators of outcomes and impacts are collected from the SCCERs.

Table 2: Classification of indicators collected from SCCERs according to their desired effects

Effect levels[1)]	Desired effects[2)]	Relevant indicators
Inputs		
Establishment of competence centres (SCCER) by HEIs	Long-term expansion of research capacity (incl. education and training), partly self-funded by HEIs	Number of positions ▪ as such (in FTE) ▪ per gender (in FTE) ▪ per function (in FTE) ▪ per HEI (in FTE)
		Amount of funding per source (focus on own funding)
		Number of training modules
		Number of completed theses
	SCCERs have a common organisational structure and thematic focus (innovation roadmap)	*[Indicators are not used to check that requirements are met.]*
	Networking between different HEI types and different disciplines	Number of R&D projects (focus on research partners)
		Number of cooperations with other SCCERs
	Networking between the SCCERs and implementation partners	Number of cooperations with the private sector and with the public sector
	Organisational and conceptual conditions for knowledge transfer	*[Indicators are not used to check that requirements are met.]*
Contributions from implementation partners	Financial and other forms of participation in innovation projects	Amount of funding per source (focus on third party funding)
		Number of cooperations with the private sector and with the public sector (focus on in kind contribution)
Other third-party funding	Acquisition of other third-party (e.g. SNSF, SFOE, EU) funding for research projects	Amount of funding per source (focus on third party funding)
Activities		
Research and innovation projects	Innovative energy research projects	Number of R&D projects (focus on project content and international participation)
	Increase in number of innovation projects on energy issues in the priority action areas that involve implementation partners (primarily Swiss industry)	Number of R&D projects (focus on project content and implementation partners)
	Greater cooperation between different types of HEI and different disciplines	Number of R&D projects (focus on research partners)
Knowledge and technology transfer (KTT)	Successful implementation of KTT programmes (incl. communications) by the SCCERs	Number of preparatory KTT measures (e.g. workshops, working groups, innovation groups, exploratory talks)
		Number of communication measures

Effect levels[1)]	Desired effects[2)]	Relevant indicators
Outputs		
Research and innovation projects	Important findings on new and relevant research topics	Number of completed theses
		Number of peer-reviewed articles and book chapters
		Number of non-peer-reviewed articles and book chapters
		Conference proceedings
		Number of scientific events and technical conferences organised by the SCCER
		Number of scientific events and technical conferences not organised by the SCCER, at which the SCCER's research findings were presented in a speech
	Implementation-oriented innovations, thus improving the transfer of research findings to market.	Number of patent applications
		Number of licences
		Number of spin-offs
		Number of prototypes, pilot plants, demonstrators
		Number of innovative products, processes or services
		Number of developments of models and data collections
	Expansion of young talent pool via joint HEI-business projects	Number of positions per function (in FTE) and per HEI (in FTE)
Outcomes		
Effects on businesses and/or organisations from the private and public sectors, as well as on energy research	*New findings from research and innovation projects*	
	Findings refined and implemented in the market (and in policy)	
	Business competitiveness improved	
	HEIs and businesses strengthen and expand energy research in the long term	
Impacts		
Transformation of the Swiss energy system	Innovations are implemented successfully in the market *(and in policy)*	
	Significant contributions to Energy Strategy 2050 objectives	

Effect levels[1)]	Desired effects[2)]	Relevant indicators
Harness the economic potential of energy system transformation	*Swiss economy becomes more competitive*	

[1)] Additions owing to the programme logic model (italics)
[2)] Explicit target effects (normal font) and implicit desired effects (italics)

Table: INFRAS.

4. Evaluation of indicators – target achievement and management

In this section, we evaluate how suitable the indicators collected from the SCCERs are for measuring target achievement and for management purposes. As management decisions are geared to the Programme targets, we concentrate primarily on evaluating the indicators which measure target achievement. We also discuss any room for improvement. In addition to our own analysis, our evaluation draws on the input of those who participated in our survey (see Annex A2.2), as well as experience with the use of indicators as part of the research accompanying the SCCER programme.

4.1. Evaluation of indicators

The indicators collected from the SCCERs are evaluated in terms of their relevance, information value and cost-benefit ratio for the measurement of target achievement and management value. We should like to make the following introductory remarks in this regard:

- The indicators' relevance to the measurement of target achievement depends on the detail in which the target is defined, and the relation between the indicators' content and that of the targets they are intended to track. The more detailed the definition (or practical implementation) of a target, and the closer the indicator reflects the content of that target, the more relevant the indicator is. It should be remembered here that the objectives of the Energy Funding Programme (see Section 2 and Annex A1) are defined with differing degrees of clarity and detail at the various effect levels. While targets concerning funding and capacity-building are comparatively detailed and clear, those for the activities of the SCCERs, research findings and various direct effects (e.g. cooperation, knowledge and technology transfer) are described in qualitative terms. By contrast, only a very general description, without any further specifics, is given of the effects that the research findings are expected to have. It is therefore likely that indicators for upstream levels of effect will be much more relevant than those for the effects that the research will have in practice.
- When assessing the relevance of the indicators in management terms, the degree to which the Steering Committee and Innosuisse are able to influence target achievement must be taken into consideration alongside those indicators' relevance in tracking target achievement. We assume that influence can be exerted in particular with regard to the indicators which track capacity-building, SCCER funding, education and further training opportunities, cooperation, R&D projects, research findings, communication and preparatory measures.
- The information value of the indicators used to assess progress towards targets depends on the measurability and definition of those targets, as well as the fitness of those indicators to

measure the targets in question. Thus, the information value of an indicator is particularly high where it relates to quantitative and easily measurable targets, or those which can fundamentally be measured in quantitative terms. Where qualitative targets are concerned, indicators can provide supplementary information by recording numbers of activities, outputs, and aspects of impact, etc. The information that these indicators contribute to an assessment of target achievement is limited, however. The data supplied for those indicators must be interpreted and evaluated qualitatively before its effect, and its relevance to the set target, can be determined. In addition, when evaluating the information value of any indicator, it must be remembered that it must relate to the SCCER's particular sphere of influence. A number of the respondents in our survey admitted that, at the beginning of the Programme, the SCCERs provided information on certain indicators (such as publications) that were unrelated to the individual SCCER's activities.

- We share the view of many of the respondents in our survey, that gathering the indicators and ensuring they are of an appropriate quality involves a certain amount of time and cost. Here, it should be noted in particular that the SCCERs take the form of an umbrella organisation, and that the indicators must be collected from the individual research groups. According to some of the interviewees, the resources that are required are likely to decline as those involved gain experience with the collection process, and it becomes more closely integrated into the SCCERs' management routines. The cost of collecting the indicators must also be placed in the context of the financial support that the SCCERs receive. Information provided by various respondents leads us to believe that the costs of collecting the indicators is in acceptable proportion to the SCCERs' funding framework and overall budget.
- Where benefits are concerned, a number of additional aspects must be considered alongside individual indicators' direct benefits as measures of target achievement, with the expected value to the management process. Many of the indicators serve to capture the SCCERs' activities, (research) findings and direct impacts, describing them with the additional information that is gathered. These indicators are a significant element of the way in which the Energy Funding Programme is monitored. They provide information on the activities and (research) findings of the SCCERs in various areas related to the Programme's objectives. They also provide clues to the direct impacts of research findings. The indicators therefore support the SCCERs' accountability to politicians and the interested public, and provide a basis for evaluating the degree to which they are achieving their targets, and for the management of the Energy Funding Programme overall. Various respondents also believe that they permit an overview of the activities and outputs of the SCCERs, help to verify the related monitoring reports, encourage reflection, and provide a basis for communication. Furthermore, a number of the SCCERs state that they actually benefit from the indicator collection process (see

Section 3.2). This is qualified, however, by the fact that many of the indicators provide valuable information at the overall level, but cannot be analysed in any further detail.

The following table evaluates the relevance, information value and cost-benefit ratio of each of the individual indicators collected by the SCCERs to measure target achievement (see Table 3). Where necessary, additional remarks are made concerning the indicators' value to the management process. When examining the cost-benefit ratio, it must be remembered that, in view of the time and cost involved, we have not systematically recorded and analysed the costs to participants (incl. SCCERs) that are associated with collecting the indicators. Our assessment is therefore based on a very general estimate.

Table 3: Evaluation of the individual indicators collected from the SCCERs in assessing the targets of the Energy Funding Programme

Targets	Indicators	Relevance	Information value	Cost-benefit ratio	Justification (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
Inputs					
Long-term expansion of research capacity (incl. education and training), partly self-funded by HEIs	Number of positions ▪ as such (in FTE) ▪ per gender (in FTE) ▪ per function (in FTE) ▪ per HEI (in FTE)	● ● ●	● ● ●	● ● ●	▪ *R:* The indicators are closely and directly related to comparatively detailed and clear strategic targets formulated by the Federal Council. The indicators are very relevant to the management of the programme ▪ *I.V.:* The indicators relate to quantitative and easily measurable targets. ▪ *C/B:* Time and cost in collecting the indicators are comparatively low. The benefits in terms of assessing the achievement of strategic targets, the management of the Programme and for accountability purposes are considerable.
	Amount of funding per source (focus on own funding)	● ● ●	● ● ●	● ● ●	▪ *R:* The indicator (i.e. the proportion of funding from the HEI itself) is closely and directly related to a detailed and clear strategic target formulated by the Federal Council. The indicator is highly relevant to the management of the Programme. ▪ *I.V.:* The indicator is related to a quantitative and easily measurable target. ▪ *C/B:* Time and cost in collecting the indicators are comparatively low. The benefits in terms of assessing the achievement of a strategic target, the management of the Programme and accountability purposes are considerable.
	Number of training modules	● ●	● ●	● ●	▪ *R:* The indicator and the additional information on the training modules are closely related to the target of expanding research capacity. ▪ *I.V.:* The indicator is related to a qualitative target. The additional information that is collected is useful in interpreting and evaluating the training modules with reference to the strategic target. ▪ *C/B:* Time and cost in collecting the indicators are comparatively low. There are benefits in terms of assessing the achievement of a specific target and the management of the Programme.

Targets	Indicators	Relevance	Information value	Cost-benefit ratio	Justification (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
	Number of completed theses	● ●	●	● ●	▪ *R:* The indicator is related to the target of expanding research capacity and skills. ▪ *I.V.:* The indicator includes an indication of the research skills of junior researchers. However, there is no information about which specific skills have been acquired. ▪ *C/B: T*ime and cost in collecting the data are low. There are some benefits in terms of measuring target achievement.
Networking between different HEI types and different disciplines	Number of R&D projects (focus on research partners)	● ●	● ●	● ●	▪ *R:* The information provided on research partners (participation of/cooperation with various research groups from different HEIs) is closely related to the associated target. ▪ *I.V.:* The data gathered on research partners is related to a measurable, quantitative target. However, there is no further information about the qualitative aspects of the networks. ▪ *C/B:* Time and cost in collecting and analysing the data on research seem to be comparatively low. There are benefits in terms of target achievement and the management of the Programme.
	Number of cooperations with other SCCERs	● ●	●	●	▪ *R:* The information provided on cooperations between SCCERs (especially on cooperations between the technical SCCERs and CREST) is relevant with respect to the corresponding targets formulated by the Federal Council and the CTI. It is also relevant to the management of the Programme. ▪ *I.V.:* The information is related to a quantitative and a qualitative target. However, the qualitative information is limited ▪ *C/B:* Time and cost in collecting and analysing the data seem to be comparatively low. There are benefits in terms of assessing the achievement of strategic targets and the management of the Programme
Networking between the SCCERs and implementation partners	Number of cooperations with the private sector and with the public sector	● ●	●	● ●	▪ *R:* The indicator and the additional information are closely related to the corresponding target. ▪ *I.V.:* The additional data gives some interesting information about cooperations. However, the information is not sufficient to permit a judgement of the importance of those cooperations to target achievement.

Targets	Indicators	Relevance	Information value	Cost-benefit ratio	Justification (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
					▪ *C/B:* Time and cost in collecting the data are low. Benefits: Interesting information about cooperations with private and public sector partners that can be used in helping to assess target achievement and for management purposes.
Financial and other forms of participation in innovation projects on the part of implementation partners	Amount of funding per source (focus on third party)	● ● ●	● ● ●	● ● ●	▪ *R:* The indicator (i.e. the proportion of funding from third parties) is closely and directly related to a detailed and clear strategic target formulated by the Federal Council. The indicator is highly relevant to the management and the accountability of the Programme. ▪ *I.V.:* The indicator is related to a quantitative and easily measurable target. ▪ *C/B:* Time and cost in collecting the indicators are comparatively low. The benefits in terms of assessing the achievement of a strategic target and the management of the Programme are considerable.
	Number of cooperations with the private sector and with the public sector (focus on in-kind contribution)	● ●	●	●	▪ *R.:* The indicator is directly related to the target. However, the target is not very clear. ▪ *I.V.:* The indicator only provides information on in-kind contributions. There is no further quantitative or qualitative information on those contributions. ▪ *C/B:* Time and cost in collecting and analysing the data seem to be comparatively low. There are some benefits in terms of assessing target achievement and the management of the Programme
Acquisition of other third-party (e.g. SNSF, SFOE, EU) funding for research projects	Amount of funding per source (focus on third party)	● ● ●	● ● ●	● ● ●	▪ *R:* The indicator (i.e. the proportion of funding from third parties) is closely and directly related to a detailed and clear strategic target. The indicator is highly relevant to the management and the accountability of the Programme. ▪ *I.V.:* The indicator is related to a quantitative and easily measurable target. ▪ *C/B:* Time and cost in collecting the indicators are comparatively low. The benefits in terms of assessing the achievement of a strategic target and the management of the Programme are considerable.
Activities					
Conduct innovative energy research projects	Number of R&D projects (focus on project content, project costs, partners and international participation)	● ●	● ●	● ●	

Targets	**Indicators**	**Relevance**	**Information value**	**Cost-benefit ratio**	**Justification** (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
Increase in number of innovation projects on energy issues in the priority action areas that involve implementation partners (primarily Swiss industry)	Number of R&D projects (focus on project content, project costs, research and implementation partners)	● ●	● ●	● ●	▪ *R:* The indicators (i.e. the additional information) are directly related to the strategic targets. However, the targets are not specified in detail. ▪ *I.V.:* The indicator provides some information on the research and innovation projects conducted. However, the content and the degree of innovation generated by the project are not specified. ▪ *C/B:* Time and cost in collecting the indicators are comparatively low. The benefits in terms of assessing the achievement of a strategic target and the management of the Programme are considerable.
Greater cooperation between different types of HEI and different disciplines, and with implementation partners	Number of R&D projects (focus on research partners)	● ●	●	● ●	▪ *R:* The information provided on research partners is closely related to the associated target. ▪ *I.V.:* The data gathered on research partners is related to a quantitative, measurable target. However, there is no further information about the qualitative aspects of the cooperations. The information is not sufficient to assess the achievement of the target. ▪ *C/B:* Time and cost in collecting and analysing the data on research seem to be comparatively low. There are benefits in terms of assessing the achievement of the target and the management of the Programme.
Successful implementation of KTT programmes (incl. communications) by the SCCERs	Number of preparatory KTT measures (e.g. workshops, working groups, innovation groups, exploratory talks)	●	○	●	▪ *R:* The information supplied on KTT measures is indirectly related to the corresponding strategic target. Not all of the information seems to be of the same relevance, however. ▪ *I.V.:* The information on KTT measures gives an overview of the activities of the SCCER and may encourage reflection. However, it does not allow an assessment of reach or the effects on the target groups. *C/B:* Time and cost in collecting the data seem to be slightly higher compared to other indicators. There are benefits in terms of an overview of the activities of the SCCER and the management of the Programme (e.g. reflection).

Targets	Indicators	Relevance	Information value	Cost-benefit ratio	**Justification** (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
	Number of communication measures	●	○	●	▪ *R:* The information gathered is indirectly related to the target. ▪ *I.V.:* The information provided gives an overview of the activities of the SCCER and may encourage reflection. However, it does not indicate the reach and the impact of communication on the target groups. C/B: Time and cost in collecting the data seem to be relatively low. There are benefits in terms of an overview of the activities of the SCCER and the management of the Programme (e.g. reflection).
Outputs					
Important findings on new and relevant research topics	Number of completed theses	●	●	●	▪ *R:* The indicator is related to a strategic target formulated by the Federal Council. That relationship is neither close nor direct, however. ▪ *I.V.:* The indicator includes information about the innovative nature and the excellence of the research. There is no information about the content and relevance of research findings, however. ▪ *C/B:* Although time and cost in collecting the data are low, the benefits regarding the assessment of target achievement and the management of the Programme are rather limited.
	Number of peer-reviewed articles and book chapters	● ●	● ●	● ●	▪ R: The information gathered is closely (but not directly) related to the corresponding strategic target formulated by the Federal Council. ▪ *I.V.:* Indicates the scientific excellence of the findings. However, the information provided on the content of the articles and books must be interpreted and evaluated before it can be related to the targets. ▪ *C/B:* Time and costs in collecting the data are low. The benefits in terms of assessing the scientific excellence of the research are considerable. The additional information also helps to manage the Programme.

Targets	Indicators	Relevance	Information value	Cost-benefit ratio	Justification (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
	Number of non-peer-reviewed articles and book chapters	●	○	○	▪ *R:* Compared to the indicator for peer-reviewed articles and book chapters, the information is less closely related to the strategic target. ▪ *I.V.:* The indicators are of lower information value compared to those for peer-reviewed articles. ▪ *C/B:* Given the indicators for peer-reviewed articles and book chapters, these indicators are not strictly necessary to assess the scientific quality of research findings. However, they provide background information about how findings are communicated within the research community. Therefore, they are of a certain but limited benefit for the management of the Programme.
	Conference proceedings	●	○	○	
	Number of scientific events and technical conferences organised by the SCCER	●	○	●	▪ *R:* The information provided is relevant with regard to networking, discussion and the dissemination of the research findings within the research community, energy experts and companies. However, it is of only indirect relevance to an assessment of the scientific quality of research findings. ▪ *I.V.:* The information supplied is of a certain value with regard to the networking and transfer activities of the SCCER. It does not indicate the impact of the conference, however. ▪ C/B: Time and costs in collecting the data are low. These indicators may supply interesting information about how the SCCERs are networked, and their transfer activities within the research community, energy experts and interested companies. However, their relevance and information value with regard to an assessment of the scientific quality of research findings is limited.
	Number of scientific events and technical conferences not organised by the SCCER, at which the SCCER's research findings were presented in a speech	●	○	●	

Targets	**Indicators**	**Relevance**	**Information value**	**Cost-benefit ratio**	**Justification** (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
Implementation-oriented innovations which improve the transfer of research findings to market	Number of patent applications	●●	●	●●	▪ *R:* The indicators and the additional information are closely related to the corresponding strategic target formulated by the Federal Council. They provide information on the results of the innovation projects. However, there are no specific operational targets to which these indicators refer. Owing to a lack of influence, the relevance of the indicators to the management of the Programme is rather low. ▪ *I.V.:* The information provided on these research outputs helps to assess their impacts, but it must be interpreted and evaluated in terms of the practical applicability and the specific milestones defined in work packages. 'Patent applications' provides slightly less additional information on the degree of innovation and market launch than the other indicators. ▪ *C/B:* Time and cost in collecting the data seem to be slightly higher compared with other indicators. Nevertheless, the benefits in terms of assessing target achievement and the management of the Programme are considerable.
	Number of licences	●●	●●	●●	
	Number of spin-offs	●●	●●	●●	
	Number of prototypes, pilot plants, demonstrators	●●	●●	●●	
	Number of innovative products, processes or services	●●	●●	●●	
	Number of developments of models and data collections	●●	●●	●●	
Expansion of young talent pool via joint HEI-business projects	Number of positions per function (in FTE) and per HEI (in FTE)	●	○	●	▪ *R:* The indicators are related to the target. However, it is not known if the young researchers worked on innovative projects in which private enterprise was involved. ▪ *I.V.:* There is no information on the quality of the young researchers. Therefore, the indicators are of limited information value in assessing target achievement. ▪ C/B: Time and cost in collecting the data are low. The benefits in assessing target achievement and the management of the Programme are correspondingly limited, however.

Targets	Indicators	Relevance	Information value	Cost-benefit ratio	Justification (Relevance = '*R*'; Information Value = '*I.V.*'; Cost-benefit ratio = '*C/B*')
Impacts					
Successful implementation of innovations in the market	–				
Significant contributions to Energy Strategy 2050 objectives	–				

● ● ● = very high/very good; ● ● = high/good; ● = less high/less good; ● = rather low/rather less good

Table: INFRAS.

The outcome of the evaluation of individual indicators can be summarised as follows:

- The indicators for SCCER funding and for capacity development are very relevant and informative with regard to the targets of the Energy Funding Programme, and display a very good ratio of costs to benefits. They allow the degree to which targets in the areas concerned have been achieved to be measured directly. These indicators are important and useful in managing the Programme and for accountability purposes.
- A second group of indicators (including the additional information that has been collected) offers relevant and informative data, although it must be interpreted and evaluated before it can be used to assess the corresponding targets. This group includes indicators on R&D projects, research outputs (peer-reviewed articles and books, patent applications, licences, spin-offs, prototypes, etc.), and on the training modules. First of all, these indicators provide valuable information for an assessment of the associated targets. Secondly, they are also of some use for management purposes. This is especially true of the indicators which track R&D projects. Thirdly, they support accountability.
- A third group of indicators is less relevant and informative. These indicators nonetheless provide interesting information for the assessment of progress towards targets, and for management purposes. In particular, they also facilitate an overview of the activities of the SCCERs, encourage reflection about the future, and provide information on the transfer activities of the SCCERs. This group of indicators are those which provide information on cooperation with the private and public sectors, completed theses, cooperation with other SCCERs, communication measures, preparatory KTT measures, and scientific events and conferences[8].
- A fourth group of indicators (number of non-peer-reviewed articles and book chapters, number of conference proceedings) is, in our view, of comparatively little relevance and little information value in an assessment of the scientific quality of research findings. However, they provide background information about how findings are communicated within the research community. Therefore, they are of a certain but limited benefit for the management of the Programme.

4.2. Optimisation potential

Where optimisation potential is concerned, a distinction must be made between: 1) indicators which relate to targets for the effects that the Energy Funding Programme should have on the inputs, activities and outputs of energy research; and 2) suggestions for indicators that might be used to assess target achievement at the outcomes (effects on market participants and

[8] Number of scientific events and technical conferences organised by the SCCER; number of scientific events and technical conferences not organised by the SCCER, at which the SCCER's research findings were presented in a speech.

longer-term energy research) and impacts (effects on Switzerland's energy system and economy) levels.

Indicators relating to the inputs, activities and outputs of energy research

We share the view of many respondents that the indicators collected from the SCCERs to evaluate the achievement of the Energy Funding Programme's targets at the inputs, activities and outputs levels are comprehensive and inclusive. We therefore do not believe that any further indicators need be gathered for these effect levels.

On the basis of our own analysis, and the views supplied by those we interviewed, we have identified the following potential for improving the indicator collection system:

- If the balance between costs and benefits, and the acceptance of the indicator system within the SCCERs is to be improved still further, it might make sense to stop collecting those indicators which score particularly poorly in Table 3 above (such as the number of non-peer-reviewed articles and book chapters, number of conference proceedings). These are less relevant to an assessment of the scientific quality of research findings than peer-reviewed articles and book chapters, for example. They do, however, provide certain information on networking and the transfer of findings within the research community.
- Secondly, specific additional details could be collected for a variety of indicators in order to improve their information value. For example, the relevance of R&D projects to the achievement of milestones for work packages (or capacity areas) could be analysed, and technology readiness levels (TRL) recorded. It might also be worth examining whether or not information on SCCER funding might be linked to work packages or capacity areas. This would permit a rough estimate to be made of the cost-benefit ratio of the SCCERs' work at the more specific level, applied to the technologies concerned, TRL and products.
- Thirdly, SCCER management might work towards improving the quality of the information supplied for the indicators, and the way in which it is interpreted. In addition to a systematic review, and the resolution of issues concerning the scope of the individual indicators[9], the information supplied with regard to communications and preparatory KTT measures, in particular, should relate to those activities which are especially relevant.[10] In addition, in their monitoring reports the SCCERs might use the information supplied for the indicators to illustrate for each topic which activities and outputs are particularly important in relation to the

[9] Many respondents stated that the SCCERs have improved in this respect in recent years, in part owing to feedback from the Evaluation Panel and from Innosuisse. Drawing on individual comments from these interviews, we nonetheless believe that there is still further room for improvement.

[10] Having reviewed the information supplied by one SCCER about preparatory KTT measures, we suspect that there is still potential for optimisation here, too.

SCCERs' targets.[11] Such an approach to interpretation and contextualisation would provide considerable assistance to the evaluation by the Evaluation Panel, Innosuisse and the Steering Committee.

- Fourthly, the annual collection round might be limited to those indicators which serve as a basis for the annual status report, and as a means of management[12]. Those indicators which track the research outputs[13] could instead be collected at intervals of several years. In the case of indicators to which this does not yet apply (such as education and further training), collection might concentrate on the new offerings and outputs in each case.

Potential indicators for the outcomes and impacts of the Energy Funding Programme

The targets relating to the effects of research results on market participants and energy research (outcomes) and to their effects on Switzerland's energy system and economy (impact) are formulated in relatively general terms, with no further detail given (see Section 2 and Annex A1). The indicators collected from the SCCERs do not relate to these target or effect levels.

It is essentially possible to develop and collect indicators as a basis for an assessment of the effects of energy research and the degree to which the corresponding targets have been achieved. Proposals for indicators to describe outcomes and impacts, and for additional data, can be found in Section 5.2.

[11] The review of one monitoring report from one SCCER revealed that, for some of the relevant topics (such as preparatory KTT measures), reference was made to the indicators, but no attempt was made to address their actual content. It may be necessary to adjust Innosuisse's requirements in this respect.

[12] Specifically those indicators which track SCCER funding, capacity-building, cooperation, education and further training opportunities, R&D projects, research findings, communication and preparatory KTT measures.

[13] Specifically, those indicators which track patent applications, licences, prototypes, pilot plants, demonstrators and spin-offs.

5. Evaluation of the indicators as a basis for a future impact analysis

In this section, we evaluate the extent to which the indicators collected from the SCCERs might be used as a basis for a future impact analysis. We also suggest possible further source information for such an analysis. Our assessment is based on our own analysis and experience with the use of indicators as part of the research accompanying the SCCER programme.

5.1. Evaluation of indicators

From the general viewpoint, collecting indicators might make the following contributions to a future impact analysis – which might be developed in the steps set out below:

- In the first step, the possible effects of the Programme – and how they are interrelated – should be described as the basis for the impact analysis. A programme logic model should then be developed using concept documents and any supplementary information, such as that supplied by stakeholders. Indicators represent the practical implementation of the effects that are to be studied, and determine which aspects should be measured. In this respect, the logic model for the Energy Funding Programme (see Section 2) and the classification of indicators according to their desired effects (see Section 3.3) can be used as the foundations of a future impact analysis.
- The second step in an impact analysis is to collect empirical evidence of the changes that, according to the logic model, the Programme is expected to bring about among participants and those otherwise affected by it. Since indicators are a suitable means of observing and describing change, their collection plays a key part in the empirical analysis of the changes resulting from the Programme. Here, a distinction must be made between indicators that are worth collecting on a regular basis (e.g. to analyse changes over time), and those which can be captured at a specific point in time as part of an impact analysis. The indicators collected from the SCCERs provide an important basis for a future impact analysis. For cost-benefit reasons, regular collection as part of the system of monitoring should be restricted to information which is readily available at the SCCER and which must be recorded at specific intervals in the interests of the impact analysis, in order to analyse time series or for management purposes. It must be remembered that regular collection as part of the monitoring programme will cease with the end of the Energy Funding Programme in 2020. The other indicators and empirical data can be collected by other means, such as surveys.
- In the third step, the changes identified by the indicators (e.g. an increase in the number of patent registrations) must be interpreted, analysed and evaluated in relation to the ex-

pected effects, which are generally worded in qualitative terms. The analysis here should focus on relationships between effects, and on the importance of the changes identified by the indicators in achieving the desired effects. For example, it might examine the importance and effects of patent registrations in relation to the market launch of corresponding products. Particular attention must be paid to the extent to which the changes that have been observed genuinely are the result of the Energy Funding Programme (the additionality question). Here it must be stated that, in themselves, indicators allow changes to be described, but do not permit any conclusions to be drawn as to cause-and-effect relationships. Further data and analyses are required in such cases. [14]

Since the targets of the Energy Funding Programme relate to desired effects at the input, activities and outputs levels, the indicators collected from the SCCERs are essentially of the same relevance and information value as a basis for an impact analysis as they are in evaluating target achievement (see Table 3). In summary, our assessment of the indicators in relation to the impact analysis is as follows:

- The indicators on capacity development and on SCCER funding provide direct, quantitative information on the effects of the Programme on the expansion of research capacity, the funding contributed by HEIs themselves, and the third-party funding they have acquired. We regard these indicators as of high relevance and information value to a future impact analysis.
- A second group of indicators, which includes the additional information that is collected, also provides important data for an impact analysis. The information on research projects (number of R&D projects), collaborative ventures (number of cooperations with the private sector and with the public sector), education and training (number of training modules), as well as comparatively relevant and informative data on research results and outputs[15] is very valuable as a foundation for an impact analysis.
- A third group of indicators tracks communications activity (number of communication measures), KTT (number of preparatory KTT measures) and conferences[16]. Although this information is rather less informative about the effects that are to be studied, it is very useful and helpful as a basis for the corresponding impact analysis. It may serve as a starting point when examining the success of knowledge and technology transfer.

[14] This also applies to the evaluation of target achievement where targets related to the Programme's additional effects.
[15] Number of peer-reviewed articles and book chapters; number of completed theses; number of patent applications, licences, spin-offs, prototypes, pilot plants, demonstrators, innovative products, processes or services, developments of models and data collections.
[16] Number of scientific events and technical conferences organised by the SCCER; number of scientific events and technical conferences not organised by the SCCER, at which the SCCER's research findings were presented in a speech.

- We regard a fourth group of indicators, designed to evaluate the scientific quality of research findings (number of non-peer-reviewed articles and book chapters, number of conference proceedings), as less informative, however. These are not strictly necessary for an impact analysis.

The potential for improvement highlighted in Section 4.2 in the evaluation of indicators to measure target achievement is also relevant in the context of a future impact analysis.

5.2. Suggestions for further source data for an impact analysis

Effects of energy research at the inputs, activities and outputs levels

In our view, the indicators collected from the SCCERs offer a good basis on which to analyse the effects of the Energy Funding Programme on the inputs, activities and outputs levels of energy research. The indicators capture relevant effects of the Programme on HEIs and implementation partners participating in the SCCERs, as well as on the conduct and findings of research and innovation projects. From the impact analysis perspective, we do not believe that any further indicators for these levels need be collected from the SCCERs on a regular basis. A future impact analysis should nonetheless investigate the following aspects in addition to the information supplied by the indicators:

- Firstly, there should be a qualitative interpretation and evaluation of the importance of the observed changes (such as those concerning research and innovation projects or the number of patent registrations) in relation to the desired effects of the Programme.
- Secondly, the extent to which the changes that have been observed genuinely are the result of support from the Programme must be investigated (cause-and-effect analysis).
- Thirdly, the unintended effects of the research on the participating HEIs (and possibly also non-participating HEIs) and implementation partners should be studied. For example, the Programme might result in the HEIs cutting research in other areas of social and political importance by more than is desirable.
- Fourthly, any feedback effects on energy research of a successful market launch of innovative solutions might also be investigated. For example, it is possible that the economy as a whole might generate further research and innovation success stories via the knowledge gained, the corresponding investment, and alliances with HEIs (see also Section 2).

These aspects might be studied by means of surveys of the researchers and implementation partners participating in the SCCERs. Certain information – such as an assessment of research

findings – might also be gathered from any concluding reports that are published for the research and innovation projects.

Effects on the outcomes and impacts levels

Additional indicators could be developed and collected to reflect the effects of research projects on individual economic actors and longer-term energy research (outcomes), as well as on the energy system as a whole and the Swiss economy (impacts). In our view, however, it does not make sense to collect such indicators from the SCCERs on a regular basis. Firstly, it may be assumed that the SCCERs will not have most of this information available, and would themselves have to generate it. Secondly, the impact analysis does not require these indicators to be collected at regular intervals, or annually. Thirdly, the time and cost involved in collecting these indicators periodically would hardly be acceptable in relation to their actual benefit. The empirical data required to evaluate outcomes and impacts should thus be gathered and analysed specifically for the impact analysis. With this in mind, it is very important to track the implementation of research and innovation projects in the market. The following are examples of indicators that might be used to analyse outcomes and impacts (see Table 4).

Table 4 Examples of potential indicators for the outcomes and impacts levels

Effect levels	Desired effects	Examples of potential indicators
Outcomes		
Effects on businesses and/or organisations from the private and public sectors, as well as on energy research	New findings/expertise from research and innovation projects	Number of companies which have gained new and relevant findings from research and innovation projects
		Number of researchers who have taken part in an innovation project and then move to a private or public-sector business and/or organisation
	Findings refined and implemented in the market (and in policy)	Number of companies which have developed prototypes into market-ready products
		Number of companies which have successfully launched innovative products and services on the market
	Business competitiveness improved	Number of companies which, following the successful market launch of new products and services, have been able to strengthen their innovative drive, access new markets, and improve their market position
	HEIs and businesses strengthen and expand energy research in the long term	Number of HEIs and businesses strengthening and expanding their energy research long term (measured using indicators for inputs, activities and outputs)

Effect levels	Desired effects	Examples of potential indicators
Impacts		
Transformation of the Swiss energy system	Innovations are implemented successfully in the market (and in policy)	Number of innovative products and services sold on the market
	Significant contributions to Energy Strategy 2050 objectives	Effect on energy (in kWh) of the innovative products and services on the market
Economic potential harnessed	Swiss economy becomes more competitive	Increase in sales of innovative products and services in Switzerland and abroad by businesses operating in relevant energy sectors (poss. comparison with foreign companies)

Table: INFRAS.

The aspects that have already been mentioned in the analysis of effects at the inputs, activities and outputs levels are also relevant to an examination of the effects of energy research itself. Of particular importance here is the interpretation and evaluation of identified changes in relation to desired effects, as well as an analysis of cause-and-effect relationships.

We could envisage the following approaches to developing a foundation of empirical data on which to analyse the effects of energy research:

- Firstly, a range of information on the (potential) effects of the research and innovation projects could be collected as part of any final reporting on those projects. This might include, for example, whether or not there are plans to refine findings or implement them in the market (or in policy) – or if this has already happened.[17]
- Secondly, several years after research and innovation projects have been completed the researchers and implementation partners who participated in the SCCER could be surveyed on various aspects of their project's impact. This would be in addition to the project reports themselves. The content of the survey could be modified depending on the individual project's development status (or the relevant phases of innovation).[18]
- Thirdly, case studies could be conducted on a range of areas, such as individual innovation projects, knowledge and technology transfer, or the implementation of innovative products in certain markets:
  - Case studies could also be used to provide a greater depth of information on selected innovation projects. For example, those with major impact potential could be examined

[17] According to Innosuisse, there are plans to standardise final reports (immediately after projects have been completed) and impact reports (several years after projects have been completed) to allow selected impacts to be tracked.
[18] The survey of implementation partners conducted as part of Module 2 of the research accompanying the SCCER 2017–2020 programme has already covered certain aspects of impact. Examples include the findings gained, views on progress generated by collaborating on research, and any effect that the project has had on energy generation or consumption on the market. In the future, this survey could be amended to give greater depth, or used as a basis for a new survey.

by means of surveys among the market participants concerned and the target groups for the innovative products or solutions.

- The success of KTT might be analysed in case studies on the individual SCCERs. The case studies might combine an expert survey (SCCERs, market experts) with a survey of selected representatives of the target groups for the SCCERs' KTT activities, as well as a survey of other market participants (businesses, etc.) in the sector concerned.
- Case studies might also be conducted on sectors (or markets) for which a range of innovative research findings were developed and at least partially implemented. These might analyse the effects of individual products or solutions, primarily by means of surveying the market participants concerned. Furthermore, the importance of the various findings for market development, the relationships between those findings, and any feedback effects on research could also be studied. In particular, the case studies might analyse the contribution that the research findings have made to the planned transformation of the energy system and to improving the competitiveness of businesses in specific sectors (or markets).

A variety of approaches might be examined, and possibly combined, to analyse cause-and-effect relationships (the additionality question):

- Firstly, the parties that were involved in (HEIs and implementation partners) and affected by (primarily market participants) the Programme could be asked about the extent to which the Energy Funding Programme had a causal relationship with the research and innovation projects, and their results and effects. Experts who were not involved in the Programme could also be asked to give their view of its additional effects.
- Secondly, it might be worth looking into whether or not a control group comparison is possible. For example, businesses which participated in innovation projects might be compared with those which did not benefit from the Programme. Econometric analyses might also be considered in addition to qualitative and static descriptive analyses on the basis of the corresponding surveys.

6. Overall evaluation and recommendations

This Section answers the research questions and sets out recommendations for optimising the set of indicators.

6.1. Overall evaluation

Does the current programme of SCCER monitoring collect indicators which permit the achievement of targets to be measured, and the Energy Funding Programme to be managed?
The indicators recorded by Innosuisse from the SCCERs provide an important basis for evaluating the degree to which the Energy Funding Programme is achieving its targets, as well as its management, with regard to the inputs, activities and outputs of energy research. However, the indicators do not refer to the outcomes and impacts of the Programme. Accordingly, they do not permit an assessment of how the targets at these levels are being achieved. It should be emphasised, however, that the targets for outcomes and impacts are formulated in very general terms, and no further detail is given.

Within their particular methodological scope, the indicators for the inputs, activities and outputs of energy research are largely relevant, informative and useful. This is particularly true of SCCER funding and capacity-building, R&D projects and their outputs, and communication and KTT work. Further positive points are the overview that the indicators offer of the SCCERs' activities, the fact that they permit the information given by the SCCERs in their monitoring reports and at site visits to be verified, that they encourage reflection, and that they are also of benefit to the SCCERs themselves. Innosuisse's decision to gather a variety of further information on the indicators, thereby aiding their interpretation, analysis and evaluation, is also positive, we believe. In our view, Innosuisse is largely making the most of the monitoring potential offered by the indicators collected from the SCCERs.

However, a variety of limitations restrict the usefulness of indicators as a means of evaluating target achievement, and as a management tool, for the inputs, activities and outputs levels of the Programme:

- Firstly, the indicators are most relevant and informative where they relate to quantitative and easily measurable targets. They also serve as an important basis for evaluating qualitative targets, but must be interpreted and their own quality assessed in each case. Since the targets of the Energy Funding Programme are formulated primarily in qualitative terms, the indicators serve to a large extent as supporting information, without being able to measure target achievement directly.

- Secondly, indicators are most effective at describing structures, observing changes, and comparing SCCERs. They cannot be used directly to draw conclusions about any cause-and-effect relationships, however. Thus, indicators cannot in themselves be used to answer questions about the additionality (i.e. the effect) of the changes associated with the Energy Funding Programme. Furthermore, the indicators become less informative the less direct their relationship with the funding framework and with the supported research projects.

Consequently, to evaluate the degree to which targets for the inputs, activities and outputs of energy research are being achieved, these indicators must be supplemented with qualitative assessments. Within the context of the Energy Funding Programme, this happens to some extent via the SCCERs' ongoing self-assessments. The Evaluation Panel also conducts annual reviews of how the SCCERs are achieving their objectives, by means of the SCCERs' monitoring reports, and the impressions gained from site visits. In our view, the Evaluation Panel is an appropriate means of assessing the activities and findings of the research projects as work is ongoing. However, we remain convinced that the cause-and-effect relationships of the Energy Funding Programme should be assessed by an impact analysis.

Does the current programme of SCCER monitoring collect indicators which might serve as one of several foundations for a future impact analysis?

The indicators collected from the SCCERs serve as a basis on which to evaluate the effects of the Energy Funding Programme at the inputs, activities and outputs levels of energy research. The indicators capture relevant effects of the Programme on participating HEIs and implementation partners, as well as on the findings of research and innovation projects. Where an impact analysis is concerned, various aspects of those effects should be investigated alongside the indicators, with a particular focus on cause-and-effect relationships.

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

Which indicators are less relevant or less informative, and thus no longer need be collected? Do any additional indicators need to be recorded?

The indicators are of differing degrees of relevance and information value in respect of an assessment of target achievement, of management, and as a basis for an impact assessment. Most indicators are nonetheless useful and fit for purpose (see Sections 4.1 and 5.1). There is no real need to continue collecting those indicators that are of comparatively low relevance and information value (number of non-peer-reviewed articles and book chapters, and number

of conference proceedings). However, they may still supply information about how the SCCERs are networked, and their transfer activities, within the research community.

The indicators that are collected from the SCCERs to assess target achievement, for management purposes, and as a basis for an impact assessment, are sufficient in our view. We therefore do not believe it is necessary to collect further such indicators. That said, it is worth considering whether or not specific additional information might be collected on a number of indicators, to raise their information value (see Section 4.2).

Additional indicators could be collected to reflect the effects of research projects on individual economic actors and on energy research (outcomes), as well as on the energy system and the Swiss economy (impacts)[19]. However, we do not believe that it makes sense to collect such indicators from the SCCERs on a regular basis. The empirical data required to evaluate outcomes and impacts should thus gathered and analysed specifically as part of a separate impact analysis.

How are the indicators collected from the SCCERs to be evaluated overall? Where is there room for improvement?

All in all, we judge the information collected from the SCCERs to be a good basis on which to evaluate target achievement and management and – with a view to a future impact analysis – the inputs, activities and outputs levels of energy research. In our view, Innosuisse is largely making the most of the monitoring potential offered by the indicators at these effect levels.

We see room for improvement in the optimisation of existing indicators (see Section 4.2). The foundations for a future impact analysis should also be laid. The enhancement and extension of this basis of data should be scheduled in coordination with the timing of the impact analysis, and might involve the following work:

- Enhancement of the outcomes and impacts level of the programme logic model (including clearer differentiation between effects, and consideration of the unintended effects).
- Development of further indicators of effects at the outcomes and impacts levels
- Designing the study and determining the research methods to be used to collect the empirical source data for the impact analysis.
- Preparatory work, such as setting out any requirements for final project reports in greater detail, including specific questions on effects, the development of data collection tools, and thoughts about possible case studies.

[19] Please refer to Section 5.1, Table 4, for examples of potential indicators.

6.2. Recommendations

We share the view of the majority of respondents that no major changes need to be made to the indicators to be collected from the SCCERs in the last remaining years of the Energy Funding Programme. Based on the potential for improvement, we derive the following recommendations:

1. If the time and cost involved in collecting the indicators is to be reduced, Innosuisse might stop gathering those indicators which are less relevant and informative. Those for non-peer-reviewed articles and book chapters, and for conference proceedings, for example, are less valuable to an evaluation of the scientific quality of research findings and the effects of the Programme. They do, however, provide information on networking and the transfer of findings within the research community.
2. We recommend that Innosuisse examine whether or not specific additional information might be collected on a variety of indicators, to raise their information value with a view to any future impact analysis, in particular. This additional information might be limited to the final reporting year (2020). Firstly, the relevance of R&D projects to the achievement of milestones for work packages (or capacity areas) could be analysed, and technology readiness levels (TRL) recorded. Secondly, it might also be worth examining whether or not information on SCCER funding might be linked to work packages or capacity areas. This would permit a rough estimate to be made of the cost-benefit ratio of the SCCERs' work at the more specific level.
3. In the interests of further improvement in the quality of indicators and their interpretation, we recommend that the SCCERs limit the information they provide about their activities, such as preparatory KTT measures, to those which are particularly relevant. It is also worth systematically reviewing and resolving issues concerning the scope of information for the individual indicators, to avoid overlap. Furthermore, the SCCERs might broaden their monitoring reports to include more interpretation and evaluation of the information they provide for the indicators, in terms of what that information actually covers, and how the activities concerned help to achieve the Programme's targets. Such an approach would be of great use in the assessment the Evaluation Panel, Innosuisse and the Steering Committee.
4. We recommend essentially limiting the annual collection of indicators to those required for the yearly status report and management cycle. The remainder, i.e. mainly those which track the effects of research findings, could instead be collected at intervals of several years. In addition, indicators to which this does not yet apply (such as education and further training) might concentrate on the new offerings and outputs in each case. For practical reasons, we would not implement this recommendation in the two years of the Energy Funding Programme that remain, but rather should the Programme be continued.

5. We recommend that Innosuisse continue to develop and expand the foundation of data for a future impact analysis. This work should focus on enhancing the programme logic model (especially where outcomes and impacts are concerned), developing further indicators of effects at the outcomes and impacts levels, designing the study and determining the research methods that will be used to collect the empirical source data, as well as other preparatory work for the impact analysis, such as developing data collection tools. The development of the basis for the impact analysis should be scheduled in coordination with the timing of the impact analysis itself.

Annex

A1. Energy Funding Programme targets

Table 5: Energy Funding Programme targets

Strategic targets	Operational targets	Specific details of operational targets	Target state
1. SCCER level			

Expansion of **research capacity** within the ETH domain, at universities and universities of applied sciences *(Federal Council 2012)*	Capacity-building by and at those institutions participating in the Competence Centres *(Federal Council 2012)*	▪ Evidence of capacity-building at the participating research institutions concerned *(Federal Council 2012)*
		▪ Evidence of skills-building at these institutions that has a long-term focus, and evidence of the corresponding contributions from the supported institutions themselves *(Federal Council 2012)*
		▪ Education and further training courses offered for the long term *(CTI 2017)*
			▪ 2013–2016 period *(Federal Council 2012):* 32 new research groups (8 at universities of applied sciences, 12 at universities, and 12 in the ETH domain [4 of which to be set up via the basic ETH domain funding framework])
			▪ 2017–2020 period *(Federal Council 2012, CTI 2016b)*:
			  ▪ ETH domain (basic financing framework): continuation of the 4 previous and creation of 8 additional research groups by 2020
			  ▪ Staggered creation of additional research groups as part of support for SCCERs
			  ▪ Target values for capacity requirements until the end of 2020: universities of applied sciences -> sponsors of higher education institutions (D) + competitive third-party-funding (federal) (B) + other third-party funding (C) = 2 * direct federal subsidies to SCCERs (A); cantonal universities -> D + B + C = 3 * A
			▪ Two-thirds of the jobs created within the SCCERs will remain beyond 2020, distributed appropriately across the various grades *(CTI 2017);*
			▪ Gradual increase of proportion of women to over 30 percent *(CTI 2017)*

Optimise **structures** in energy research in Switzerland for the long term, by promoting the division of work and coordination between research in-	Creation of competence centres and/or of national networks, for the long term; centres to focus on prioritised action areas and areas of research emphasis	▪ Participation of /cooperation with various research groups in the ETH domain, universities of applied sciences and/or other universities *(Federal Council 2012)* ▪ Research activities within the network to share a thematic focus, in accordance with	▪ Creation of 7 competence centres in the medium term *(Federal Council 2012)* ▪ Innovation roadmaps that are updated/enhanced annually and rated 'good' or 'very good' by the Evaluation Panel *(CTI 2017)*. In addition, a top innovation chart focusing on the key research results having a substantial impact in the implementation of the Energy Strategy 2050

Strategic targets	Operational targets	Specific details of operational targets	Target state
stitutions (networking, centres of competence) *(Federal Council 2012)*	*(Federal Council 2012)*	areas of research emphasis; research plan covering several years *(Federal Council 2012)* ▪ Minimal shared organisational structure with central management *(Federal Council 2012)* ▪ Demonstrable interest on the part of private-sector companies in cooperating with the network *(Federal Council 2012)* ▪ Existence of a business plan with a budget for funding the competence centres *(Federal Council 2012)*	*(CTI 2016b)*. ▪ Total funding of the SCCER until the end of 2020 should match the following threshold values *(CTI 2016b)*: ▪ Direct federal subsidies to SCCERs -> max. 40% ▪ Competitive third-party funding -> min. 20% ▪ Other third-party funding (private sector) -> min. 20% ▪ Sponsors of higher education institutions -> min. 20%
	Networking of HEIs and their research activities in the energy sector (or in the seven prioritised research areas) *(Federal Council 2012)*	▪ Cooperation (between the different types of HEI and between the different disciplines) continues *(CTI 2017)* ▪ More specific cooperation between the technical SCCERs and CREST SCCER on the social, economic, legislative and political aspects of their research activities *(CTI 2016b)* ▪ Industry is – and continues to be – involved systematically *(CTI 2017)*	▪ There are accounts of inter-university and inter-disciplinary cooperation and its benefits, which are rated ‘good’ or 'very good’ by the Evaluation Panel *(CTI 2017)* ▪ There are accounts of cooperation with implementation partners, and its benefits, which are rated ‘good’ or 'very good’ by the Evaluation Panel *(CTI 2017)* ▪ Depending on the specific nature and relevance of the socio-economic issues, scientific activities and financial resources should be allocated accordingly in the corresponding SCCER as well as in CREST, and the interface concerned should be clearly identified *(CTI 2016b)*
Strengthen **energy research** in Switzerland for the long term, to support the successful implementation of the new energy policy, taking the entire knowledge generation chain into account *(Federal Council 2012)*	Focus of funding on areas with the highest impact on the Energy Strategy 2050 *(CTI 2016b)*	▪ Focus of funding on the most promising research topics and projects, and reflection on the innovation road map *(CTI 2016b)*	
	Generation of important findings on new, relevant and Swiss-specific research topics *(Federal Council 2012)*	▪ Encourage innovative new projects/activities and collaboration between SCCERs *(CTI 2016b)*	▪ Progress with research is rated ‘good’ or ‘very good’ by the Evaluation Panel *(CTI 2017)*

Strategic targets	Operational targets	Specific details of operational targets	Target state
	The SCCERs' research findings are recognised internationally *(CTI 2017)*		▪ Number of peer-reviewed publications per FTE (target = 1) *(CTI 2017)*
Step up **application-oriented research** under the aegis of innovation projects involving Swiss industry, with a particular view to transferring research findings to the market *(Federal Council 2012)*	Join forces with industry to conduct innovation projects on the energy topics in the priority action areas *(Federal Council 2012)*	▪ Conduct projects that meet the following conditions, in particular: market relevance, degree of novelty (innovation), implementation potential in the priority action areas, and sound partnerships *(Federal Council 2012)* ▪ Emphasis on implementation-oriented activities (such as specific pilots and demonstrators and/or policy and business interaction based on robust scientific results) *(CTI 2016b)* ▪ Encourage strong industrial involvement in advanced projects *(CTI 2016b)*	
	Primarily ETH domain: training for the next generation of talent via shared research initiatives with universities of applied sciences, universities and the private sector *(Federal Council 2012)*	▪ Establish a world-beating, up-and-coming generation of talent *(CTI 2017)*; encourage young talent and advance women *(CTI 2016b)*	
	Successful implementation of KTT measures *(CTI 2017)*	▪ KTT strategies should be drafted and put into practice *(CTI 2017)* ▪ Knowledge and technology transfer (KTT) between participating research institutions and cooperation partners must be lasting, intensive and integrated *(CTI 2016b)* ▪ In particular where projects have reached a high TRL, the technology should be transferred to industry *(CTI 2016b)*	▪ The current KTT strategy is rated 'good' or 'very good' by the Evaluation Panel *(CTI 2017)* ▪ Where meaningful, the SCCERs must develop and run a suitable continuing training programme at SCCER-affiliated institutions *(CTI 2016b)* ▪ Each year, the SCCER should organise a specialist conference to serve as a platform for all participating researchers and institutes. The conferences should report on the latest findings and results, and provide specific examples of implementation *(CTI 2016b)*

Strategic targets	Operational targets	Specific details of operational targets	Target state
		▪ The CTI expects these KTT measures to be consolidated and professionalised, for example by appointing a specific KTT officer *(CTI 2016b)* ▪ Each SCCER must proactively share their new knowledge with external parties *(CTI 2016b)*	
2. Impacts			
Successfully implement innovations in future markets *(Federal Council 2012)*			▪ There are examples of implementation in the market, society and in law *(CTI 2017)*
Contribute significantly to improving the efficiency of the energy system in Switzerland and to meeting electricity needs after nuclear generation capacity is switched off *(Federal Council 2012)*			
Harness the economic potential of new energy policies *(Federal Council 2012)*			

Table: INFRAS. References: Federal Council 2012, CTI 2016b and 2017.

A2. Expert interviews

A2.1 Additional information on the interviews

Experts interviewed

Table 6: Experts interviewed

Parties	Persons interviewed	Job title
Innosuisse, Energy Funding Programme	Dr. Kathrin Kramer Marc Gerber Alessia Salmina	Head of Division, Energy Funding Programme Project Manager, Energy Funding Programme Project Manager, Energy Funding Programme
SCCER Steering Committee	Walter Steinlin, CTI	Chair of SCCER Steering Committee (until 31.12.2017)
	Dr. Adriano Nasciuti, SUPSI	Chair of SCCER Steering Committee (since 1.1.2018)
	Dr. Martin Riediker, CTI	Member of SCCER Steering Committee (until 31.12.2017)
	Prof. Dr. Frank Scheffold, University of Fribourg, SNFS	Member of SCCER Steering Committee
	Dr. Bernhard Eschermann, ABB Group	Member of SCCER Steering Committee
SCCER Evaluation Panel	Dr. Stefan Nowak, Net Energy	Head of SCCER Evaluation Panel core group
	Prof. Dr. Hans-Rudolf Schalcher, ETH Zurich	Member of SCCER Evaluation Panel core group
	Prof. Dr. Andreas Balthasar, University of Lucerne	Member of SCCER Evaluation Panel core group
	Prof. Dr. Philippe Thalmann, EPFL	Member of SCCER Evaluation Panel core group
	Prof. Dr. Eberhard Umbach, Karlsruhe Institute of Technology	Member of SCCER Evaluation Panel core group
	Dr. Sandra Hermle, Swiss Federal Office of Energy SFOE	Technical Expert, SCCER Evaluation Panel
	Dr. Nicole Mathys, Federal Office for Spatial Development	Technical Expert, SCCER Evaluation Panel
Expert	Dr. Rolf Schmitz, Swiss Federal Office of Energy SFOE	Member of SCCER 2017–2019 Accompanying Research advisory group
SCCERs	Prof. Dr. Matthias Sulzer, EMPA	Head of FEEB&D (Future Energy Efficient Buildings & Districts) SCCER
	Prof. Dr. Philipp Rudolf von Rohr, ETHZ	Head of EIP (Effiency of Industrial Processes) SCCER
	Prof. Dr. Mario Paolone, EPFL Georgios Sarantakos	Head of FURIES (Future Swiss Electrical Infrastructure) SCCER Manager and KTT Coordinator, FURIES SCCER
	Prof. Dr. Thomas Justus Schmidt, PSI	Head of HaE (Heat & Electricity Storage: Materials, Systems, Modelling) SCCER

Parties	Persons interviewed	Job title
	Dr. Jörg Roth	Coordinator, HaE SCCER
	Prof. Dr. Domenico Giardini, ETHZ Dr. Gianfranco Guidati	Head of SoE (Supply of Energy) SCCER Manager of SoE SCCER
	Prof. Dr. Frank Krysiak, University of Basel	Head of CREST (Competence Center for Research in Energy, Society and Transition) SCCER
	Prof. Konstantinos Boulouchos, ETHZ Dr. Gloria Romera Guereca	Head of Mobility SCCER Managing Director of Mobility SCCER
	Prof. Dr. Oliver Kröcher, PSI	Head of BIOSWEET (Biomass for Swiss Energy Future) SCCER

Table: INFRAS.

Interview guidelines: questions on the set of indicators

The experts were interviewed on various topics relating to the accompanying research: networking and cooperation, the implementation of scientific findings, preparing the permanent establishment of SCCERs, and the set of indicators. Drawing on the research questions, and the example of the interview guidelines for SCCER heads, the following questions were asked about the set of indicators:

- How do you assess the indicators collected by the SCCERs? Especially:
  - Are the indicators relevant, meaningful, comprehensible and accepted? How do you assess the cost-benefit ratio of indicators and the quality of data provided by the SCCERs?
  - How do you evaluate the benefits of the indicators for assessing target achievement, managing SCCERs, and as a basis for an impact analysis? What are the benefits of the indicators for SCCERs or for other stakeholders?
- Which optimisation possibilities do you see? Are there any indicators that can be omitted? Do some indicators need to be adjusted? Are there any additional indicators that need to be collected?

A2.2 Outcomes of the expert interviews

In the following section we describe the findings of the 22 expert interviews on the collected set of indicators. The results are grouped according to the different bodies concerned.

Innosuisse: Management of the Energy Funding Programme

Innosuisse needs the indicators to assess the extent to which the SCCERs are achieving their targets. The indicators also offer an overview of the SCCERs' activities that would otherwise not be possible. The reporting system opens up opportunities for managing the Programme, and is an important basis for communication activities. However, reporting overall is very time-consuming, extensive, and involves a large number of documents. Innosuisse aims to make reporting leaner and to reduce volume. The Steering Committee can evaluate only a small proportion of the information that is collected. Comparing the effort involved in reporting in an international context, it still seems to be acceptable (e.g. compared with Horizon 2020).

Based on the legal framework, there are few quantifiable targets which might be used as indicators of target achievement. The reporting contains a great deal of qualitative information. It is therefore good also to have some quantitative indicators. An evaluation of achievement is always based on an overall picture, however, and not solely on these quantitative indicators. Most indicators are relevant in assessing target achievement – albeit to a greater or lesser degree – and can still contribute to the overall picture. The indicators have been adjusted over time, and those that required too high a level of human or time resources have already been dropped. Any change to indicators must be well considered, and placed in the context of the potential loss of time series data. The comparability of time series data should not be affected too much.

Innosuisse finds it difficult, if not impossible, to compare SCCERs directly based on the indicators, because different SCCERs submit different reporting data. The quality and level of detail often also depend on the standards and requirements of the SCCER management teams.

SCCER Steering Committee

The members of the Steering Committee who were interviewed need the indicators and monitoring reports as a basis on which to evaluate the SCCERs' activities. Most Steering Committee members state that these reports, along with site visits, provide the foundations on which the Committee's decisions are made. There are, however, differing opinions about the importance and the role of the indicators and the monitoring reports in the evaluation procedure and in management decisions.

One Steering Committee member regards the site visits and exchange with Evaluation Panel experts as more efficient. This is because the monitoring system is too broad, and cannot

be used by the Steering Committee for management purposes. Furthermore, this person stated, the indicators were important only in the initial phase of the SCCERs. They are no longer needed, as they are not useful for content-related management. Site visits have become much more important.

The impact of the SCCERs' activities should also be assessed, as should their contribution to Energy Strategy 2050 goals. The Steering Committee members agree that this is not possible with the current set of indicators, mainly because the indicators are not the right ones. Also, the Energy Strategy 2050 timescale is very long, and the indicators are only useful for short-term management. In this context, it was also mentioned that the focus should be more on the economy and society, and not only on technology, and that cause-and-effect relationships are difficult to assess.

The Steering Committee members have the impression that the time and cost involved in reporting is bearable for the researchers. One member nonetheless suggested that the benefits of the indicators should be weighed up against the effort involved.

Members of the Evaluation Panel (including SFOE experts)

According to the members of the Evaluation Panel, there is a need for monitoring activities, because the SCCERs have a specific purpose. This group of individuals describes the indicators as generally relevant and helpful. Some view them as a useful guideline: they help the evaluation experts to objectivise assessments, and they help researchers to focus on the targets and to optimise their work by reflecting on and assessing their own activities.

The monitoring reports and indicators are evaluated by the members of the Evaluation Panel, all of whom have different backgrounds and perspectives. They assess different SCCERs according to different reporting standards. Some of the members of the Evaluation Panel take the view that the interpretation and evaluation standards applied by individual members have become harmonised over time, so that the indicators now permit comparisons between the individual SCCERs. Other members of the Evaluation Panel emphasise that, given the aforementioned differences, any comparison between the SCCERs should not be based on the indicators and evaluation reports. One member of the Evaluation Panel added that comparisons can only be made within one evaluation report.

According to some members of the Panel, the indicators should not be accorded too much weight in an evaluation of the SCCERs' activities. The main reason for this is that the indicators cannot measure the quality of research and findings, or of innovation.

The effort that SCCER reporting and Evaluation Panel assessments involve is generally regarded as acceptable. Some members of the Evaluation Panel stress, however, that the associated time and cost have reached their limits, and should be watched or reduced. The Panel is

not able to check all of the indicators in detail, as this would demand too much time. Quality assessments are extremely time-consuming.

Indicators' value and limits

Many members of the Evaluation Panel regard the indicators as valuable tool by which to collect important information on the activities and development of the SCCERs. The indicators and monitoring reports give a good overview of the SCCERs' activities.

Some of the quantitative indicators make sense in any case, according to many members of the Evaluation Panel. These include financial reports stating third-party contributions, the number of R&D projects, peer-reviewed articles and book chapters, patents, papers, and the capacity gained. However, the indicators do not permit an assessment of the scale or quality of interdisciplinary collaboration, or the impact of activities.

Some members of the Evaluation Panel mentioned that not all of the indicators are relevant to an assessment of target achievement. Another issue is that the legal targets are generally not quantitative ones. This makes it much more difficult to evaluate the degree to which they are being achieved. Further, the cause-and-effect relationship between the SCCERs' activities, and their outputs, is riddled with uncertainty and difficult to prove.

As the evaluation of target achievement and impacts presents considerable challenges, many members of the Evaluation Panel suggest that it should be based on the overall picture, which is first and foremost a qualitative assessment. The indicators can nonetheless serve as a basis or aid to this evaluation.

One member added that it is still too early to discuss the contribution that the SCCERs' outputs have made to the Energy Strategy 2050.

Evaluation Panel members' opinions on optimisation potential

Most members of the Evaluation Panel would keep the set of indicators as it is until 2020.

- Some Panel members would continue with the indicators as they are in any case, because they see them as useful. If the SCCER programme were to be continued after 2020, with the same goals, the indicators could remain unchanged, in their view.
- Other Panel members would reduce the overall number of indicators that are collected, or make the whole reporting and monitoring procedure leaner. A couple of fairly easily prepared, quantitative key indicators might be sufficient, for example. Fostering closer relationships with the SCCERs enables the evaluation experts to stay informed about their activities. Individual members of the Evaluation Panel believe that the indicators are currently being used too formally, and that they should serve more as a guiding principle and information source. These respondents state that the SCCERs' achievements should be evaluated more

on the basis of expert opinions (such as peer reviews), and an overall picture, than on indicators.

- Most of the Panel members who would omit some or most of the indicators would still not change the set as a whole before 2020. Changes would make it more difficult to analyse time series, and would also involve additional work. Time series can be very useful. In this context, one Panel member suggested that developments over time should have been included in the annual reports. Another member saw no need for time series, with a comparison between the start and the end of the SCCER programme phase being sufficient. However, in this case the SCCERs would have to be monitored more closely. This Panel member also suggested classifying projects according to the SCCERs' core themes in order to keep track of research direction.
- Individual members of the Evaluation Panel proposed linking reported SCCER outputs more closely with activities, and allocating them to specific work packages. This would provide important information for the evaluation, they said. Furthermore, they would like to see financial reports – and particularly those concerning third-party financing – accessible for each work package, and not simply for the SCCER as a whole. To add, one member suggested that the reporting period should be October to September, and not January to December. This would synchronise the reporting process more closely with the basis of that reporting, they said.

SCCER heads and managers

Acceptance and reporting effort

The SCCERs generally understand the need for reporting and the use of indicators. Most SCCERs accept the indicators as they are collected now, although they do report that the system demands a great deal of work on their part. Opinions about annual reporting differ considerably between SCCERs. Some are unconcerned by having to submit information every year, but would reduce its scope. Some SCCER heads and managers still regard reporting intervals as too short – in particular because research programmes and findings take more than six months or a year, and not all indicators are meaningful when collected annually. Therefore, according to many SCCER heads, it would be more efficient and helpful to extend reporting intervals or to reduce the scope of annual reporting.

A great deal, if not most of the effort that is put in to reporting is made by researchers and work package leaders. The resources that are needed for reporting therefore cannot be allocated to any other tasks. For small research groups, especially, the time and cost of reporting can be very high. This can also have negative consequences on quality.

Benefits

In the view of some SCCER heads, the indicators and reporting also constitute a valuable feedback mechanism, from the Steering Committee to the SCCER boards, and on to the research groups. Individual SCCER heads and managers emphasise that preparing information for the reporting rounds encourages reflection on the part of researchers and SCCERs, and thus improves quality. Furthermore, one SCCER stated that the fact that KTT is reported ensures that research groups recognise KTT activities as important.

Many of the SCCERs see the reporting mechanism as helpful to their management activities. It serves, for instance, as a useful means of staying in contact with research groups, keeping track of their activities, and as source for reporting to the educational institution concerned. The indicators about outputs, cooperation partners, and funding also provide very relevant information for the SCCERs. Some SCCERs mentioned that a direct exchange of information with research groups and work package leaders is a more efficient communication and information channel. These SCCERs collect the necessary information about developments and for management decisions by means of discussions about activities and procedures as part of annual internal SCCER site visits, for example.

Difficulties

Many indicators are not related to a specific goal, neither do they directly measure their subject's contribution to SCCER and Energy Strategy 2050 goals. Some SCCERs regard the indicators as relevant and comprehensible. Others, meanwhile, ask whether Innosuisse and the Steering Committee really need all of this information, and if this is the right set of indicators to assess contributions to the Energy Strategy 2050. For many SCCER heads, the indicators serve as a means of assessing their own particular SCCER's activities. The question is how the indicators will ultimately be used. Some SCCERs see the indicators as useful for Innosuisse or as a basis for monitoring, and it is regarded as generally positive that all this information is available. Others point out that the indicators may not be sufficient in themselves as a basis for decision-making.

Half of the SCCERs view the reporting system as very extensive, and the level of detail as too high. This is because it is impossible for the Evaluation Panel to analyse all of the information properly, neither does it permit cause-and-effect relationships to be established. The current level of detail thus seems unnecessary, especially since it is not even being used by Innosuisse or the Steering Committee. According to individual SCCERs, this is also reflected in the nature of the feedback that is typically given by the Evaluation Panel and Innosuisse – it is typically rather scarce in comparison to the great detail of the information supplied. The indicators are used simply to observe, and not to run analyses or generate findings.

Individual respondents mentioned the following additional points:

- The difficulty with monitoring and impact assessment is that the Steering Committee wants to see results after only a short period of time. The SCCERs' research activities take longer until results become visible, and the Energy Strategy 2050 has a much longer timeline. It only makes sense to assess the SCCERs' achievements after a number of years.
- The evaluation experts might not always have the specific knowledge required to evaluate certain projects, or the assessment of indicators leads to discussions between the Evaluation Panel and the SCCERs.
- Information about conference proceedings and participation is regarded as irrelevant. In most cases it will be combined in any event with conference papers. Whereas peer-reviewed articles and book chapters are perceived as relevant and interesting (especially for socio-economic research), non-peer-reviewed contributions are not regarded as relevant.

Optimisation potential

- Shorter and more concise reporting would improve quality and reduce redundancies in annual reports.
- Longer reporting intervals would make personnel resources available for both Innosuisse and the SCCERs. These newly released resources could then be used for more site visits (e.g. internal SCCER site visits) or more KTT activities on the part of Innosuisse.
- Reporting could be better aligned with the needs of the Evaluation Panel and Steering Committee. It should be adapted further according to a given project's technology readiness level.
- Some indicators are not clearly defined, meaning that a researcher, an SCCER, and evaluation experts might all arrive at different interpretations. For example, the indicators about education and further training and in-kind cooperation leave room for misunderstanding.
- One SCCER believes it important to link outputs with the corresponding research groups, especially for SCCER management. This link is not included in the actual reporting documents.
- According to one SCCER, it is important to collect more information on the content and the quality of outputs, as this is important in evaluating their relevance. The corresponding reporting tables could be more precise about the information that has been requested, and about how outputs and qualitative information are allocated to specific research groups and milestones.
- The methodology used to evaluate the indicators and the SCCERs' achievements should be strengthened, and subtly different approaches used depending on the technology or research area concerned. The information that is collected should be used to create a form of

management cockpit. The analyses that this produces should be made available to the SCCERs. This would generate learning effects for SCCERs and research institutes alike.

- Increasing reporting requirements creates a great deal of extra work, and the additional benefit is questionable (e.g. delegate lists for conferences). Changing requirements should also be avoided, as this also causes more work.
- An impact assessment could be done for each SCCER after five years. This should consider more information than the current set of indicators. An international comparison of the state of Swiss energy research would also be desirable. In addition, the research should be evaluated in itself, to determine whether or not collaboration actually leads to better quality findings than conventional research.

Abbreviations

CTI	Commission for Technology and Innovation
HEI	Higher education institute
KTT	Knowledge and technology transfer
R&D	Research and development
SCCER	Swiss Competence Centers for Energy Research
SFOE	Swiss Federal Office of Energy
SNSF	Swiss National Science Foundation
TRL	Technology readiness level

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