**NTNU – Trondheim**
Norwegian University of
Science and Technology

# Collaboration in research centres

How firms benefit from collaborating in
Centres for Environment-friendly Energy
Research


## Emil Johan Oliver
## Hans Christian Toftesund



NTNU School of Entrepreneurship
Submission date: July 2014
Supervisor: Ola Edvin Vie, IØT
Co-supervisor: Roger Sørheim, IØT



Norwegian University of Science and Technology
Department of Industrial Economics and Technology Management

NTNU
Det skapende universitet

# SAMARBEIDSKONTRAKT

## 1. Studenter i samarbeidsgruppen

| | |
|---|---|
| Etternavn, fornavn<br>**Oliver, Emil Johan** | Fødselsdato<br>**05. aug 1990** |
| Etternavn, fornavn<br>**Toftesund, Hans Christian** | Fødselsdato<br>**03. nov 1987** |

## 2. Hovedveileder

| | |
|---|---|
| Etternavn, fornavn<br>**Vie, Ola Edvin** | Institutt<br>**Institutt for industriell økonomi og teknologiledelse** |

## 3. Masteroppgave

| |
|---|
| Oppgavens (foreløpige) tittel<br>**Collaborations between Centers for Environmental-friendly Energy Research and Industry** |

## 4. Bedømmelse

Kandidatene skal ha *individuell* bedømmelse
Kandidatene skal ha *felles* bedømmelse ☒

Sted og dato
Trondheim 14/2-14

Emil Johan Oliver

Hovedveileder

Hans Christian Toftesund

Originalen oppbevares på instituttet.

NTNU
Det skapende universitet

# MASTERKONTRAKT
**- uttak av masteroppgave**

## 1. Studentens personalia

| Etternavn, fornavn | Fødselsdato |
|---|---|
| **Toftesund, Hans Christian** | **03. nov 1987** |
| E-post | Telefon |
| **toftesun@stud.ntnu.no** | **41661954** |

## 2. Studieopplysninger

| |
|---|
| Fakultet<br>**Fakultet for samfunnsvitenskap og teknologiledelse** |
| Institutt<br>**Institutt for industriell økonomi og teknologiledelse** |
| Studieprogram<br>**NTNUs Entreprenørskole** |

## 3. Masteroppgave

| Oppstartsdato | Innleveringsfrist |
|---|---|
| **17. feb 2014** | **14. jul 2014** |
| Oppgavens (foreløpige) tittel<br>**Collaborations between Centers for Environmental-friendly Energy Research and Industry** | |
| Oppgavetekst/Problembeskrivelse<br>A comprehensive analysis of Norwegian Centers for Environmental-friendly Energy Research, innovation activities and collaboration with industry partners.<br><br>Our main research question reads: how does the structure of the collaboration in the CEERs affect the innovation activities in the centres?<br><br>The study will be a qualitative single case study where we will use focused interviews to interview informants from the research centre and their industry partners.<br><br>We will use organizational theory, including theory on knowledge management and organizational proximity to analyze our findings. | |
| Hovedveileder ved Institutt<br>**Førsteamanuensis II Ola Edvin Vie** | Medveileder(e) ved Institutt<br>**Roger Sørheim** |
| Merknader<br>**1 uke ekstra p.g.a påske.** | |

**4. Underskrift**

**Student:** Jeg erklærer herved at jeg har satt meg inn i gjeldende bestemmelser for mastergradsstudiet og at jeg oppfyller kravene for adgang til å påbegynne oppgaven, herunder eventuelle praksiskrav.

Partene er gjort kjent med avtalens vilkår, samt kapitlene i studiehåndboken om generelle regler og aktuell studieplan for masterstudiet.

**Sted og dato**

Trondheim 14/02/14

**Student** Hans Christian Tøttesund

**Hovedveileder**

Originalen lagres i NTNUs elektroniske arkiv. Kopi av avtalen sendes til instituttet og studenten.

NTNU
Det skapende universitet

# MASTERKONTRAKT
## - uttak av masteroppgave

### 1. Studentens personalia

| Etternavn, fornavn | Fødselsdato |
|---|---|
| **Oliver, Emil Johan** | **05. aug 1990** |
| E-post | Telefon |
| **emiljoo@stud.ntnu.no** | **90877422** |

### 2. Studieopplysninger

| |
|---|
| Fakultet<br>**Fakultet for samfunnsvitenskap og teknologiledelse** |
| Institutt<br>**Institutt for industriell økonomi og teknologiledelse** |
| Studieprogram<br>**NTNUs Entreprenørskole** |

### 3. Masteroppgave

| Oppstartsdato | Innleveringsfrist |
|---|---|
| **17. feb 2014** | **14. jul 2014** |
| Oppgavens (foreløpige) tittel<br>**Collaborations between Centers for Environmental-friendly Energy Research and Industry** | |
| Oppgavetekst/Problembeskrivelse<br>A comprehensive analysis of Norwegian Centers for Environmental-friendly Energy Research, innovation activities and collaboration with industry partners.<br><br>Our main research question reads: how does the structure of the collaboration in the CEERs affect the innovation activities in the centres?<br><br>The study will be a qualitative single case study where we will use focused interviews to interview informants from the research centre and their industry partners.<br><br>We will use organizational theory, including theory on knowledge management and organizational proximity to analyze our findings. | |
| Hovedveileder ved institutt<br>**Førsteamanuensis II Ola Edvin Vie** | Medveileder(e) ved institutt<br>**Roger Sørhelm** |
| Merknader<br>**1 uke ekstra p.g.a påske.** | |

## 4. Underskrift

**Student:** Jeg erklærer herved at jeg har satt meg inn i gjeldende bestemmelser for mastergradsstudiet og at jeg oppfyller kravene for adgang til å påbegynne oppgaven, herunder eventuelle praksiskrav.

Partene er gjort kjent med avtalens vilkår, samt kapitlene i studiehåndboken om generelle regler og aktuell studieplan for masterstudiet.

**Sted og dato**

Trondheim, 14/2-14

| **Student** | **Hovedveileder** |
|---|---|
| | |

Originalen lagres i NTNUs elektroniske arkiv. Kopi av avtalen sendes til instituttet og studenten.

# Abstract

This thesis aims answer how knowledge intensive firms benefit from collaborating in research centres, which is based on our desire to study Norwegian Centres for Environmentally Friendly Energy Research (CEER) where several research institutions and firms are involved. The study is applies the field of knowledge management, and the most central theories covered in this thesis are related to knowledge management, knowledge integration, proximity and information and communication technologies (ICTs).

We have employed a qualitative research strategy and designed a single-case study of the CEER Solar United. A total of 20 interviews were conducted, where the interviewees were representatives from 12 current and previous industry partners, in addition to 4 out of 5 research partners in Solar United, using thematic analysis. Our theoretical foundation is framework which was based on a literature review conducted in the fall of 2013. From this theoretical framework, we created four sub-research questions that have been applied in the discussion in order to answer our main research question. We presented empirical data for further discussion, explaining how Solar United operates as an organization as well as challenges in having partners which are geographically spread.

The insight we gained through answering our sub-research questions were used to answer the main research question. Our conclusions are that large firms with funds for R&D have the research partners develop firm-specific competence which is later applied in binary research projects. Smaller firms with lower R&D capacity conduct research that advances their technological development within the research centre. Supporting industry partners primarily benefit by gaining insight into the state-of-the-art as well as customer insight. Thus, all industry partners benefit from different kinds of knowledge creation.

These findings are constituted in a model which we suggest should be validated through further research on other research centres. The thesis is ended by pointing out theoretical and practical implications, as well as proposals for further research.

## Sammendrag

Denne oppgaven besvarer hvordan kunnskapsintensive bedrifter drar nytte fra å samarbeide i forskningssenter, som er basert på vårt ønske om å studere norske Forskningssenter for Miljøvenlig Energi (FME) hvor flere forskninginstitusjoner og firma er involvert. Oppgaven bruker kunnskapsledelse som teoretisk felt, og de mest sentrale teoriene i oppgaven er kunnskapsledelse, kunnskapsintegrering, nærhet og Informasjon- og kommunikasjonteknologier (IKT).

Vi har brukt en kvalitativ forskningstrategi, og designet en single-case-studie av den norske FMEen Solar United. Vi har gjennomført totalt 20 intervjuer, som inkluderer 12 tidligere og nåværende industripartnerene og 4 av 5 forskningspartnere i Solar United, hvor vi har brukt tematisk analyse på funnene. Vårt teoretiske rammeverk er basert på en litteraturgjennomgang som ble gjennomført høsten 2013. Fra det teoretiske rammeverket har vi laget fire underforskningsspørsmål som har blitt brukt i diskusjonen for å svare på hovedforskningsspørsmålet vårt. Vi har presentert empiriske data for videre diskusjon som viser hvordan Solar United drives som organisasjon og hvilke utfordringer som følger med å ha deltagende organisasjoner som er geografisk spredd.

Vi har brukt innsikten vi har fått fra besvare underforskningsspørsmålene våre til å besvare hovedforskningsspørsmålet vårt. Vi konkluderer med at store firma med store FoU-midler får forskningspartnerene til å utvikler kompetanse som er av spesifikk interesse for dem, for så å utnytte denne kompetansen i binærprosjekter. Små selskap med lav FoU-kapasitet gjennfører forskning innenfor forskningsenteret for å gjennomføre utvikling av egen teknologi. Støtteindustri drar i hovedsak nytte av å få innsikt i banebrytende teknologi samt kundeinnsikt. Dermed drar alle industripartnere nytte av forskjellige typer av kunnskapsutvikling i senteret.

Disse funnene har vi brukt til å lage en modell som vi foreslår kan valideres gjennom videre forskning på andre forskningssenter. Vi avslutter oppgaven ved å peke ut teoretiske og praktiske implikasjoner, og og kommer med forslag til videre forskning.

# Preface

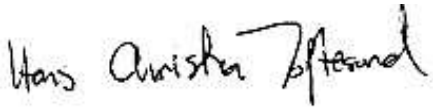
This master´s thesis is a part of our Master of Science degree in Entrepreneurship at the Norwegian University of Science and Technology (NTNU) in Trondheim. The thesis is a single-case study of how industry partners in Solar United, one of eight Centres for Environmentally Friendly Energy Research (CEER), benefit from collaborating in this research centre.

We would like to express gratitude to our academic supervisor, associate professor Ola Edvin Vie at the Department of Industrial Economics and Technology Management, and project coordinator at Centre for Sustainable Energy Studies (CenSES), for his guidance and patience. We would also like to thank all interviewees from the different partners in Solar United for their interest and involvement in the case study, for answering all our questions thoroughly. Without their help, we would not be able to conduct the case study in a proper way.

We would also thank Marit Holan Brattås and Anette Gjerde Andersen for being patience girlfriends, and also soon-to-be-born Hans Victor for providing motivation to make the master's thesis in time.

We have spent the last two years at NTNU School of Entrepreneurship, where we have enjoyed the solidarity and support of our fellow students. It has been an awesome roller coaster ride and a unique learning experience. We thank our fellow students and the Chieftain and Sheriff at NTNU School of Entrepreneurship for making these last two years an unforgettable experience.

Trondheim, 25th July 2014



Emil Johan Oliver

Hans Christian Toftesund

# Table of content

# Table of figures

# Table of tables

# 1 Introduction

Knowledge and innovation has become the main driver of economic growth and social wellbeing in modern society (Solow 1957 as cited by Gassmann 2006, David and Foray 2002). Thus, society's problems are being addressed with modern knowledge intensive solutions. One of the greatest issues of our time is that of climate change, which calls for major knowledge driven solutions, including advances in environmentally friendly energy (IPCC 2014). However, most kinds of renewable energy suffer from market failures (Jaffe, Newell et al. 2005), barriers that hinder firms from making renewable energy available to the mass market, or is pre-competitive (Brown and Duguid 2001).

On a national level, Norwegian authorities have helped renewable energy companies overcome these barriers by introducing different incentives and initiatives. One of the initiatives was introducing eight Centres for Environment-friendly Energy Research (CEERs) which would be established in research fields including offshore wind, solar energy, energy efficiency, bioenergy, energy planning and carbon capture and storage. The main purpose of the centres was "to create innovation and competence". Such collaborations between and industry in research centres and in other contexts have long been considered crucial to the development of innovation systems in any country (Lundvall 2009, Patel and Pavitt 1998). This is because organizations no longer possess all the knowledge necessary to innovate (Cohen and Levinthal 1990) and must therefore interact in networks where they utilize diverse bodies of knowledge (Hislop 2005, p160). Research centres that rally academics and firms along the value chain of an industry can thus provide this diversity.

The CEER initiative is thus meant to provide societal benefits by uniting research institutions and firms from highly technological industries in research centres funded by the partners and the government (NRC 2014). However, basic economic principles dictate that firms should benefit from such collaborations if they are to participate. This is not necessarily the case, as the mid-term evaluation of the CEER scheme showed that the centres spend most of their funds on basic research. Some of the activities are not at all related to creating benefits for their participating firms (NRC 2014). Thus, a question arises:

*How do knowledge intensive firms benefit from collaborating in research centres?*

This constitutes the main research question for this master thesis. We emphasize that we are exclusively interested in knowledge intensive firms, as the CEER scheme focuses on the development of competence and innovation. Thus, knowledge is desired product of the centres, and focusing on knowledge intensive firms may hence provide a clearer picture of how firms benefit from the knowledge created in the research centres.

To answer this question, given the limited scope of this master thesis, we have chosen to do a single case study. This allows us to focus our energy on unveiling processes in that particular centre in much more detail than we would in a multi-case study.

One of the eight centres stands out as particularly interesting. The global solar industry has made a shift, causing most European solar companies to flee the solar industry (TU 2009) or downsizing their operations (Aftenposten 2012). Still, the CEER for solar cell technology, Solar United, has stood as a uniting pillar in the Norwegian solar industry.

During its lifetime, the landscape of firms in the Norwegian solar industry has changed, focusing on more knowledge intensive niches rather than labour intensive (NIFU 2010). The centre has altered its focus accordingly, displaying exceptional adaptability in the heated solar industry. As the centre only has highly knowledge intensive industry partners, we believe Solar United is a suitable case to investigate in search of what benefits a research centre creates for its industry partners.

Knowledge provides most opportunities to create competitive advantages for firms (Grant 1996, Kogut and Zander 1992) . Because of this, and since we are to look exclusively on knowledge intensive firms, we aim to answer how knowledge intensive firms benefit from collaborating in research centres from a knowledge management perspective.

In the following chapter, we will first review theory on knowledge management. Particularly, we will look into integration and coordination of knowledge; how actors in a collaboration use external knowledge; how ICTs can facilitate innovation processes; and how actors in a collaboration use external knowledge collaboration between industry and academics, followed by a review of literature on research collaborations and research centres. Finally, we will review theory on proximity, which is relevant as there are great differences and distances between the different institutions involved in the centre. These theories add up to a set of sub-research questions used to synthesize a framework for answering our main research question.

The theory chapter is followed by a review of the methodology used to review literature and generate data for our research, followed by an in-depth description of the research centre Solar United. Then, we will present our findings in the results chapter, followed by an analysis chapter where we answer the sub-questions from our theory chapter. In the discussion chapter, we use the answers from our analysis to answer our main research question, and evaluate the quality and transferability of our findings. Finally, we will briefly render our findings in the conclusion chapter, in addition to proposing implications for further research and management.

Now, in the following chapter we will present the theoretical foundation for answering our specific research question:

*How do knowledge intensive firms benefit from collaborating in Solar United?*

# 2 Theory

## 2.1 Organizational Innovation and innovation process

Innovation is necessary for most firms to stay competitive (Hislop 2005, p157). As we are attempting to figure out how knowledge intensive firms benefit from collaborating in research centres by studying a centre where the main purpose is to develop competence and innovation (NRC 2008), it is first necessary to establish a firm understanding of the terms innovation and innovation process. The following section describes some basic principles

We first establish a definition of innovation. Organizational innovation can be understood as *a process where an organization creates and defines problems and then actively develops new knowledge to solve them* (Nonaka 1994) or as *a deliberate modification or transformation by an organization of its products/services, processes or structures* (Hislop 2005, p158). Thus, both definitions involve the deliberate creation of new knowledge for a predetermined application. However, the activity described in Nonaka's definition is knowledge creation, and we will hereby use this definition as we have chosen knowledge management as our point of attack.

Note that the definition concerns both radical innovations such as new technologies and products, and incremental modifications of existing technology. The majority of innovation activities belong to the latter, and are usually an outcome of applied science or development activities rather than basic scientific research (Narula 2004).

With this definition of innovation in mind and an understanding of its´ scope, we will look more closely at the processes where innovations are developed.

### 2.1.1 Innovation process

The literature describes multiple models for innovation process, including the stage model and more interactive models (Leonard-Barton 1995) R&D is becoming increasingly trans-disciplinary (Gibbons, Limoges et al. 1994) and has led to a need for an interactive innovation processes (Jacquier-Roux and Bourgeois 2002).

For the purposes of this thesis, we find the most relevant description of innovation process to be by Meeus, Oerlemans et al. (2001), whom state that innovations are created through interactive learning. In their words, "*the continuous exchange and sharing of knowledge resources conducive to innovation process between an innovating firm and its customers and suppliers"*. Hislop (2005, p161) claims this definition also will be valid for collaborations between other kinds of organizations, and may thus be applied to a collaboration between a firm and research institutions. As will be seen in chapter 4, all the firms participating in Solar United are highly

knowledge intensive, and they may thus be seen as the innovating firms depicted by Meeus, Oerlemans et al. (2001) , making their statement inherently valid for our case.

Summing up the definitions provided above, innovation is creating new knowledge for solving predetermined problems. Innovations are best created through interactive processes between organizations with different knowledge bases, particularly when the nature of the innovation is trans-disciplinary. Now, the following sections will outline the most fundamental terms in knowledge management, and will provide a deeper understanding of some terms that we will use to analyse how knowledge intensive firms benefit from collaborating in research centres.

## 2.2 Knowledge management and organizational learning

In this section, we will make the first part of our analytical framework by reviewing literature on knowledge management and formulating sub-research questions related to this topic. We will do this by first establishing an understanding of the knowledge term, and of different kinds of knowledge. This is necessary to understand the later sections on knowledge integration, knowledge management and the use of information and communication technologies, and management of external knowledge.

### 2.2.1 Fundamental terms in knowledge management

We first define knowledge as the term is used in the knowledge management literature. Knowledge has suitably been defined as "justified true beliefs" (Nonaka 1994). This diverges from the traditional epistemological definition of knowledge which focuses on an absolute, static and non-human form of truth Hislop (2005, p22). This definition, on the other hand, sees knowledge as a dynamic human process where personal belief must be justified. Nonaka's definition is useful because knowledge about, for instance, a market can arguably be said to not be universally true, yet it can be justified and viewed as "true".

Now that we have an understanding of what we view as knowledge, we will present the most common dimensions used to describe knowledge in the literature: the objective, codifiable *explicit knowledge*, and the personal *tacit knowledge*, where the latter is difficult to articulate and codify (Polanyi 1966, p4, as cited by Nonaka 1994). Tacit knowledge consists of both technical skills and cognitive tacit knowledge, or *mental models* (Johnson-Laird 1983) which are analogies, metaphors and working models we use to understand the world. It is worth mentioning that there are other dimensions of knowledge described in the literature such as declarative and procedural knowledge (Singley 1989). Though these dimensions might serve as useful, we have purposefully excluded them from this thesis to maintain a narrow scope of analysis.

The literature debates how one can address these kinds of knowledge. One radical perspective is *the objectivist view*, which views knowledge as an entity and assumes that all knowledge is ultimately codifiable (Hislop 2005, p17) such as in documents or computer systems. This perspective has become the subject of growing critique (Hislop 2005, p25) as this

conceptualization of knowledge is troublesome: how could one for instance fully codify emotion or the skills of craftsmanship?

These issues are taken into consideration in the practice-based view, which is in radical opposition of the objectivist view. The practice-based view does not view knowledge as an object, but sees knowledge as inseparable from practice, culture and the people that possess the knowledge in question (Hislop 2005, p27). Moreover, the practice-based view treats tacit and explicit knowledge as inseparable, meaning that all knowledge has some tacit and explicit component (Polanyi 1966, as cited by Hislop 2005, p31). Tsoukas articulated this by stating that tacit and explicit knowledge is mutually constituted, and thus should not be viewed as two separate types of knowledge (Tsoukas 1996).

The previous sections outline the objectivist view and the practice-based view as two radically different views on knowledge. Recalling the definition of knowledge presented in section 2.2, which states that knowledge should be viewed as "justified true beliefs", we quickly see that this definition is more in line with the practice-based view than the objectivist view. This in turn implies that we should keep an emphasis on the practice-based view when we later conduct our analysis. However, we should consider the nature of the knowledge at hand when we argue what perspective is best suited for the analysis, as much research in the solar industry such as mathematical models are highly codifiable.

In the previous sections, we have focused on fundamental terms in the knowledge management literature, but have not differentiated between different levels of analysis for knowledge such as the individual level and organizational level. If we are to understand how firms benefit from collaborating in research centres when individuals in fact represent them, it will be necessary to gain an understanding of these levels. In the following section, we will therefore briefly introduce these different levels before we look more closely at how organizations *create* knowledge.

### 2.2.2 Levels of analysis and organizational knowledge

The literature commonly refers to four levels of analysis in organizations: individual, group (Edmondson, Dillon et al. 2007), organizational (Schulz 2002) and inter-organizational (Ingram 2002). Learning on these different levels are linked in complex ways that are well, but not fully, understood. For instance, it is known that individual learning is necessary, but not sufficient for group and organizational learning(Argote and Miron-Spektor 2011) (Zietsma, Winn et al. 2002).

In these terms, the case of Solar United consists of individuals collaborating on behalf of their organizations in an inter-organizational collaboration (IOC). In this respect, some different conceptualizations regarding organizational learning are applicable. Grant (1996) has conceptualized that knowledge resides exclusively within the individual, and that the

organization's purpose is to coordinate, or *integrate*, the specialized knowledge of its members. Knowledge integration will be explained in greater detail in section 2.2.4.

Another angle found suitable for describing how knowledge resides within and across organizations is communities-of-practice, which is tightly bound to the practice-based view. A community-of-practice is an informal group of people who have some work-related activity in common (Brown and Duguid 1991), have a sense of shared identity, and/or share some common values (Hislop 2005, p60). The informal nature of such communities fosters creative and free-thinking, making it a an applicable topic for managers (Wenger and Snyder 2000). Duguid and Brown (2001) have conceptualized that entire organizations may be seen as a communities-of-practice, as knowledge workers are best managed when they are not micro-managed.

Though communities-of-practice may serve as a useful framework for analysing research centres, we will focus our attention on the topics described in the following sections and exclude communities-of-practice due to the limited scope of the thesis. A continuation of our research may benefit from taking on this perspective.

For the rest of the thesis, we will use Grant's conceptualization of organizational knowledge. In the next section, we will see what processes create knowledge in organizations, which will be fundamental for understanding how firms benefit from collaborating in research centres.

### 2.2.3 Organizational knowledge creation

As the primary function of the CEERs is to create innovation and competence for the centres' participants (NRC 2008), understanding the processes where knowledge i created in organizations is key. Organizational learning includes both knowledge creation, retention and transfer (Argote and Miron-Spector 2011**)**, but as the CEER scheme is primarily concerned with knowledge creation we have dedicated the following section to that particular topic. Facilitating knowledge transfer will be covered specifically for research collaborations in section 2.2.6. In this section, we will introduce Nonaka's theory of organizational knowledge creation, followed by some remarks on how one can facilitate more knowledge creation.

Nonaka (1994) claims that organizational knowledge is created in a continuous dialogue between tacit and explicit knowledge. Nonaka categorizes four kinds of knowledge creation, where either explicit or tacit knowledge may be transformed to either tacit or explicit knowledge. Particularly, the articulation of tacit knowledge is key in creation of new knowledge, which is done by using mental models to articulate tacit knowledge and thus creating new explicit knowledge (Nonaka, Byosiere et al. 1994). In the context of a research centre, researchers hold tacit and explicit knowledge that potentially can be used to develop new knowledge through dialogue with other researchers.

Contemporary literature has found that the factor that most strongly influences knowledge creation on the group and organizational level is the heterogeneity of the knowledge base among researchers (Haunschild and Sullivan 2002, Schilling et al. 2003 as cited by Argote and Miron-Spector 2011). This is because a large, deeper and more diverse knowledge base contributes to creativity, because it increases the number of potential paths to pursue in search for a solution as well as the number of potential new solutions (Rietzschel, Nijstad et al. 2007) (Shane 2000).

This implies that a research centre, where the knowledge base is inherently diverse and large, may foster creativity. In section 2.1.1 on innovation process, we stated that trans-disciplinary R&D requires more interaction and iteration than R&D within a single discipline. Given the trans-disciplinary nature of Solar United, which will be reviewed in chapter 4. We now have presented theory that implies that Solar United will foster knowledge creation, but also require extensive interaction in doing so. In order for that to happen, the specialized knowledge of the participants in the centre must be combined and coordinated in an appropriate way on the individual level. This coordination is the theme for the next section on knowledge integration.

### 2.2.4 Knowledge integration

Academics and industry are likely to hold quite different competences and knowledge bases. Coordination of these highly specialized competences has, as mentioned in section 2.2.2, been used to conceptualize the mere existence of firms (Grant 1996). The concept of knowledge integration describes this coordination process on the level of cooperation between individuals, and we will attempt apply it to describing the coordination of diverse and highly specialized knowledge in research centres.

In the following sections, we introduce some effects of knowledge integration to emphasize its relevance. Then we will review the different processes used in the literature, before we take a closer look at what specific mechanisms that can be applied in management situations. We then review the most important factors facilitating successful knowledge integration, before we discuss how knowledge integration can be used to assess coordinate research centres. Finally, we propose a sub-research question, which will be part of our framework synthesized in section 2.5.

The field of knowledge integration is concerned with understanding the problem of coordinating highly specialized knowledge (Postrel 2002) and how differentiated knowledge can be effectively integrated in economic activities (Grant 1996)(Roberts 2007) such as technological firms. Successful knowledge integration can lead to effective strategic response to fluctuations in the market (Lessard and Zaheer 1996) and innovation in the form of enhanced product performance (Marsh and Stock 2006).

Now that we have seen some of the outcomes of successful knowledge integration, we will review how the literature has described knowledge integration. Different literature on the topic has, though essentially describing the same topic, used different terminology and processes to describe the phenomena. Particularly, three different processes have been used (Tell 2011)**:**

1. sharing or transferring knowledge
2. use of similar or related knowledge
3. combination of specialized, differentiated but complementary knowledge

Though these approaches are to some extent complementary, Tell (2011) argues the first to be least relevant. The argument for this from a transaction cost point of view, where the goal of knowledge integration is to minimize costs of applying knowledge (Postrel 2002). From that perspective, simply sharing knowledge can hardly be argued to be a cost efficient way of coordinating specialized knowledge. The key to efficiency through knowledge integration is, in the words of the most cited article on the topic, *"to achieve effective integration while minimizing knowledge transfer through cross-learning by organizational members"* (Grant 1996), thus avoiding unnecessary transfer of knowledge. The second kind is much more rarely used in the literature than the others, while the latter seems quite relevant given the widely different specializations of researchers in Solar United. We will hence use the latter definition when referring to knowledge integration in this thesis.

In the next section, we will see that Grant applies elements of both the second and third definitions listed above in his work. The implications below will serve as a part in our framework in section 2.5.

#### 2.2.4.1 Applying knowledge integration in organizations

In this section, we will review the most central mechanisms in knowledge integration outlined by Grant (1996). Though it is nearly 20 years since the publication of the article in reference, Tell (2011) argues in his review of the knowledge integration literature that it is still highly relevant.

Grant presents four mechanisms for integrating specialized knowledge:

1. *Rules and directives*, which include "plans, schedules, forecasts, rules, policies and procedures, and standardized information and communication systems" (Van de Ven et al. 1976 as cited by Grant 1996). In practice, this means that an organization can embed complex tacit knowledge into standardized procedures.
2. *Sequencing* refers to organizing production activities in a time-patterned sequence so that each specialist's input occurs independently through being assigned a separate time slot.
3. *Routines* are useful mechanisms, as they have a superb ability to support complex patterns of interactions. In the words of Grant, *"routines are capable of supporting a high level of simultaneity of individuals' performance of their particular tasks, such as a crew*

*manoeuvring a ship"*. They also permit highly varied sequences of interaction, making routines a flexible mechanism.

4. *Group problem solving and decision making* does not minimize knowledge transfer between organizational members, but is necessary in situations where other mechanisms are fail to coordinate the members of an organization, such as in crisis. Efficient organizations should maximize the use of rules, routines and other integration mechanisms to economize on communication and knowledge transfer activities.

The above mechanisms may be applicable for studying how knowledge integration between organizations in research centres can be conducted, and will therefore serve as tools in our analysis in chapter 6. Note that these mechanisms have some connection the objectivist view, as it is assumed that tacit knowledge may be embedded in physical objects, systems and procedures.

In order for the mentioned mechanisms to function, a number of factors must be in place. The following section reviews the main drivers for successful knowledge integration.

#### 2.2.4.2 Factors facilitating knowledge integration

The main prerequisite to efficient knowledge integration is a common knowledge base within the organization (Mengis, Nicolini et al. 2009) as common knowledge allows individuals to share knowledge which they do not have in common (Grant 1996). This is tightly bound to the concept of cognitive proximity, reviewed in section 2.4.4.

Many other factors have, however, been found to influence knowledge integration (Tell 2011), including knowledge characteristics such as internal vs. external knowledge (Mitchell 2006) and relational characteristics such as social capital (Frost and Zhou 2005). To narrow our scope we find that Grant (1996) provides an applicable framework. To evaluate common ground between individuals in a collaboration, Grant divides common knowledge into five categories:

1. *Language.*
2. *Other forms of symbolic communication*, such as understanding of numeracy or statistics.
3. *Common specialized knowledge*.
4. *Shared meaning,* as in gaining a common perspective on tacit knowledge through metaphors, stories and frameworks.
5. *Recognition of individual knowledge domains.*

Grant emphasizes that higher levels of any of the above categories increase the likelihood of successfully integrating the knowledge of a team. However, we suspect that some kinds of common knowledge may play particularly important parts in the context of research centres. First, language skills may vary, as research centres are highly international. Second, as the specialized knowledge in research centres are highly diverse, it will be interesting to see if the different parties have sufficient overlapping knowledge bases (cognitive proximity). Lastly, it will be interesting to investigate how well the centres' management and work package leaders recognize the knowledge embedded in both participating firms and researchers. Recall that we

stated in section 2.2.3 that a wide knowledge base fosters creativity in an R&D project. To achieve this, management thus needs a firm overview and recognition of the different partners' knowledge bases to utilize their competences in creative trans-disciplinary projects.

Summing up the above sections, we see that as long as the specialists organized in a research centre have sufficient common knowledge, the literature indicates that they may successfully integrate their knowledge, leading to better firm performance. We believe this is a suitable point of attack to help answer how firms benefit from collaborating in research centres. An interesting aspect of using knowledge integration for analysis is that it may be explained by tangible micro-processes such as mechanisms on the group level, though the subject of analysis may be on any level of analysis from individual to inter-organizational. We thus believe it is very applicable for our case study. Keeping in mind Grant's four mechanisms of knowledge integration and five kinds of common knowledge, we propose the following sub-research question to support our main research question:

> *How is specialized knowledge from research institutions and firms integrated in Solar United?*

In the following section we move our attention to ICTs, which are commonly used as tools to facilitate collaborations.

### 2.2.5 Information and communication technologies and knowledge management

Companies, particularly in highly creative knowledge and information-intensive activities such as R&D, have long recognized the importance of efficient communication**.** For this reason, ICTs are used to improve coordination and management of R&D across sites in collaborations (Howells 1995)**.** ICTs can also help facilitate scientific collaboration and organizational learning, and give rise to new collaborations, for instance when scientists cannot be collocated (Sonnenwald 2007) which is the case for Solar United**.** Therefore, we will briefly review perspectives on ICTs in the knowledge management literature.

The two primary uses of ICT in knowledge management is codification and storage in repositories (Hislop 2005, p107). Among the ICTs most frequently used to support research collaborations are e-mail, instant messaging, telephones, shared data repositories and video conferencing, the latter is the closest to physical meetings (Sonnenwald 2007). ICTs are thus not tools that create knowledge, but facilitate knowledge sharing and organizational learning which may further facilitate knowledge creation.

Literature supporting ICTs in knowledge management is firmly embedded in the objectivist perspective. Some claim that learning on levels of analysis higher than the individual level requires that the knowledge of the individual have to be embedded in a supra-individual

repository, such as a database, so that others can access it (Argote and Miron-Spector 2011). Not surprisingly, ICTs are the subject of massive critique from the practice-based view because ICTs fail to communicate tacit knowledge. For instance, ICTs remove social cues such as tone of voice and other human factors (Hislop 2002).

#### 2.2.5.1 Factors contributing to successful use of ICTs in knowledge management

Many factors have been found to be related to successful use of ICTs. First, if ICTs are to be efficient tools for R&D collaborations they should provide benefits over current practices for the users. Regarding the interaction between user and the technology, the ICT should be compatible with researchers' values, experiences, and needs, and they need to be easy to try out and to use (Rogers Everett 1995). Other factors regard the relation between different users of the ICT, as it has been found that ICTs are most efficient when there is a pre-existing social relationship between the users (McLoughlin and Jackson 2002). Furthermore, it has been stated that ICTs can contribute to a rich form of communication in collaborations where ICTs are combined with face-to-face interactions (Nandhakumar 1999) **,** (Maznevski and Chudoba 2000).

Regarding communication technology, different kinds of technologies have been found to have different levels of information richness (Hislop 2005, p112-113). For instance video conferences are a better tool for transferring tacit knowledge than e-mail, as social cues that are transferred by video and audio can be lost when the information is converted to a written form (Ngwenyama and Lee 1997, p147).

In the context of a research centre, ICTs might prove useful despite their highly objective nature. Social bonds and regular physical meetings can help the users overcome the difficulties associated with transferring the inherent tacit knowledge of R&D related knowledge

(Fichman and Kemerer 1997). Thus, despite our preference to lean towards the practice-based view, we believe ICTs may very well be a suitable way to support collaboration and contribute to organizational learning in a research centre. Keeping in mind that the literature reviewed above has both focused on the group level and organizational level of analysis, we propose the following sub-research question to support our main research question:

> *How do ICTs facilitate the collaboration between individuals in Solar United, and how do ICTs facilitate organizational learning?*

Thus far, we have reviewed fundamental literature on innovation, knowledge management, organizational knowledge creation and knowledge integration. The above sections have reviewed central views on ICTs in knowledge management, which we have put in the context of research centres. We now shift focus from the management of internal knowledge to what becomes the major challenge in research centres, namely the management of external knowledge.

### 2.2.6 Managing external knowledge

So far, we have reviewed literature concerning processes between individuals confined within the boundaries of an organization. However, most of the concepts reviewed are likely to be so generic that they may be applied between organizations as well. In section 2.3, we will focus exclusively on IOCs such as research centres. This section, however, focuses on management of knowledge outside the borders of an organization and serves as a bridge between sections 2.2 on knowledge management and section 2.3 on collaborations.

In this section, we will first answer the hack question of why companies acquire external knowledge. Then, to avoid ambiguity in topics related to external knowledge acquisition, we develop a taxonomy for this topic. This is followed by a section on how organizations can achieve external knowledge acquisition successfully, before we finally focus on the challenges of one kind of external knowledge acquisition, namely R&D outsourcing.

#### 2.2.6.1 Why organizations acquire external knowledge

Though the headline of this section may seem obvious and trite, it is important to remember that internal R&D has long dominated firms' knowledge creation activities. However, in the words of (Gassmann 2006), "the do-it-yourself mentality in technology and R&D management is outdated". Since the late 80s there has been a tremendous growth in the use of external networks for R&D by firms of all sizes (Narula 2004), when firms began experimenting with combining internal R&D activities with external knowledge acquisition activities to improve their innovation performance (Howells 1999) (Cassiman and Veugelers 2006). This is because organizations no longer possess all the knowledge necessary to innovate (Cohen and Levinthal 1990) and must therefore interact in networks where they utilize diverse bodies of knowledge (Hislop 2005, p160).

The trend of more R&D collaboration has borne fruits, and effects of partnering in innovation projects range from higher innovation success (Laursen and Salter 2006) (Cassiman and Veugelers 2006) to increased novelty of innovations (Landry and Amara 2003) as well as higher returns to R&D investments (Nadiri 1993).

Partners in external knowledge acquisition may include organizations (or individuals) such as customers, suppliers, private specialized consultants, universities, research centres, and public research institutions (Grimpe and Kaiser 2010). In particular, contract research and technology organizations (CRTOs) have grown in tandem with firms' need for external specialized knowledge (Howells 1999). Customer have been found to be the most valued collaboration partners (Bayona Sáez and Huerta Arribas 2002) as their knowledge is often highly tacit and focused on their specific needs (Von Zedtwitz and Gassmann 2002).

Above we have seen the main reasons why external knowledge acquisition has become so common. Before we have a look at how organizations acquire external knowledge, we want to eliminate some ambiguity in the terminology regarding knowledge acquisition, and have therefore created a taxonomy for differentiating between different kinds of internal and external knowledge acquisition.

#### 2.2.6.2 Taxonomy of knowledge acquisition

The knowledge management literature suffers from some ambiguity regarding how external R&D projects are defined. Where some distinguish between joint R&D projects and R&D outsourcing (e.g. others treat them as one and the same (Gassmann 2006)). The subject of this ambiguity is thus the level of cooperation in the collaboration.

Though the ambiguity is undoubtedly due to unclear borders between the two, both kinds of external knowledge acquisition may be the case for the firms participating in a research centre. Hence, we eliminate this ambiguity by establishing a taxonomy of external knowledge acquisition. Firstly, we define internal knowledge creation as *any knowledge creation conducted solely by employees of the firm*. Consequently, external knowledge acquisition, which includes both knowledge creation and knowledge transfer, may be defined as *any knowledge acquired as a consequence of deliberate knowledge transfer or creation activities between employees of the firm, and external researchers*.

Furthermore, there are two ways of achieving external knowledge acquisition. The first is R&D collaborations, which may be defined as *the working together of researchers to achieve the common goal of producing new scientific knowledge* (Katz and Martin 1997) Similarly, (Hagedoorn, Link et al. 2000) define a research partnership broadly as *an innovation-based relationship that involves, at least partly, a significant effort in R&D*. As Katz and Martin's definition is more exact regarding the creation of knowledge, we will use their definition in our taxonomy.

Lastly, we derive a definition of R&D outsourcing from two partial definitions, and depict R&D outsourcing as *the contractually agreed, non-gratuitous and temporary performance of R&D task for a client* (Howells, 1999), *where research outcomes are transferred to the client with all specific exploitation rights upon completion of the task (Teece 1987)* **.**Our taxonomy is summarized in figure 2.1.

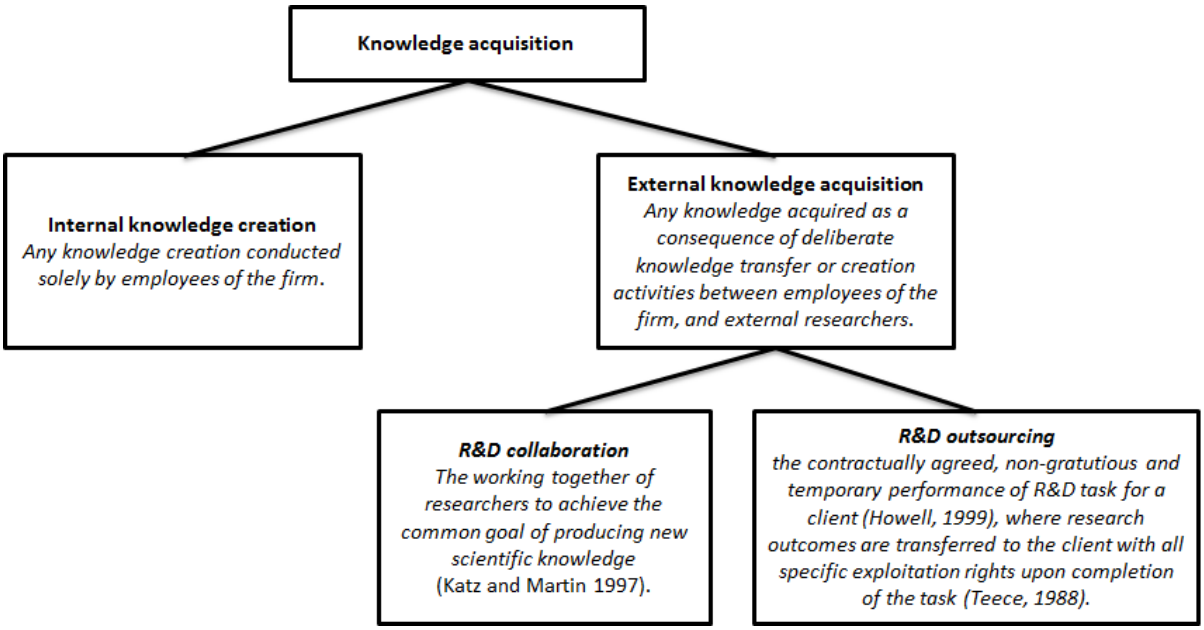



**Figure 2.1 Taxonomy of knowledge acquisition**

Not that we have established a taxonomy, we will review some literature on the relation between internal and external knowledge acquisition in an organization.

### 2.2.6.3 Achieving efficient external knowledge acquisition

Though transaction cost theory suggests that external knowledge may substitute for internal R&D investment (Williamson 1985), most contemporary knowledge management literature states that internal R&D capacity is a prerequisite for acquiring external knowledge e.g. Cohen and Levinthal 1989 and Freeman (1991). Cassiman and Veugelers (2006) even argue that internal and external R&D activities are complements which amplify each other. Cohen and Levinthal depict the capability to utilize external knowledge absorptive capacity (Cohen and Levinthal 1989, 1990, 1994). Firms with high absorptive capacity may acquire knowledge externally and subsequently re-deployed it with the existing internal resources so that the combination results in firm-specific organizational capabilities (Grimpe and Kaiser 2010).

Some of the aspects of absorptive capacity are indeed relevant for studying firms' benefits from collaborating in research centres. The literature suggests that firms' internal R&D capacity is essential for their ability to utilize external knowledge, meaning that an existing knowledge base is a prerequisite for external knowledge acquisition. This is however the only aspect of absorptive capacity, which we will utilize for the purpose of our analysis: internal R&D capacity as a factor amplifying an organization's ability to acquire external knowledge. However, absorptive capacity is indeed an appropriate angle for analyzing how firms benefit from research collaborations (Stensli 2013), the vast stacks of literature on the subject and complexity of the term would require substantial attention and greatly widen our scope.

At this point, we see some links between section 2.2.3 on knowledge creation and the above section. Nonaka (1994) suggests that knowledge is created through dialogue between explicit and tacit knowledge. Hence, when knowledge is created outside the organization, both a tacit and explicit component is created. Suppose a client firm outsources all or parts of an R&D project to a research contractor, and the client firm wishes to have the knowledge created by the contractor transferred to their organization. The explicit component of the knowledge created by the contractor should, by its definition, be codeable so it may be transferred to the client firm. The tacit component, on the other hand, may roughly be transferred in one of two ways. It may either be transformed entirely to explicit knowledge, which is limiting as all tacit knowledge can hardly be fully transformed to an explicit form. The second alternative is letting the knowledge stay tacit within the researchers that conducted the research, and transferring it through their presence in the contract firm. As these transfer mechanisms both are both quite unfeasible, it is important to keep in mind that not *all* the tacit knowledge must be transferred. The client firm may in fact only need the amount of tacit knowledge necessary for the explicit knowledge to be properly understood. We believe this is where internal R&D capacity (and absorptive capacity) becomes relevant; as the prior knowledge on the topic of interest lets the client firm understand the explicit knowledge without having the tacit knowledge component transferred. In this sense, internal R&D capacity may be said to substitute for the tacit knowledge component when a firm acquires knowledge externally.

We also see that only partially contracting R&D to another organization will maintain a larger portion of the tacit knowledge created within the firm, hence reducing the need for transfer of tacit knowledge. It follows from this that external knowledge acquisition through R&D collaborations should be easier to manage than R&D outsourcing, particularly if a firm does not have strong internal R&D capacities to help understand the knowledge acquired.

Now that we have tied the concept of external knowledge acquisition to knowledge creation theory, we will focus on R&D outsourcing, the challenges associated with outsourcing, and how one can successfully overcome these challenges. External knowledge acquisition through R&D collaboration will be the topic of section 2.3. Both these kinds of external knowledge acquisition are, as will be seen in chapter 5, used by the firms participating in Solar United and are thus highly relevant in explaining how the firms benefit from the collaboration.

#### 2.2.6.4 Benefits and challenges of R&D outsourcing

R&D outsourcing have normally adopted to achieve cost advantages, as the specialization of the contractor allows them to cut costs within their scope of research (Grimpe and Kaiser 2010). However, there are many challenges with R&D outsourcing. In the following section, two of these issues will be addressed, and ways to cope with them will be presented.

First and foremost, the effectiveness of R&D outsourcing is linked to the client firm's internal R&D capacities (Chatterji 1996) as indicated in the section above. Firms hope to acquire rare and valuable resources from outsourcing R&D, but externally produced knowledge is typically not firm-specific since potential competitors may benefit equally well from the contractor's expertise (Grimpe and Kaiser 2010). Good integrative capabilities, however, can enable firms to tailor external knowledge resources to firm-specific needs and to redeploy them within the firm, making them unique and valuable (Winter 1982 as cited by Grimpe and Kaiser 2010). Over-outsourcing of R&D may have a negative impact on firms' innovation performance because too much external knowledge acquisition hurts these integrative capabilities, which furthermore means that the client firm fails to receive the tacit component of external knowledge (Weigelt 2009).

There are at least three ways a firm can enhance their integrative capabilities. First, firms can make investments in internal activities that create new knowledge (Winter and Nelson 1982) or in R&D collaborations (Grimpe and Kaiser 2010). This finding strengthens our argument in section 2.2.6.2 to distinguish between R&D outsourcing and R&D collaboration, and matches our argumentation in section 2.2.6.3 where we stated that internal R&D capacities enable external knowledge acquisition.

Secondly, experience with external knowledge acquisition can help substitute for the tacit knowledge component that is difficult to transfer from the R&D contractor to the client firm, because it allows the customer firm to better understand the cause-and-effect relationships of the externally acquired knowledge (Fichman and Kemerer 1997).

Lastly, a firm can successfully outsource more R&D if they have a large research breadth, which means collaborating with many different kinds of organizations. This could be suppliers, customers, competitors, consultants, universities, and public research institutions **(**Grimpe and Kaiser 2010) as firms with a variety of external partners can be assumed to be more open to external knowledge (Laursen and Salter 2006). This in turn indicates that research centres, where all of the above categories of partners may participate, increase a company's integrative capabilities, which enable them to successfully make use of R&D outsourcing.

The second challenge, which we will address regarding R&D outsourcing, is that it requires a considerable amount of management attention, which is a scarce resource (Ocasio 1997). This is because a firm's performance is determined by management's ability to build capabilities from combining their internal knowledge base with their externally acquired knowledge (Grimpe and Kaiser 2010). Thus, both internal and external knowledge acquisition should be complemented with managerial dedication to operationalize on the knowledge acquired.

In the above sections, we have seen why companies acquire knowledge externally, developed a taxonomy for knowledge acquisition, and provided multiple tools to use when evaluating whether firms benefit from collaborating in research centres. However, before we use any of these tools to formulate research questions focused on how firms acquire external knowledge, we should review literature on the most important topic of this chapter, namely research collaborations.

## 2.3 Collaborations between research institutions and industry

In the last decades, the link between academics and industry has received a lot of attention because of the growing importance of knowledge and innovation (Ranga, Debackere et al. 2003).

There is considerable evidence indicating an increasing number of R&D collaborations, patent licenses, and alliances between industry and academics (Czarnitzki, Ebersberger et al. 2007). As a result, collaborations between firms and research institutions has become one of the priorities in recently developed innovation policies in European- and OECD-countries (Bayona Sáez and Huerta Arribas 2002).

In the following sections, we investigate aspects relevant to studying research collaborations and research centres, while maintain a strict focus on collaborations in research centres. First, as the research centre term is seldom defined in the literature, we craft our own definition of the term, followed by a review of firms' motivation and incentives for participating in research centres from the literature. Lastly, we compare these aspects for small and large firms.

### 2.3.1 Defining research centres

We find the concept of a research centres to be quite vague and ill defined, and therefore wish to start this chapter with establishing a definition of what a research centre is. As we have found few well-cited definitions, we synthesize a new one from definitions on similar topics. We will use definitions of university-industry linkages (UILs) and research collaborations, which both are tightly linked to the topics of this thesis.

Katz and Martin's (1997) define research collaborations as *"the working together of researchers to achieve the common goal of producing new scientific knowledge".* This definition seems quite relevant for Solar United, and provides a good basis for a definition of a research centre. However, this definition does not limit what kinds of participants can contribute for a collaboration to qualify as a centre. We want to limit our definition to collaborations where both industry actors and research institutions participate, and turn to a similar term frequently used in the literature namely UILs.

(Plewa, Korff et al. 2013) define a UIL as "*a two-way linkage between university and industry entities to enable the diffusion of creativity, ideas, skills and people with the aim of creating mutual value over time"*. We find that the words *creativity* and *ideas* in this definition is strongly

in line with the CEER scheme's goal of creating innovation; *skills* is in line with the scheme's goal of creating competence, and that *people* is in line with the scheme's goal to educate researchers. Given this strong fit between the definition of UILs and the CEER scheme, we use the definitions provided by Katz and Martin (1997) and (Plewa, Korff et al. 2013) to define a research centres as: "*a research collaboration between research institutions and industrial actors to create new scientific knowledge and enable diffusion of creativity, ideas, skills and people with the aim of creating mutual value over time".*

Now that we have established a definition, which is in line with the CEER scheme, we will move our focus to firms participating in research centres, as they are the focus of our research questions.

### 2.3.2 Firm's motivation for entering research centres

The literature highlights many different reasons for why firms participate in research centres. In this section, we first review some of the reasons why a firm would choose a research centre rather than another kind of partner in research collaborations, and review different kinds of outcomes for firms described in the literature.

Given that knowledge intensive firms' most important input is knowledge, it follows that knowledge acquisition and R&D are central to the operations and competitiveness of such firms. We may divide the knowledge that they acquire into two categories; basic research and innovation. For basic research, firms tend to seek the support of universities and research centres, who are primary producers of fundamentally new knowledge (Grimpe and Kaiser 2010). This may be because basic research activities are too resource demanding to carry out internally.

As for innovation there are, as mentioned in section 2.2.6.4, many potential kinds of external research partners. Customers are often the most highly valued collaboration partners in innovation projects since their needs often are tacit (Bayona Sáez and Huerta Arribas 2002) Interestingly, research centres have been found to be among the least attractive partners and yield far less commercial output than collaborations with other kinds of partners, yet they are among the most common research partners in innovation projects.

This is peculiar as the focus in research centres commonly is on basic research. The reason for this may be that firms distinguish between the generation of innovative ideas, usually associated with customers, and the competence necessary to develop such ideas that resides in research centres. Following this rationale, Bayona Sáez and Huerta Arribas (2002) draw the conclusion that public funding of basic research in research centres is money well spent, even though this produces few measurable commercial results. The funding of research centres may be another reason for why firms participate in research centres, as they gain access to government research funds (Rasiah and Govindaraju 2009).

Another positive effect for firms participating in research centres is the networking effects. Research centres may grant participating firms access to a wider network of contacts in the international scientific community and create bonds with research institutions and other firms (Katz & Martin 1997). Networks are valuable for a firm, and some authors have even argued that a firm's competitiveness may more strongly be related to its external network than its size (Mytelka 1991 as cited by Narula 2004).

Summing up this section, we have seen that research centres are common partners in research collaborations, but that most often create knowledge related to basic research rather than commercial innovations. This is somewhat in violation with the purpose of the CEER scheme, which aims to create innovation and competence. We have seen that firms that participate in research centres commonly participate to carry out basic research, gain access to government research funds and new networks. It will be interesting to see whether this is the case for Solar United given that the CEER scheme dictates a stronger focus on innovation. Before we formulate a research question related to this topic, we will review some of the differences between small and medium firms (SMEs) and large firms in relation to research centres.

### 2.3.3 SMEs and large firms in research centres

In this section, we outline some of the differences between large firms and SMEs in relation to research centres. We start out by introducing some differences between large firms and SMEs and their knowledge creation abilities, before focus on their motivations for participating in research centres. We use the EU's definition of an SME, setting the limit at 250 employees, though we will later use the term micro enterprise in describing firms with less than 10 employees.

We have found some quite nuanced literature regarding the connection between firm size and innovativeness. Some have found that SMEs are less innovative than large firms (Bougrain and Haudeville 2002), whilst others have found that small (but not necessarily medium size) firms have higher R&D productivity than large firms (Audretsch and Vivarelli 1996), meaning that resources invested in R&D generates a greater output per input for SMEs than for large firms. This may be related to the breadth of SMEs R&D focus, which we believe may be narrower for SMEs than for large companies. Recalling section 2.2.4 on knowledge integration, we see that the higher effectiveness in R&D may be due to SMEs ability to efficiently integrate their specialized knowledge and focus those resources on their particular R&D topics. This enables SMEs to innovate, and some have found that this makes SMEs particularly prone to develop radical innovations (Laursen and Salter 2006) (Lee, Park et al. 2010)**.**

We now direct our attention to how firm size is associated with participation in research centres. Large knowledge intensive firms commonly participate more in research centres than SMEs. This may be because large firms carry out R&D internally (Bayona Sáez and Huerta Arribas

2002) which gives them a strong internal R&D capacity, letting them utilize externally created knowledge more easily

The literature is conflicted in their findings on how SMEs absorb external knowledge. Some have found that SMEs commonly do not have the resources to conduct as much R&D internally as large firms, meaning that they have a lower internal R&D capacity. Thus, they absorb less knowledge from external sources than large firms do. This may seem paradoxical, as it means that small firms cannot manage innovation processes because they may neither conduct internal or external knowledge acquisition. However, SMEs overcome this catch 22 by interacting in networks where they may utilize other resources held by other organizations, such as universities (Audretsch and Vivarelli 1996). In this way, SMEs manage innovation processes with limited resources and relatively low internal R&D capacity (Rasiah and Govindaraju 2009) (Edwards, Delbridge et al. 2005).

There are at least two more reasons for the limited participation of SMEs in research centres. Firstly, it may be due to a failure to promote research centres for SMEs. Secondly, it may be that SMEs associate research centres with excessive bureaucracy and administrative tasks (Bayona Sáez and Huerta Arribas 2002) such as securing joint funds from sponsors, jointly defining tasks and research problems, and keeping partners informed (Katz and Martin 1997). This may demand more resources from a small firm than it is worth. As outlined in section 2.2.6.4, management attention is regarded as a limiting factor for how much R&D an organization may outsource. Hence, given that SMEs necessarily have less management resources than large firms do, we see that management attention also may be a factor limiting the participation of small firms in research centres, as the firm's management may be tied up in bureaucratic tasks.

The last difference in motivation between SMEs and large firms for participating in research centres that we will mention is that large firms may participate just to keep an eye on the developments in the centre as a kind of market screening. SMEs will typically not have the resources to use this listening post variety (Narula 2004).

In the above sections, we have seen that the literature depicts that large firms participate more in research centres than small firms do, and that there may be different reasons for this. However, as will be seen in chapter 4, more than half of the companies participating in Solar United are SMEs. This may be due to a number of reasons: maybe the centre has managed communicate its presence particularly well to the industry; maybe the centre has eliminated the bureaucracy that often scares away SMEs; maybe the benefits of participating exceed the costs. We are also curious as to the outcomes for large firms: if they are present to access research funds; if they participate to conduct basic research; if they use the centre as a listening post. As we seek to uncover how knowledge intensive firms benefit from collaborating in research centres, we may get some interesting inputs from the following sub-research question:

*What outcomes do firms participating in Solar United expect from the collaboration, and what does the centre do to meet these expectations?*

This concludes our review of literature focused on research centres, and we will now shift focus to a research topic that may further help us understand the dynamics of research centres, namely proximity.

## 2.4 Proximity in collaborations

Close proximity between organizations is often seen as an important pre-condition for knowledge sharing, knowledge transfer and technology acquisition (Gertler 1995). However, not all collaboration can be conducted in a practical way over short distances. Such collaborations are often facilitated by different kinds of proximity, which have been found to be closely related to successful research collaborations and knowledge transfer between organizations, and particularly between academics and industry (Boschma 2005) (D'Este, Guy et al. 2012).

In this section, we will review four kinds of proximity found particularly relevant to study research collaborations between research institutions and firms: geographical-, organizational-, cognitive- and social proximity. The section is summarized up by creating a fourth and final sub-research question to help us answer how knowledge intensive firms benefit from collaborating in research centres. Firstly, we will introduce the most central proximity literature.

### 2.4.1 Proximity in the literature

The proximity term often relates to what the literature calls geographical proximity (Knoben and Oerlemans 2006). There are, however, many different dimensions of proximity described in the literature, including institutional proximity (Kirat and Lung 1999), cultural proximity (Gill and Butler 2003), technological proximity (Greunz 2003), organizational proximity (Knoben and Oerlemans 2006), cognitive proximity (Wuyts, Colombo et al. 2005) and social proximity (Oerlemans and Meeus 2005).

These different types of proximity are strongly associated with the performance and survival of organizations, as they strengthen firms' competitive positions through inter-organizational knowledge transfer and technology acquisition (Boschma 2005). Though many of these dimensions overlap (Knoben and Oerlemans 2006), some dimensions have been found to complement each other quite well. Broekel and Boschma (2012) have studied the interplay between geographic, cognitive, social and organizational proximity in the innovation performance of academic-industrial research collaborations. Steinmo and Rasmussen (2013) have used this four-dimensional framework to study research collaborations between industry and academics in Norway. As these dimensions provide a rich variety of terms to describe the collaboration between organizations, they will be represented in the following sections. For each dimension, we will review definitions and present their effects on collaborations.

### 2.4.2 Geographic proximity

Geographical proximity is important in IOCs because small geographical distances facilitate face-to-face interactions, both planned and serendipitous, and therefore fosters knowledge transfer and innovation (Knoben and Oerlemans 2006). The larger the distance between actors, the more difficult it is to transfer tacit forms of knowledge. This is argued to be true even for the exchange and use of codified knowledge, because it's interpretation still requires tacit knowledge and thus geographical proximity (Howells 2002).

In addition to contributing to more efficient knowledge transfer, geographical proximity has has been found to make the creation of research partnerships more likely (D'Este, Guy et al. 2012). Research collaborations between universities, research centres, and firms are a typical example of interaction susceptible to benefit from geographical proximity. This is because they entail bidirectional knowledge transfer, which requires learning for both organizations and the establishment of enduring social relationships between the partners involved (Katz and Martin 1997, D´Este and Iammarino 2010).

Though geographical proximity has its´ advantages in R&D collaborations, creating permanent geographical proximity by co-location is expensive and most often highly impractical, since each new IOC would require a reconsideration of the location of the partner(s). Many collaborations are therefore between organizations, which are not geographically, close. Such collaborations can be challenging, since knowledge transfer between academics and industry requires some levels of trust and understanding (Boschma 2005).

Geographically distanced research collaborations are being established despite these challenges, which, as seen in section 4.2, is the case for Solar United**.** Such collaborations are made possible by using *temporary geographical proximity* (e.g. Gallaud and Torre 2004, 2005; Hyypia and Kautonen 2005; Torre and Rallet 2005 as cited by Boschma 2005). This implies that collaborating actors need do not need constant geographical proximity, but can use meetings, short visits and temporary co-location like office spaces now and then. These activities can build other forms of proximity, such as organizational, cognitive and social proximity, which subsequently allow collaboration over large geographical distances (Boschma 2005).

Though other kinds of proximity may to some level substitute for geographical proximity, some have found that there are limits for how much geographical distance there can be between the parties in a productive research collaboration. Arita and McCann (2000), for instance, found that the possibility to use air travel to make a round trip in a day, with time for a meeting, to be important in the formation of inter-firm R&D-collaborations.

In sum, geographical proximity may facilitate inter-organizational learning and the development of new collaborations. Organizations in research collaborations that are not co-located can share geographical proximity by taking advantage of temporary geographical proximity to develop

other kinds of proximity (Torre 2008 cited by Balland 2012, Boschma 2005). However, geographical proximity is neither a necessary nor a sufficient condition for successful collaborations, because other forms of proximity may function as substitutes to solve challenges related to coordination and knowledge transfer. For instance, Rallet and Torre (1999) demonstrated that the need for geographical proximity is weak when there is a strong organizational proximity, as tacit knowledge may be transmitted across large distances if aided by such types of proximity. It may be the case that the disadvantages associated with spatially divided partners is mitigated by organizational proximity between partners (Ponds et al, 2007 cited by D´Este, Guy et. al 2012), which is the topic of the next section.

### 2.4.3 Organizational proximity

Organizational proximity has been proved crucial in innovation networks and research centres, and has been defined as the extent to which relations are shared in an organizational arrangement, either within or between organizations (Boschma 2005). Roughly, this type of proximity can be interpreted as how close two organizations are to each other, including the organizations' relatedness of routines and rules. In Knoben and Oerlemans' review of literature on proximity (2006), they found that organizational proximity may be said to include social, cognitive, institutional and cultural proximity, whereas the two latter will not be further outlined.

Organizational proximity is useful in IOCs because it generates a capacity to combine information and knowledge from the collaborating parties, to transfer tacit knowledge and other non-standardized resources between collaborating parties (Burmeister and Colletis-Wahl 1997)**.** IOCs are more efficient and yield better research results when the organizational context of the interacting partners is similar because this similarity facilitates mutual understanding (Boschma 2005).

How can two organizations develop organizational proximity? One common measure is prior joint experience in research partnerships (D´Este, Guy et. al 2012), and two organizations which have collaborated earlier thus have good preconditions for having productive collaborations again. Another way of developing organizational proximity is by using strong control mechanisms, such as agreements to ensure ownership rights (IPR), sufficient return on investments. This grants the parties some control through reducing uncertainty and risk of opportunism in the collaboration (Boschma 2005). This process may take time, but should be seen as a learning process necessary for the parties involved to have an efficient collaboration.

Now that we have seen how important organizational proximity is to IOCs, we move on cognitive proximity, which may be seen as a complement to organizational proximity. Together, these two dimensions strongly facilitate productive research collaborations (Steinmo and Rasmussen, 2013).

### 2.4.4 Cognitive proximity

Cognitive proximity refers to similarities in the way actors perceive, interpret, understand and evaluate the world (Wuyts, Colombo et al. 2005) meaning that organizations which have a somewhat overlapping knowledge base may learn from each other. It is the form of proximity that is most determining for an organization's selection of future research partners (Boschma and Frenken 2010), as cognitive proximity practically means that the firms have a knowledge base which is related or similar in some way.

Unlike the other dimensions of proximity, it is not necessarily better to have more cognitive proximity in a research collaboration. To have a creative and productive collaboration, the collaborators should not have too similar, nor too different knowledge bases (Knoben and Oerlemans 2006). External knowledge of a partner is not interesting if it is the same of the other organizations in the collaboration. In other words, when two organizations share a high level of similarity of their knowledge bases, they might even avoid collaboration, as there is less to gain on collaboration (Balland 2012). The collaborating organizations should thus have a moderate level of cognitive proximity, as some cognitive distance increases the parties' potential for learning (Boschma 2005).

### 2.4.5 Social proximity

Lastly, social proximity relates to socially embedded relations between actors, which further relates to trust, friendship and common experience (Boschma 2005). High levels of social proximity between organizations strengthens an IOC's ability to innovate and learn because trusty relationships facilitate the exchange of tacit knowledge (Boschma 2005). Generally, knowledge more easily diffuses between organizations with high levels of social proximity (Boschma & Frenken 2010). Another positive effect of high social proximity is that it grants the organizations involved access to innovative networks (Oerlemans and Meeus 2005).

Social proximity is developed in IOCs through past collaborations and repeated contact between the partners (Steinmo and Rasmussen 2013). Hence, the partners in a collaboration need to dedicate much attention to their counterparts. Therefore, social proximity is more difficult to develop in project collaborations with multiple partners than in bilateral collaborations (Balland 2012).

Social proximity differs somewhat from the other dimensions of proximity because. While the other dimensions are exclusively concerned with the inter-organizational level of analysis, social proximity is concerned with networks on an individual level as well as on the inter-organizational level. The personal relations of an individual acting on behalf of his organization is highly relevant for the individual's ability to transfer and receive tacit knowledge (Balland 2012) and is tightly linked to the social proximity phenomenon**.**

Note that this dimension of proximity is the subject of much ambiguity, as social proximity also has been defined as "*actors who belong to the same space of relations"* (Knoben and Oerlemans, 2006). This is, as we saw in section 2.5.3, similar to Boschma's (2005) definition of organizational proximity. We cope with this ambiguity by disregarding Knoben and Oerlemans' definition and consequently use Boschma's definition.

Now that we've reviewed the four dimensions of proximity presented by Broekel and Boschma (2012), we move on to discuss how this literature may relate to the literature reviewed in sections 2.1-2.3.

### 2.4.6 Discussing proximity

We have now presented the most relevant proximity terms for research collaborations described by the litterature. We will use this section to tie the above sections to the literature reviewed in sections 2.1-2.3 and tying it to the setting of a research centre.

First, we wish to see how the proximity literature relates to the different views in knowledge management. The proximity literature is largely concerned with the difficulties of transferring tacit knowledge between organizations. It also treats knowledge as embedded within the practices of the respective organizations, and we hence see the topic as most tightly connected to the practice-based view. Furthermore, as mentioned in the above section on social proximity, all our four dimensions of proximity except for social proximity are exclusively concerned with the inter-organizational level of analysis. We will keep this in mind as we further discuss proximity.

We will now compare the different dimensions of proximity to the literature in sections 2.1-2.3, keeping in mind that the purpose of the CEER scheme is to create competence and innovation. Hence, knowledge *creation* is the main focus of the scheme. As will be seen in chapter 4, there are large geographical distances between the organizations in Solar United. Section 2.4.1 indicates that the large geographic distances between the participating organizations might not be an obstacle for a productive collaboration, as the different actors can achieve knowledge transfer by substituting geographical proximity with other dimensions of proximity, or some other condition. We assume this is not only true for knowledge transfer, but for knowledge creation as well. The literature reviewed above suggests that this condition may either be specific to the collaboration at hand, such as organizational or social proximity, or a general condition that is non-specific to the collaboration at hand, such strong internal R&D capacity that a firm may use to understand external knowledge. Thus, there are multiple factors that we can crosscheck to see if they are present in the organizations participating in Solar United, which will help us understand how firms benefit from the collaboration.

Another difficulty that arises in collaborations between geographically spread organizations is related to the integration of knowledge described in section 2.2.4. The parties in such a collaboration may meet less frequently and communicate only deliberately, as opposed to local

collaborations where informal dialogue may be initiated much more frequently. The flow of knowledge and information between the parties in such a collaboration is thus limited to fewer interactions, and the parties may have to combine their knowledge by using any of the mechanisms listed in 2.2.4.1 to operationalize the collaboration. Particularly, we believe sequencing may be applied, as it allows the organizations to plan who is to do what activity in a particular order as illustrated in figure 2.2. In our analysis in chapter 6, we will see whether these kind of integration mechanisms are applied to overcome the difficulties of combining dispersed knowledge bases.

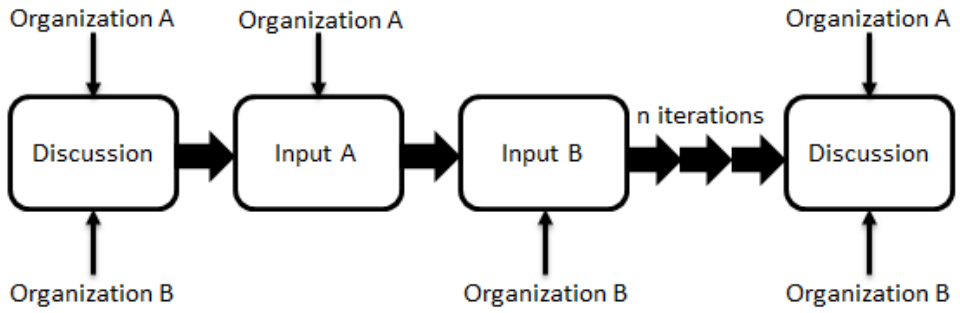



**Figure 2.2 Knowledge integration between organizations through sequencing.**

As outlined in 2.2.4.2, knowledge integration requires common knowledge between the organizations, which we see are factors that resemble cognitive proximity. We choose to link them throughout our analysis so that Grant's five factors (language, other symbolic communication, specialized knowledge, shared meaning and recognition of each other's knowledge) become part of our understanding of cognitive proximity. We will evaluate the quality of this assumption in our analysis in section 6.4.

Another link that between the sections above is between organizational proximity and knowledge integration. From the description of organizational proximity above, we see that routines and rules in collaborating organizations represent their organizational proximity. Recalling section 2.2.4.1, we see that rules and routines also are mechanisms in knowledge integration, indicating that collaborations with a high degree of organizational proximity can more easily integrate their knowledge resources.

The final link that we will point out is between proximity and ICTs. Particularly, common digital infrastructure between organizations may contribute to organizational proximity. This is because such ICTs let different organizations relate to the same system and framework, and which resembles the definition of organizational proximity above. Thus, we see a link between ICTs, organizational proximity and knowledge integration: two organizations who relate to the same digital system increase their organizational proximity, allowing them to more efficiently integrate their knowledge bases. The relevance of this link will be evaluated in section 6.4.

Above, we have juxtaposed our entire literature review. Now we will use the literature review on proximity to figure out how knowledge intensive firms benefit from collaborating in research centres by answering the following research question:

> *How do firms cope with lack of geographical proximity when collaborating with other organizations in Solar United?*

In the following section, we recap all the above sub-research question and reorganize them to answer our main research question in a more orderly fashion.

## 2.5 Recapping research questions and synthesizing a framework

This chapter has produced four sub-research questions to support our main research question. They have, however, been presented in an order which limits the relevance of each answer to the next. To enable us to use the answer from one research question to answer the next, we re-organize the sub-research questions to the following order outlined below. After we answer these sub-research questions in chapter 6, we will apply these answers to our main research question that will be answered in chapter 7:

| | |
|---|---|
| **Main research question** | *How do knowledge intensive firms benefit from collaborating in Solar United?* |
| **Sub-research question 1** | *What outcomes do firms participating in Solar United expect from the collaboration, and what does the centre do to meet these expectations?* |
| **Sub-research question 2** | *How do firms cope with lack of geographical proximity when collaborating with other organizations in Solar United?* |
| **Sub-research question 3** | *How do ICTs facilitate the collaboration between individuals in Solar United, and how do ICTs facilitate organizational learning?* |
| **Sub-research question 4** | *How is specialized knowledge from research institutions and firms integrated in Solar United?* |

We believe the research questions support and complement one-another quite well in this order. Sub-research question 1 takes on the background and motivations of the different firms for joining the research centre, before it takes on the way these expectations are met. Thus, this sub-research question supports our main research question by addressing what benefits the industry partners want to gain from the centre. Then, sub-research questions 2 and 3 address the context

of how firms benefit from the collaboration. Finally, sub-research question 4 utilizes the answers to the previous sub-research questions to show just how knowledge is created in the centre. Thus, we expect that at least some of the outcomes which firms expect from the research centre are new knowledge outcomes.

This concludes our literature review, and we will now review the methodology applied in this thesis.

# 3 Method

In this section, we will present the methodology applied in this thesis, including data collection, analysis of empirical data and critique to the method. We have designed the study as a qualitative single-case study to understand how knowledge intensive firms benefit from collaborating in research centres.

The chapter starts by introducing our literature review, which has been the basis for the theoretical framework and the research questions presented in section 2.5. We then review our research design and data collection, including a description of how the collected data was analyzed. This is followed by a brief evaluation of the trustworthiness of our research, before we end the chapter with critique of the method.

## 3.1 Literature review

In this section we review the method used in our literature review, which will give the reader an understanding of how we have come to use the literature presented in chapter 2.

Our literature review followed a sequence suggested by Bryman (2012 p119**)** where we have read Newell et al. (2002) and Hislop (2005) to provide an overview of literature on knowledge and knowledge management. We also have read five articles (Plewa et al. 2013, Tell 2011**,** Vie 2012, Steinmo and Rasmussen 2013, Stensli 2013) which were recommended by our supervisor to get an introduction to relevant topics. Based on this foundation we conducted two parallel searches.

First, we noted and read articles which were cited in Hislop (2005) and Newell et al. (2002), and which covered central issues in the literature. Those articles cited other articles on subjects we found relevant, and through this process of "snowballing" we went deeper until we understood the themes at hand. As we gained a better understanding of the theory during our snowballing, we noted key words which were seen as suitable for searching in databases.

In the second part of our search, we searched for the keywords found in our review of Hislop (2005) and Newell et al. (2002), and the keywords we found during the snowballing process. Conducting the search in databases at this late stage of the search process allowed us to gain a thorough understanding of the basic knowledge management literature before the search. This made us better fit to understand what search results were relevant and which were not. Our search started in Google Scholar and Elsevier where we used combinations of the following search words:

- Research collaboration
- R&D collaboration
- Proximity
- Research center
- Research centre
- Innovation
- Knowledge management
- SME
- UIL
- University industry linkage
- IOC
- Inter-organizational collaboration
- ICT

For instance, we searched for *"proximity research centre"* and *"SME research centre"*.

There was also some snowballing from the search results because the search results cited relevant articles which we did not find through our initial searches. The databases, Elsevier in particular, suggested other related articles, which we had not found in our literature search, leading to even more snowballing. We also searched for the most cited authors in the databases to see if they had reviewed or conducted more research on the subjects they researched earlier, giving us an impression of the state-of-the-art in the literature.

Ultimately, the vast majority of our reviewed literature was found through snowballing, likely because they we understood their context when we read articles that cited them. Now that we have reviewed our literature review, we will describe our research design.

## 3.2 Research design

This master thesis has been conducted as a qualitative single-case study. The background for this is threefold. First, since our research question is formulated as a *how*-question, a qualitative case study is a natural choice (Yin 2009 p4). Second, we are studying the CEER scheme, we thought that *qualitative data may take us where the action is* (Irwin 2009 p1136 as cited by Bryman 2012), meaning that we hope to uncover topics which may be studied further by others. Lastly, given the limited scope of a master thesis, we have limited our study to a single case as this allows us to search deeper for interesting topics and angles in our particular case.

Based on this choice of research style, we will now discuss what kinds of data collection are optimal for the purpose of our research.

### 3.2.1 Data collection

To figure out how knowledge intensive firms benefit from collaborating in research centres, we have used many different sources of information to maximize our information base with our limited resources and scope. First, we have used the homepages of NRC and Solar United in addition to search and tips, leading us to public documents and reports, which helped us get an overview of facts and the background of the research centre. This, combined with our literature review, was the foundation for choosing our research questions which further left implications for our choice of empirical data collection. Our choice of methodology and analyses were mainly based on the interviewees' knowledge, practical experiences and influence in their respective organizations, ensuring the anonymity of the interviewees, their availability and the number of informants. The last factor is important for generating a solid base of information (Tjora 2009, p30).

In the following section, we introduce interview styles in qualitative research, which was the basis for our choice of interview form.

### 3.2.2 Interviews in qualitative research

The high potential flexibility in interviewing makes it an attractive method for the qualitative researcher, as interviews are probably the most widely employed method in qualitative research (Bryman 2012 p469). In qualitative research interviews, there is an emphasis on greater generality of initial research ideas and on the interviewees 'own perspective, the interviewee's point of view, in contrast to the quantitative interviews (Bryman 2012, p470). Using interviews to conduct case studies is a good way to ensure collection of god data for further investigation.

The following sections review the different kinds of interviews to clarify their different applications, advantages and disadvantages.

#### 3.2.2.1 Qualitative interviews - depth interviews

The depth interview is one of the most efficient methods to reveal hidden information, tacit knowledge and personal experiences, and to discover potential new topics that the interviewers otherwise might not have thought of (Tjora 2009, p105). Depth interviews should be conducted face-to-face to capture more personal aspects, because some interview forms in contrast, for example phone- and email interviews, lack the information about the informant(s) local situation, and it is hard to pick up emotions and reactions on the different topics that are discussed during the interview session (Bryman 2012, p488).

The main objective with depth interviews is to create an atmosphere for an open, free conversation about specific topics set by the researcher(s), where the focus is the informant´s subjective relations to these topics (Tjora 2009, p104).

In depth interviews, the researcher wants rich and detailed answers, questions are typically open and allows the informant to come with digressions and his/her own thoughts (Bryman 2012, p470). Leading to a high chance that during the interview it would be discussed topics the interviewer did not plan for, but still would be relevant for the study (Tjora 2009, p105).

The depth interview as method is based on a phenomenological perspective, where the researcher wants to understand the informants' experiences and his/her reflections **(**Spradley 1979, as cited by Tjora 2009, p105). It is the informants subjective relations to the discussed topics which are the focus.

We can divide the depth interview into two main types (Bryman 2012, p471):

*The completely unstructured interview*. There may be just a single question that the interviewer asks, and the interviewee are allow to respond freely, with the interviewer sometimes following up on interesting topics that comes up. Such unstructured interviews seems very similar to a conversation (Burgess 1984, as cited by Bryman 2012, p471).

*The semi-structured interview*, were the researcher has a list of questions related to specific topics to be covered, an interview guide. At the same time, this interview form gives a flexibility for the interviewee to go into other related and interesting topics.

The depth interview can be divided into three main phases (Tjora 2009, p112):

- *"Warm-up" phase.* The main goal for "Warm-up" questions are to prepare the informant and to get him/her to understand the situation and feel safe about the interviewer and the settings. It could be simply questions like: "What is your educational background"
- *The reflection phase.* This is the core of the interview were the informant opens up and have the possibility go deep into the relevant interview topics. The interviewers' main task is to ensure that all topics and questions are included, and to do follow-up questions to ensure that all details are provided.
- *Closing phase*. The function of this phase is to normalize the situation between the interviewer(s) and the informant by drawing the attention away from the reflection questions. Typical is to inform the informant about how the data will be processed etc.

Since we had a clear focus of what we were looking for, the plan was to conduct semi-structured interviews with all interviewees as far as it was possible (Bryman 2012, p472). To ensure a moderate level of comparability of interviewing style we wanted to use an interview guide. In addition, since we were at least two interviewers present in all interviews, semi-structured interviews seemed like the best choice.

We also prepared for potential *focused interviews*, depending on each interviewee´s attitude and level of comfort to the interview situation. Use of shorter interview forms such as focused interviews, which are presented in the next section. These should be considered if the topic is

strongly limited and if trust could be established relatively quickly in the interview situation (Tjora 2009 p126).

#### 3.2.2.2 Focused interviews

In a typical depth interview, one can encourage informants to reminisce about their experiences. In the focused interview, the interviewer can play a more active role as he can introduce more explicit verbal cues to stimulate the situation, or even "reconstruct" the situation (Merton 2008)**.** The interview is focused on the subjective experiences of a person exposed to a pre-analyzed situation in an effort to ascertain the interviewer's definition of the situation. Like in depth interviews, there is a use of predominantly open questions about specific situations and events that are relevant to the interviewees and of interest to the researcher (Bryman 2012, p213).

#### 3.2.2.3 Interview issues

During a common interview session, the interviewer may experience that the informant tries to answer "correct" or avoidance from the informant to answer sensitive questions (Tjora 2009, p118). This is something we were prepared for by communicating with the interviewees in advance, developing good follow-up questions and strategies, as well as emphasizing that *their opinion* is what we wanted to know. This in order to collect valuable trustworthy data. In addition, as qualitative interviews depend on a good dialogue between researcher and informant to reveal relevant personal reflections, we developed a suitable interview guide that helped us facilitate this (Bryman 2012, p471).

### 3.2.3 - Interview guide

Unlike a questionnaire survey, where the questions must be fully designed, the questions in an interview guide can to a greater extent be more "keyword characterized". Still, for a depth interview the interview guide should be relatively detailed and thoroughly formulated (Tjora 2009, p132). All the questions in the guide should be included in every interview, and a similar formulation should be used with all interviewees (Bryman 2012, p471). Questions that are not included in the guide may also be asked, as the interviewer notices new information from the interviewees.

Two interview guides, one for research partners and one for industry partners, were made based on a well-tested interview guide developed by Thomas Lauvaas and Marianne Steinmo, who both are PhD candidate at the University of Nordland. Their interview guide had been made for interviewing research and industry partners from others CEERs in Norway, and was adjusted so the expected interview time was approximately one hour to avoid tiring of the informants (Tjora 2009, p107).

We prepared to use the interview guides in a flexible way because depth interviews should ideally be informal. Thus, there is not necessarily a "straight-line" through the interview even if the informants may expect to be asked pre-set questions (Bryman 2012, p471). We also made

follow-up questions, which is important to further investigate interesting topics which emerged during the interviews. Only minor adjustments were made to the interview guides after the first interviews as some of the topics overlapped. We ensured to go through the whole guide with all of the interviewees to ensure that collected data could be compared.

In the interview guide for industry partners, the following topics were included:

- Introduction and background about the firm and informant
- Background of the initiation of the collaboration, Solar United
- The firm's participation in the centre, including communication, routines, involved people and use of knowledge
- Dynamics of the collaboration, including relations and use of ICTs
- Innovation activities and how innovation was treated in the centre
- Closing remarks and implications for improving the collaboration

In the interview guide for research partners, the following topics were included:

- Introduction and background about the research organization and informant
- Background for the research centre, including acquisition of industry partners
- Dynamics of the collaboration, including relations and use of ICTs
- Innovation activities and how innovation was treated in the centre
- Closing remarks and implications for improving the collaboration

The full guides can be found in appendix I and II**.** An example of some questions from the interview guide for industry partners:

**Main question**: Please tell us about the background for your participation in the center.

**Possible follow-up 1:** Can you tell us more about your incentives for participating?

**Potential follow-up 2:** Can you provide an example of an outcome from the collaboration that has been feasible for your company?

### 3.2.4 Sample

We aimed to find suitable interviewees through purposive sampling (Bryman 2012, p418). Initially our supervisor, Dr. Ola Edvin Vie from NTNU, put us in contact with relevant persons he knew in Solar United, including the centre leader. After explaining the purpose of our research to the centre leader, he arranged and set up three interviews at IFE, which is where the main office of Solar United is located, with relevant persons in different positions. The three interviews at IFE was set up on the same day, for practical reasons. Thomas Lauvaas did also participate in these three interviews, as he will use them as part of his PhD-research. After conducting the interviews at IFE, we contacted the other research partners and all of the industry partners in Solar United, in order to arrange the rest of the interviews. We succeeded to book and

conduct a total number of 20 interviews, with 5 of 6 WPs and 12 current and previous industry partners (some of the industry partners having more than one interviewee). The University in Oslo, representing WP5, was the only research partner not wanting to participate due to lack of time. Because of practical challenges 5 of the interviews were conducted by phone, and 1 by video conference. The remaining 16 were conducted face-to-face, either at their location or at NTNU. We also made sure that the quotes pulled out for categorizing were not taken out of context, and that quotes which claimed the opposite of others were included, e.g. table 5.2 in chapter 5.3.

The interviews were conducted during the late autumn 2013 and early spring 2014. All the interviewees in the sample were given a short introduction to the master thesis, and were aware that they would be anonymised. All of the interviewees agreed to let us use a tape recorder during the session, the interviews were conducted in Norwegian.

**Table 3.1 Informants from industry partners**

| Informant pseudonym | Firm size (#employees) | Firm type | Education | Interview length (h:mm) |
|---|---|---|---|---|
| Peter | 100<#<250 | Support | MSc | 0:55 |
| Barry | 100<#<250 | Support | MSc | 0:55 |
| George | 100<#<250 | Core | MSc | 1:24 |
| John | 250<# | Core | PhD | 0:45 |
| James | 250<# | Core | PhD | 0:28 |
| Arthur | 250<# | Core | Ing. | 1:16 |
| Andrew | 250<# | Core | PhD | 0:56 |
| Cathrine | 250<# | Core | PhD | 0:30 |
| Bob | 100<#<250 | Core | PhD | 0:31 |
| Joan | 100<#<250 | Support | PhD | 1:11 |
| Tom | 100># | Support | MSc | 0:51 |
| Ian | 100># | Support | MSc | 0:42 |
| Jack | 100># | Core | PhD | 1:00 |
| Carl | 100># | Core | PhD | 0:49 |

**Table 3.2 Informants from research partners**

| Informant pseudonym | Organization type | Education | Interview length |
|---|---|---|---|
| Lucy | CRTO | PhD | 1:00 |
| Henry | CRTO | PhD | 1:14 |
| Aron | CRTO | PhD | 1:14 |
| Alice | CRTO | High School | 1:02 |
| Gary | CRTO | PhD | 2:45 |
| Stacy | University | PhD | 0:53 |
| Mary | University | PhD | 1:09 |

From the table we see the code for the different anonymized interviewees. The different roles of the interviewees varied from administration secretary to researchers and WP-leaders within Solar United. The real names have been replaced with pseudonyms that have been used for quotes in this thesis.

After the completion of all the interviews, they were analyzed based on the different interview criteria. Even if we planned our default to be semi-structured interviews, the majority of the interviews developed naturally into focused interviews. A part of the explanation is that we had some communication with the interviewees in advance of each interview and some level of trust may have been made (Tjora 2009, p126).

## 3.3 Analysis of data

We will now review our data analysis by first describing the data collection process. We then justify why we have chosen to conduct a thematic style of analysis. The final section explains how we categorized our findings.

After finishing the interviews, we transcribed them ourselves in order to get closer to the data (Bryman 2012 p486), while focusing on rendering the interviewees emotions, thoughts and opinions on the different topics. For the transcription of data, we used a combination of the computer softwares *Microsoft Office Word* and *IncScribe*. The total interview time was 20 hours and 42 min, which made 374 pages of transcripted raw interview data. These are not attached in this thesis due anonymizing, though CENSES have been handed the raw tapes and transcriptions for potential further research.

Thematic analysis was considered as a suitable approach to analyze the topics covered in the interviews and to follow up the research questions that were made in advance of the interviews. Just to clarify, thematic analysis is about coding, categorizing and evaluating qualitative data

(Bryman 2012, p578). In a thematic analysis the researcher searches for themes to conduct research on, and unlike grounded theory, there is no one "right" approach. A theme in this context can be, among other definitions, a category identified by the analyst through collected data or research questions chosen by the researcher (Bryman 2012, p580).

To reduce the amount of data for the further process the transcripts were coded by extracting quotes, which were relevant to the interview topics, as coding is a good mechanism for reflecting upon the meaning of the data, and to reduce the data amount for further analysis (Miles and Huberman 1994)**.** In addition, summaries of the interviews were made.

We looked for patterns among the different interviewees´ quotes and statements, and began categorizing them. As the patterns became visible we started the process of the thematic analysis (Boatzis 1998, p3).

As categorization structures the results of a data collection (Tjora 2009, p185), the quotes were categorised according to the different research questions for the project thesis. We started out with picking out a few quotes working as headlines/themes, and noted page numbers containing relevant data in the transcription as well as new quotes that supported the belonging theme. This database was then used in the analysis to try to first answer the sub-research questions, thereafter using this to answering the main research question, and lastly to suggest new interesting topics for later research.

This concludes the description of our data analysis, and we will now evaluate how we can be sure our data is trustworthy.

## 3.4 Trustworthiness of data

It has been suggested by many authors that qualitative studies should be evaluated according to quite different criteria from those used in quantitative studies (different forms of reliability and validity), because of the nature of qualitative studies. Two primary criteria have been proposed by the literature: trustworthiness and authenticity. (Bryman 2012, p390-393) . Because of we have not focused on the wider political impact of this case study, the latter criteria has not been found relevant for our study.

Bryman (2012, p390) & Malterud (2001) both sites to Guba & Lincoln (1985) who divide trustworthiness into four criteria:

*Credibility* in qualitative research is to establish that the results are credible from the perspective of the participant in the research, by ensuring that research is carried according to the guidelines of good practice and *respondent validation*, the latter referring to the researcher(s) providing the people conducted research with, e.g. informants, with an account of the findings.

*Transferability* refers to the degree of which the results of qualitative research can be generalized or transferred to other contexts or settings. Transferability is primarily the responsibility of the one doing the generalizing.

*Dependability* in qualitative research bases itself on the "auditing approach of study", including keeping records from all phases of the research process, establish how far proper procedures should be followed, and assessing the degree to which theoretical inferences that can be justified. Though auditing is very demanding and there are challenges with potential large datasets, a main reason why this has not become a pervasive approach to validation.

*Confirmability* - this is concerned with ensuring that the researcher can be shown to have acted in good faith, while recognizing that complete objectivity is impossible - it should be apparent that the researcher has not overtly allowed personal values of theoretical inclinations to influence the conduct of the research and the findings from it.

Regarding the four different trustworthiness criteria, in this case study we have as far as possible used credibility by following guidelines of good practice in the execution of our research (Bryman 2012) by for instance not disregarding conflicting statements and theories. We haved stayed respectful on account of transferability by describing the research context and the assumptions linked to each finding, which we attempt to transfer from one context to another. Dependability have been attended by documentation and storage of the collected data and the process, for instance by securing interview transcriptions and tape records. Finally, we have intended to "act in good faith" to assure confirmability by being as objective as we have seen possible when we have interpreted our transcriptions. We have also used internal reliability (Bryman 2012, p390), by asking each other continuously during the process to check if we both had the same understanding of their statements.

## 3.5 Critique of method

There are of course parts of the method and execution of the research which ideally could been have been done differently, which may had improved the case study. We will review this critique related to the order of previous topics in these following sections.

**Unstructured literature review**

First, our literature review could beneficially have been performed more structured; by making more specific search algorithms, using a wider variety of keywords and additional databases, which may have led to more diversity in the literature findings. Furthermore, after we articulated our research questions we stumbled upon relevant literature for the case study, which also may lead to new interesting sub-research questions. This has resulted in a lower number of research questions than there potentially could have been. However, we are nonetheless satisfied with the

scope of the research questions presented in the thesis, regarding having a more focused case study.

**Unstructured triangulation**
Second, we have had triangulation (Bryman, 2012, p392) in a less structural way than optimal, e.g. executed not confirming the data from interviewees shortly after an interview was conducted. We still think we have managed to confirm our collected data, methodologies and theoretical perspectives by third parties in a proper way, e.g. cross checking quotes from the interviewees with official data on the web, and used the interviews from the research partners to triangulate the responses from the industry partners.

**Irrelevant interviewee**
Third, by letting the centre manager book three of the interviews for us, we were unable to communicate with those interviewees prior the day of the interview, making it difficult to assure the relevance of the interviewees. One of the interviewees is in hindsight regarded as irrelevant to our research, as the informant was newly hired and had a purely bureaucratic position in the centre. In addition, since all three interviews at IFE were scheduled on the same day, there was a chance that one of the informants would might not be able to attend the interview.

**Homogenous interviewees**
Fourth we have not interviewed any industry partner who would not join the centre/declined the offer to be a part for Solar United. Still this information was confidential so we would have had to guess whom this might be, seen as not an efficient use of time.

**Uncertainties regarding thematic analysis**
Fifth, we have used thematic analysis intentionally, as we found it appropriate for our research. However, thematic analysis is considered as an underdeveloped form of analysis. This is because there are few common definitions of themes, and there are few specifications as to the steps and ingredients of thematic analysis (Bryman 2012, p580). This means that we may have interpreted the existing guidelines of the method differently than other researchers would have had, and our approach is thus less structured than it could have been with another more developed method. Still, we do believe the method is suitable due to the limited scope and the exploratory role of the thesis.

**Time crunch**
Finally, we must direct some critique toward our time management. As both authors dedicated most of our attention during the spring semester to our commercialization projects at NTNU School of Entrepreneurship, we have been forced to work with the case study in concentrated periods rather than evenly through the semester. A steadier progress would likely have eliminated some of the elements that we have criticized above because our fractured progress has forced us to make swift decisions, as entrepreneurs often must (Busenitz and Barney 1997, Simon, Houghton et al. 2000).

**Excessive snowballing**

As mentioned in 3.1 snowballing has been a central method for finding relevant literature in order to make our theoretical fundament. Doing this can lead to potential bias in what we base our theory on, especially if we would try to adjust it to our empirical findings, something we tried to avoid and were fully aware of. Trying to avoid this we have been critical to all literature we have read, and tried to find literature within the same searches and categories that were well sited. In addition, we spent some time going back to the fundamental authors within the different theoretical frameworks we were using to see the development of the theoretical fields over time - mixing our sources both from new and old literature. Still there is a chance that there is some bias in the theoretical framework, something the reader should keep in mind.

This concludes the walkthrough of the methodology used to conduct this study. We will now give a brief description of the case of Solar United before we review our empirical findings.

# 4 Case description

So far we have outlined the background for our research, crafted an analytical framework and reviewed the methodology used in this thesis. Before we present our empirical findings, we will briefly review background information on the CEER scheme in general and our case centre, respectively. This section is necessary to put our findings into context, but may also prove useful by providing a societal perspective, enabling us to make practical implications in section 8.3.

## 4.1 Centres for Environment-friendly Energy Research

As outlined in the introduction, the CEERs are a result of the climate settlement which states that Norway should be carbon neutral by 2030, and Energi21, the national strategy for R&D. In table 4.1, the most important facts about the CEER scheme are summarized.

**Table 4.1 Overview of the CEER model.**

| | |
|---|---|
| **Purpose** | "The CEER scheme should develop competence and innovation through focusing on long-term research on specifically chosen areas within environment-friendly energy … in close collaboration between distinguished research communities and users"<br><br>"The scheme should strengthen technology transfer, internationalization and the education of researchers" |
| **Financing** | ¼ by research partners, ¼ by industry partners, and ½ by NRC. Partners may contribute with cash and in-kind contributions such as materials and work-hours. |
| **Duration** | Centres will be established for a time period of maximally five plus three years. |
| **Management** | The collaboration must be managed in a consortium, which should regulate organization and execution in the centre. In addition, it should dictate duties and ownership to property rights among partners.<br><br>The industry partners should always hold the majority of board seats. |

## 4.2 Solar United - The Norwegian Research Centre for Solar Cell Technology

In this section we will review the structure of Solar United and the partnering firms with their respective positions in the solar industry value chain.

Solar United is the only CEER for solar cell technology, and consists of the Norwegian institute for energy research (IFE) as the host-institution, The Norwegian University of Science and Technology (NTNU), the University of Oslo (UiO), and SINTEF. As both IFE and

SINTEF are CRTOs, the centre has an equal part of universities and CRTOs as research partners. The centre currently has ten industry partners that are widely geographically spread, as shown in figure 4.1.

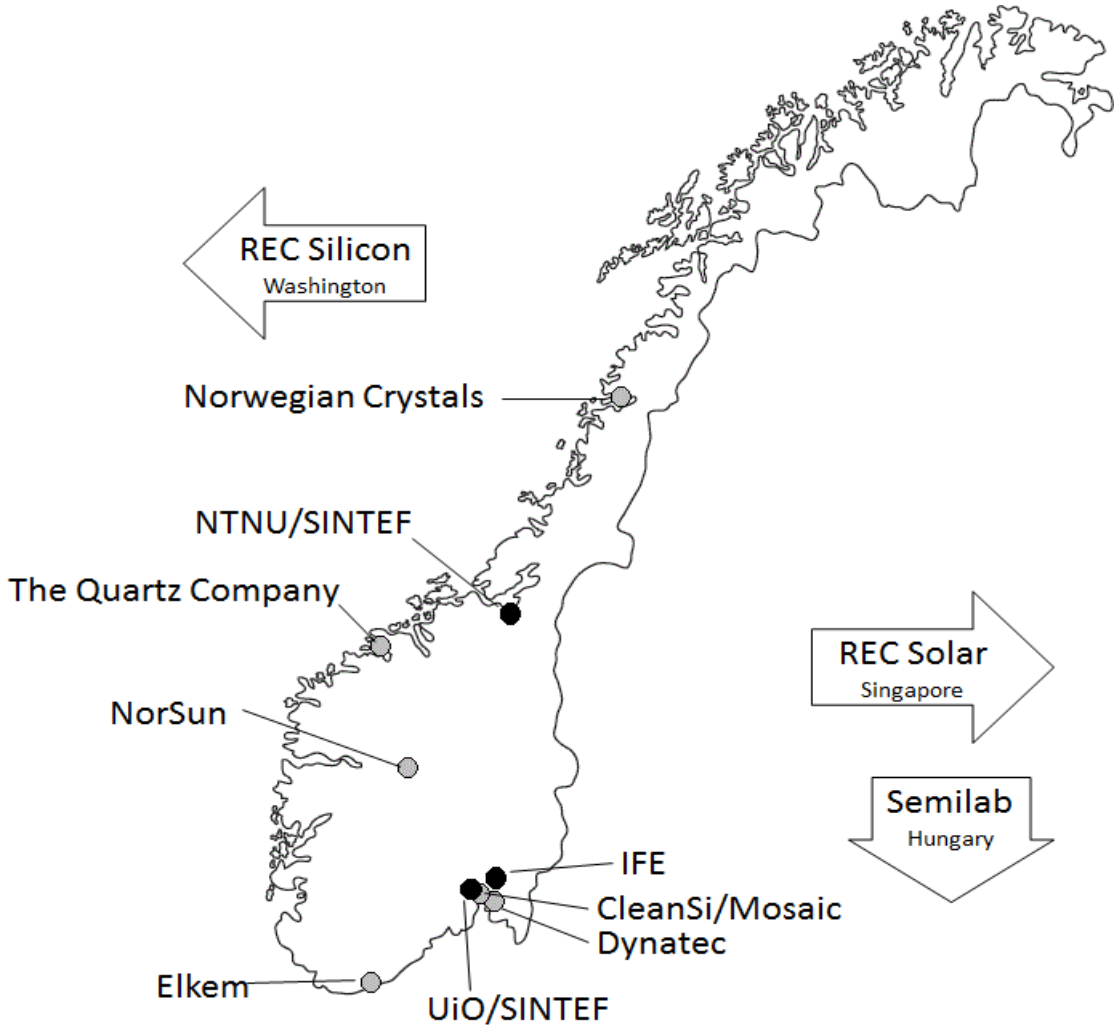



**Figure 4.1 Geographical dispersion of the research partners (black dots) and industry partners (arrows and gray dots) in Solar United.**

The research centre is organized in seven work packages, where each package focuses on a specific application or area of research related to solar cell technology. Figure 4.2 outlines the centre structure in detail.

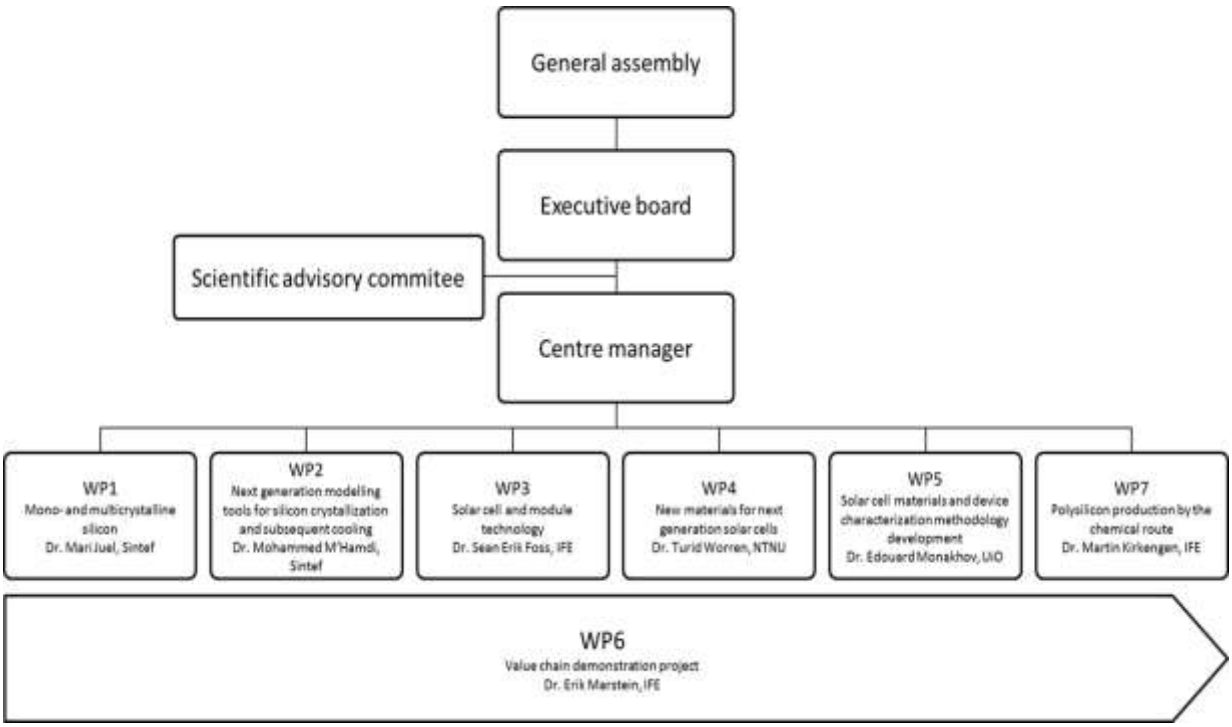



**Figure 4.2 Organizational structure of Solar United, including topics and leaders of the work packages (Solar United 2014).**

### 4.2.1 Industry partners

The industry partners in Solar United cover most of the solar industry value chain, as shown in figure 4.3. The firms shown in the figure are the firms present in the centre between 1st of January and 15th of July 2014, which was the period for production of this thesis. See appendix X for a full timetable of what firms have participated in the centre and their respective positions in the value chain.

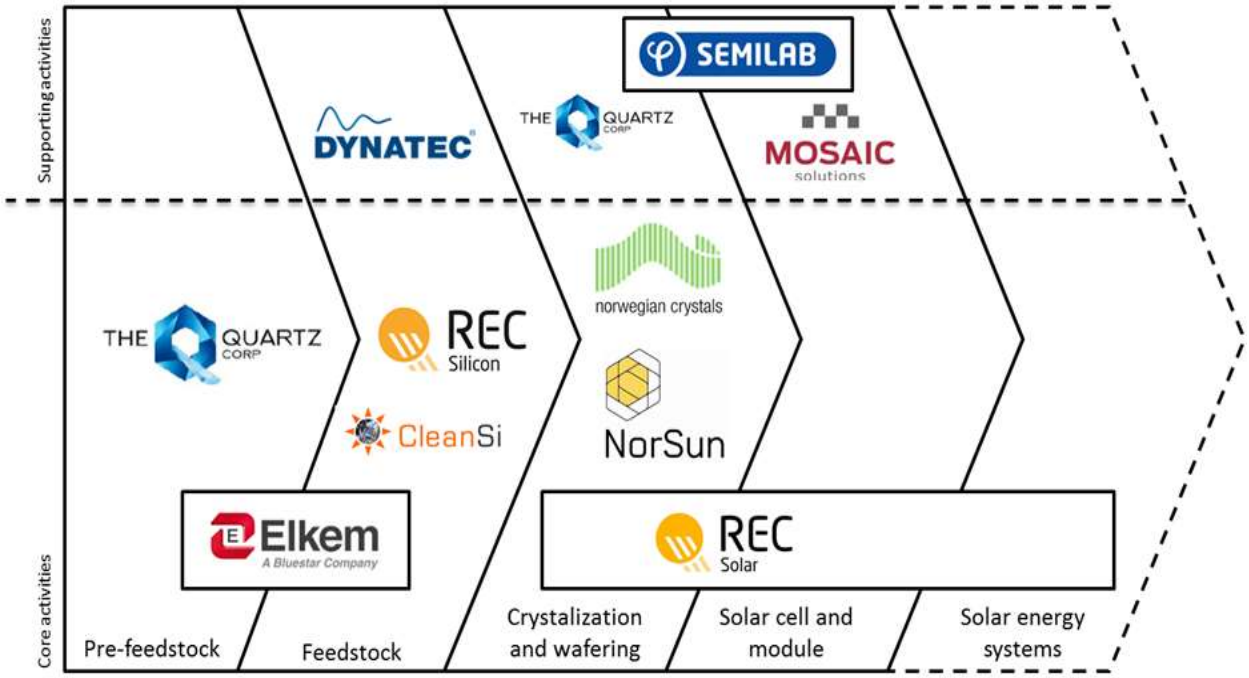



**Figure 4.3 Firms participating as industry partners in Solar United from January 1st to July 15th 2014. The categorization of the value chain has been derived from internal documents from Solar United. The outermost right category, solar energy systems, is not included in the research centre.**

# 5 Empirical findings

In the following sections we will present our empirical findings which were most relevant to the thesis. The findings are divided into five topics, where the first regards firms' motivation for participating in the research centre. The second section shows findings on how industry partners are able to influence and contribute to the research centre's activities. Thirdly, we address how ICTs are used to communicate in the centre. The fourth section concerns relations are created in the centre and mutual understandings between involved partners. Lastly, we show findings on how the centre works with innovation.

As the observant reader might notice, there is no correlation between the interview guides used to collect the data and how the data is presented in this chapter. Hence, this is no problem as the data most relevant for answering the research questions are presented, while the remaining data can be used as a fundament for later research.

## 5.1 Firms' motivation for participating in Solar United

The interviews with industry partners indicate a wide array of reasons why firms wish to participate in Solar United. The main motivations have been summarized in the matrix in figure 5.1, and the more specific motivations will be reviewed below. As can be seen from the figure, we have found that there are correlations between firm size and their main motivations. Below, we will review the main motivations for large firms and SMEs in the core solar industry, and supporting industry, respectively. The supporting industry consists exclusively of SMEs

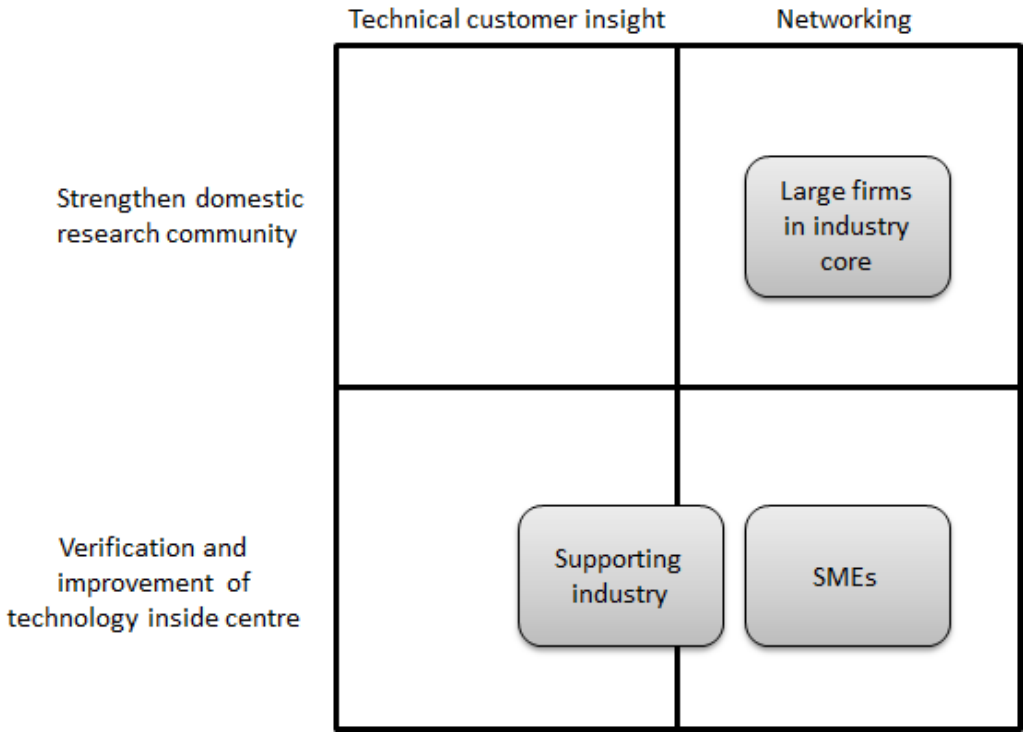



**Figure 0.1 Industry partners' motivation for participating in Solar United. The "supporting industry" box in the bottow left square refers to the nomenclature presented in figure 4.3.**

At least four informants from both research partners and industry partners point out that knowledge intensiveness is important to the participating firms, because they perceive that Norway has a unique position. This position concerns good access to cheap electricity, water, and a workforce that is highly educated with moderate wage levels. The informants perceive that this has implications for how the Norwegian industry might position itself.

> *"We're in a good position for everything than can be automated, which requires very high competence and is energy demanding. I believe some production also can conducted in Norway, naturally. However, everything labour intensive is of the table. [...] I think the clue is competence and advanced production"*

Large industry partners unanimously view strengthening of the Norwegian solar research community as their main motivation for participating in the centre. Prior to the establishment of the centre, the the different research partners had already begun to specialize on particular aspects of the solar industry value chain, which made the basis for the creation of the different WPs when the centre was initiated.

In addition, many of the activities in the centre were already initiated in binary projects between single industry partners representing different parts of the value chain and one of the CRTOs. A

binary project have been described by the interviewees as a contract based research project between a firm and a research institution. The binary projects seems to be the arena where the large industry partners utilize the knowledge created in the centre.

> *"Normally [the research partners] don't implement anything in our facilities; it's not how we normally do things. We build up competence, primarily in the institutes. Then that knowledge is put to use in binary projects, that's what's most important" Arthur*

Thus, this example points to binary projects as the large firms' innovation arena, whilst the research centre only lays a foundation of basic research. In figure 5.2, the concept of binary projects is illustrated.

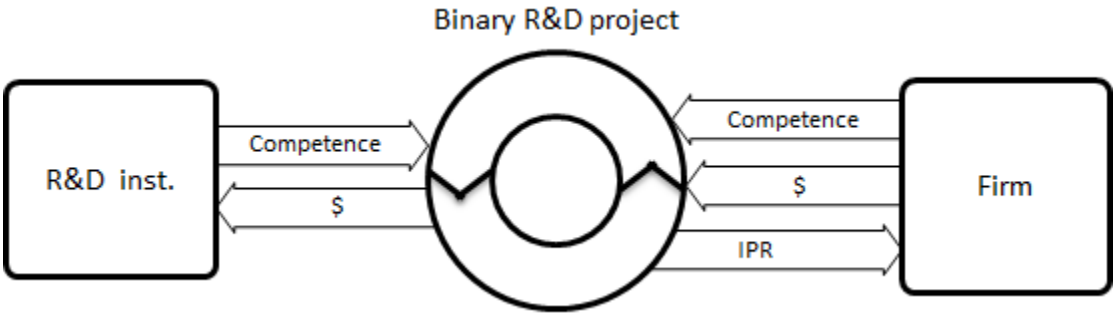



**Figure 0.2 Binary projects with different organizations' inputs and outputs.**

These binary projects normally result in spillovers and discoveries of topics which the firm does not want to follow up on their own. We have found empirical proof that the spillovers have been brought into the centre, according to one of the research partners.

> *"We come across interesting topics which are aside of our focus area when we [industry partners and research partners] are working together. The most potent of those topics are sometimes followed up within the centre instead of in a binary project." Henry*

The centre has served as a way to formalize and improve the coordination of research activities in related to solar cell technology in Norway, thus strengthening and focusing the research:

> *"We have such strong communities at Kjeller and in Trondheim that we could easily "beat each other to death", which is meaningless in an international industry where no one needs what's second best. That is why the research communities have, more and more deliberately, developed the complementary competence that we have today, which covers the entire value chain" Gary*

Though they all list basic research as a main motivation, only a single large industry partner showed any particular interest in the research on radical new materials in WP4. More findings related to this particular research focus is presented in section 5.5

The large companies' second motivation for participation is the potential for creating relations to the other actors in the Norwegian solar industry, both firms and research institutions. Particularly, they seem to be eager to establish personal relationships between their representatives. However, some (but not all) of the industry partners mention that, among the research partners, they almost exclusively communicate with the CRTOs rather than the universities because of the CRTOs' focus on applied research. On the other hand, some firms list education of candidates-for-hire as a reason why they wish to support the centre, indicating a direct contribution from universities as well.

Regarding the SMEs, it is worth noting that the three out the four smallest companies in the centre joined the centre 1st of January 2014. This is the result of an intense industry partner acquisition process, which was necessary to maintain the centres' funding as many industry partners have gone out of business. This partner acquisition process has taken much of the centre managements' time in the past year, and though some other researchers have been involved, the centre manager has dedicated a large proportion of his attention to acquiring new partners.

> *"He [the centre manager] has run "until his legs fell off" to acquire new industry partners" Stacy*

In this process, the SMEs have become the largest group of industry partners in the centre. The smaller companies participating in the research centre have somewhat different motivations for participating. As shown in figure 5.1, SMEs use the centre both to test their technologies and equipment in the centres' labs and to create relations with the different actors in the industry, but the different SMEs point to different incentives as the most important ones. On the on side, the two of the smallest firms in the centre have gained access to laboratory facilities and other resources they would not have had access to otherwise. Though these firms may have conducted the same research in binary projects with one of the research partners instead, the centre has allowed them to contribute in-kind rather than paying cash. Thus, companies lacking funds may participate despite their unsolid financial status. One of the participating firms even claim that the centre has been instrumental to their progress.

> *"Without Solar United we would have had to stop our EU-project [their main research project] and might have had to declare bankruptcy." Jack*

Other small firms emphasize networking as the most valuable outcome from their participation, as participation has led directly to new connections and new business.

> *"Personal relations are possibly the most important outcome for small companies. [...] The network we've obtained through Solar United has led to inquiries from people we wouldn't have spoken with otherwise." Tom*

Our final findings in this section regards firms within supporting industry, who are specifically interested in technical insight among their customers. They believe this insight may help them improve their products, which in turn allows them to become a preferred supplier of their respective products. In addition, they appreciate the new connections they develop through participating in the centre, but see this mainly as a prerequisite to gain customer insight and successfully transfer knowledge. One of the supporting industry partners points out that because they deliver their services to multiple industries, the social bonds to each specific industry is limited. The centre has made those bonds to the solar industry much stronger.

Though their main focus is technical customer insight, the supporting industry partners point out that they are interested in creating relations with both industry partners and research partners. However, they point out the importance of the mindset of the research partners, as they must have some insight into what research may be applied:

> *"I would not mention negative examples, but there are some institutions in some other places in Europe which carry out solar related research that is not really relevant from a high-tech or state-of-the-art industry applications. We like the kind of guys in Solar United." Peter*

We have now reviewed the most important input from the research partners on their participation in the centre, and will now review how they influence the activities in the centre.

## 5.2 Firms' influence, inputs and involvement in the centre activities

In this section, we will present the industry partners' ability to influence research activities, resource inputs and involvement in Solar United.

There are mainly two levels where the industry partners influence the research centre activities: the directional level and the project level. The directional level is related to deciding the strategic direction of the centre and is influenced through the board. One of the research partners stated the direction that has been set, is a good mix of current problems, upcoming problems and basic research.

*"Our research consists of things that the industry either needs today or tomorrow. [...] More than half of the activities in the centre contribute to creating a knowledge base which is natural and necessary to improve today's production and to enable the production methods of tomorrow." Gary*

As mentioned in section 4.1, the industry partners have majority of board seats in Solar United. Until 2014, each industry partner had their own seat on the board of Solar United, but due to the increased number of industry partners, this is no longer the case. Following quote explains how the process typically is carried out practically:

*"We typically decide if we should include new areas of research or other technologies. For instance, if a new company makes demands for specific activities, the board will make recommendations for management to follow through or not. [...] So it's about the direction of our research activities" Arthur*

Thus, the board only makes recommendations to the management on behalf of the participating organizations and does not have direct power to influence activities. There does however seem to be trust between the board and the centre management. To illustrate, one informant answered the following when he was asked to outline the most important criteria for having a successful collaboration.

*"There has to be a genuine interest to achieve something, and there has to be a management. The leader of this kind of consortium needs to have a certain professional weight, because he represents the entire centre in many settings. Our manager has this kind of professional weight" Arthur*

On the project level, the process of defining research projects is less formal and driven by dialogue in the different meeting arenas. All industry partners are encouraged to suggest topics for research projects for the different work packages in the centre. The industry partners seem pleased with this policy, and acknowledge that participation in the centre means that all participants should have some influence on the research agenda. One informant walked us through how her company perceived the process of joining the centre and defining activities:

"We started by attending the annual conference, and then we had some dialogues with the centre manager before we started attending other activities, such as work package meetings. [...] It was a mix of formal and informal conversations, we attended the conference and discussed and met the right people. [...] As time passed, we saw what activities were going on and we presented our business, and the others understood what was important to us. Then we tried to define how existing activities could most easily be changed and become relevant to us. Now they've defined an activity that's spot on for us." Joan

Another informant described the process of defining research activities as much more straightforward. This indicates that the task of defining new activities, which blend in with the other activities that varies in complexity.

> *"I think Solar United has been very flexible in adapting to the industry partner´s needs. When we joined the centre, I talked to the centre manager and told him what we needed, and he thought we could make it happen" Jack*

We will now present findings regarding resource contributions. The industry partners are bound by the consortium agreement, which also addresses management of IPR produced in the centre, to contribute with one fourth of the total budget. This could either be cash, in-kind, such as materials, datasets, research equipment and personnel hours, or a mix of the two. The typical contributions from each research varies from a half to one and a half full time equivalents (FTEs). The smallest industry partners contribute mainly in-kind, and mostly in form of personnel hours, whilst the large companies typically contribute with some cash, materials and equipment.

Though both cash and in-kind contributions allow industry partners to affect the research topics to a greater degree, the industry partners that contribute in-kind perceive a greater outcome from the centre than the ones that mostly contribute with cash. Most of the companies that contribute in-kind contribute by having their personnel partaking in the research activities, but now all:

> *"We contribute in-kind by partaking in discussions and sometimes by donating materials if that's of interest." James*

The industry partners that contribute with personnel sometimes station their researchers in the different research partners' facilities. For instance, we know that at least three of the current and one previous industry partner have had such temporary relocations to partake in the research.

> *"Industry researchers have spent weeks at a time in our laboratories and contributed to the research. The same happens in Trondheim" Gary*

Some of the research partners also contribute in-kind by conducting some of the research in-house. For instance, two firms who are vertical to each other in the value chain conducted an industrial experiment in one of the firms' factories with materials from the other firm. Research partners were also involved to apply new characterization methods to the experiment. Thus, we have found examples of research in the research partners' facilities conducted by the researcher partners alone and in collaboration with research partners, and examples of research conducted in the industry partners' facilities.

Another interesting finding is that three of the largest industry partners, both based abroad, are do not attend the work package meetings. Thus, they must perceive a less active role as valuable. This reflects the firms' motivations for participation outlined in figure 5.1.

The findings in this section show how industry partners seems to be able to influence the research focus in Solar United, and it seems they are quite pleased with the practices. However, though we pushed the interviewees to tell us their actual perception of the collaboration, we think the some of the interviewees may be saying what they think they are expected to say, rather than their actual perception. We have conducted the analysis in chapter 6 with this in mind.

In the next section, we will have a look into the communication procedures between individuals and involved partners in the research centre.

## 5.3 Communication, forums and ICTs

In this section, we review the forums and media used to communicate within Solar United. In the end of the section, we will review opinions regarding the use of ICTs within the research centre.

Our interviews mapped the meeting activities in the centre, summarized in table 5.1. In addition to board meetings every other month and a yearly general assembly, we found that meetings largely took place within each work package when the participants found it necessary. The barriers for informal communication seem to be low, allowing spontaneous follow-up communication by e-mail and phone to supply details and updates between work package meetings. Surprisingly there were no evidence for use of video conferences.

**Table 5.1 Arenas in Solar United.**

| Forum | Participants | Main topics | How many times per year |
|---|---|---|---|
| General assembly and conference | All centre participants | Presenting results from the past year. Establishing new connections. | 1 |
| Board meetings | Board members: one from almost every industry partner and every research partner. | Strategic decision making | 6-12 |
| Intra-work package meetings | Research partners and industry partners active in the respective work package. | Discussion and planning for upcoming research activities. | 2 per work package |
| Inter-work package meetings by phone | Centre manager and work package leaders. | Updates from each work package. | When needed |
| Spontanious communication by phone or e-mail | Any research partner or industry partner. | Details necessary for completing tasks. | When needed |

The industry partners seem happy with this arrangement and heavily emphasize how important they think the physical meetings are. This is because they feel that they share more knowledge face-to-face. In addition they claim that physical meetings create relations to a much greater extent than conversations through different ICTs. Discussing the further use of research results has also been mentioned to be far easier in person than per phone and email. Two quotes nicely sum up these opinions:

> *"I find workshops, seminars and active presentation to be superior ways of sharing knowledge." Joan*

> *"For me, the most valuable part of the general assembly and board meetings is the possibility of meeting the other industry representatives. We can share some news and grab a beer in an informal setting. The more technical discussions and day-to-day activities like sharing results are mostly made by email and phone" Bob*

Though the partners find physical meetings to be useful and effective, their intensive nature somewhat limits their outcome. This is because the geographical spread of the partners is a factor that causes them to meet quite rarely, forcing them to discuss very many topics in one single session. These sessions have been regarded as tiring by some of the industry partners, making it difficult for them to efficiently process all the information presented. Though summaries from

the meetings are available, it is vital to attend these meetings in order to keep up with the development of the project.

> *"We share a lot of information and details when we have one-and-a-half day lasting workshops and WP-meetings. It can be a bit much to process, this information overload." Andrew*

Some of the industry partners even have multiple contact persons that follow up one work package each. For instance, one industry partner gathers their contact persons periodically in order to brief each other on the centres' most important progress. This allows them to focus on that particular work package and sort out the findings and activities that are relevant to the firm.

> *"It would demand a lot from me to attend and absorb everything in all the meetings, which is why we've split up so that different contact persons communicates the findings that are most important for the firm to the other contact persons." Andrew*

Some industry partners also think that the information flow in general too detailed, that they struggle to stay up-to-date. The main tool for updating the different partners on progress in the centre is an ICT referred to as "the e-room". From what the authors understand, the e-room is an online space where the participants can share and access presentations, reports, papers and research results, and board members get notice when a new publication have been uploaded, in order to censor the results that they wish to keep confidential.

However, opinions about the e-room vary quite strongly within the centre as shown in table 5.2. Many of the interviewees have never used it; some think it is just a hassle; some think the e-room needs to be updated more frequently in order to be useful; some think it functions just fine. However, those informants who think it functions well are also those interviewees with the best conditions for understanding the context of it's content, because of their use of it linked to their positions as board members or administrative post in the research centre.

**Table 5.2 The interviewees' opinions regarding the e-room.**

| | | Opinion regarding current e-room solution |
|---|---|---|
| Industry partners | Haven't used it | «I don't know anything about that.» |
| | | «I know of it, but I haven't been there» |
| | | «We haven't been involved in technical activities, so we haven't used it» |
| | | «Something I miss in the collaboration is a strong electronic platform. […] Where I can get access to documents, have access to previous work and research plans so that I don't have to call someone every time I'm uncertain. […] I've heard about the e-room, but I don't really know where to find it» |
| | | «We have not used it yet, but are open to this kind of solutions. … we use this in general (in collaborations), we see the advantages. |
| | Don't think it works well | «When we joined Solar United we were eager to get up to date. But it was hard to sit down and understand it by ourselves, so we had to make an effort and establish (other) good communication before we understood what had been done in the centre before we joined. The e-room could beneficially be more frequently updated.» |
| | | «There's always an extra threshold to upload a report (to an e-room). There were so few documents that we thought it easier to just send them by mail» |
| | | «I think it's cumbersome. One has so much else to remember that it would be alot easier if they could just send us the information we need» |
| | | «I've used it, but I'm not a vivid user. People upload alot of presentation slides, which has very limited value to me. I wish there was more content.» |
| | Think it works well | «I think it functions well as it is. I've used it in other collaborations as well, and I think it's a good ICT platform since we were spread all across the country» |
| | | «Yes, it's alright to use, we were fermiliar with it from previous projects» |
| Research partners | Don't use it | «We primarilly use email and phone calls in our work package.» |
| | Don't think it works well | «It's really miserable and not user-friendly at all. It's an obstacle for communication streams. … the PhD candidates really wish for a simple bulletin board where they can establish connections with others in the centre. If they have a particular skill, they want others to use it, or if they have a material they don't know all the properties of they want help to characterize it. Then we might imagine the solar cell people start to see what materials they could actually use» |
| | Think it works well | «I personally haven't used the e-room much. I usually check it when there are conferences and meetings coming up. It's nice to be able to check what my collegues in Oslo are up to. I think we should be better at using this type of tools» |
| | | «I use it sometimes, I'm sure we could use it more. The problem is that people don't bother to upload everything that should be there. Its very nice to have a place where everything accumulates, but it requires that the other parties actually login and actively read. … I think it's important to combine these kinds of passive channels with active channels.» |
| | | «The activity in the e-room varies between the different work packages and partners. I think it's safe to say that it is used, but it could be used much more.» |

## 5.4 Relations and mutual understanding

In this following section, we will first review how the relations between the different organizations in the centre have developed, including some details on the initiation of the centre. We will then

As mentioned in 5.1, there were bonds between the research partners and industry partners prior to the establishment of the centre. All of the industry partners except one had previously had binary research projects with one of the research partners that was a CRTO, in addition at least five of the industry partners had worked with the other CRTO. There were, however, few clear relations between the different industry partners before the centre was established. Their common relations to the research partners have thus united them in the centre, and the fact that the centre urges the industry partners to partake in the same projects may well be an efficient mechanism for creating relations between firms. Two of the informants pointed out that the initiation of the centre required roughly a year of planning between the four research partners. Additionally it took approximately half a year to make the consortium agreement, which was required before the parties could start their collaboration in the centre.

One informant pointed out that it was quite easy to be introduced with the right people in the centre once the formalities were done. This made it easy for new industry partners to become involved with the research activities that was most relevant to them.

> *"I think that the centre manager has a very good overview of the centre. He knows his work package leaders well and has a good overview of what is going on. Off course, not all details, but I think it works well." Joan*

Regarding the creation of inter-firm relations, the centre arranged informal events after the formal meetings to create bonds between the different partners. As stated by "Bob" in section 5.3, an informal setting allows the representatives to share news that do not fit in the context of the formal meetings. The geographical spread between the industry and research partners, as shown in figure 4.1, makes it difficult to meet face-to-face as frequently as desired. This makes these informal settings quite rare, and most of the participating organizations are prevented from meeting other parties in the collaborations in person on a daily basis. All of the informants from industry partners point out how much they learn and how tight relationships they establish in these settings, and one informant explicitly points out that the centre may benefit from even more social events.

> *"Events such as dinners after conferences make the setting more "off the job" in a way, even though you're still at work. It has been fewer of these activities in the recent years [in collaborations both inside and outside the centre], which is a negative trend. You network in a different way during a dinner and with some beers compared to the pure conference setting, something I think would be very valuable in a collaboration in the long term." Andrew*

This in mind, a limiting factor for why industry partners do not meet more often is the tight schedules and geographical distances between the parties involved. The industry partners' contact persons are most often involved in multiple projects, and Solar United only takes up a small part of their attention. To allow more people to meet more frequently, WP1 and WP2, and WP4 and WP5, arrange their meetings together. The time needed to attend a meeting or workshop is an entire working day for most industry partners day (excluding the ones in close geographic proximity to their work package's headquarters) where most of the time is spent traveling.

When asked "if more physical meetings were possible", all the research partners replied that this was very hard to arrange. They were already struggling to find two dates that fit all the industry partners for the work package meetings. We found that this was due to tight and full schedules, leading to less flexibility for the industry partners.

> *"Some are good at following up these work meetings, others aren't that good. It often depends a lot on their status internally. It's very hard to prioritize such a meeting if there's a [metaphorical] fire in the factory." Arthur*

Another measure for creating and maintaining relationships in the centre in addition to the measures and ICTs mentioned in section 5.3, is the disposition of office spaces at IFE, the main office of Solar United. This makes it convenient for personnel to work and meet away from their normal workspace in shorter periods, e.g. if they participate in experiments as was mentioned by Gary in section 5.2. We could not find direct evidence of remote workspaces at the other research partners' facilities, but as stated by Gary in section 5.2, industry partners have carried out collaborative research in Trondheim, implying that facilities have been made available for their visits.

Now that we have seen how relations are created and maintained in Solar United, we direct our attention to the different partners mutual understanding. In order to be able to work productively together, the different informants pointed the need of some mutual understanding among the research partners and the industry partners. One such precondition related to the different contact persons' educations, as almost all of them had a PhD relevant to some of the technical aspects in the centre, or at least a degree at the master level. Most of them also had a central role in their respective organizations' research departments. The informants found this as a prerequisite to understanding the discussions between the different parties:

> *"People in the centre and from the industry partners are very knowledgeable, they know what they are doing and what they want to achieve, I would say there is a cognitive proximity between us." Jack*

Overall, there seems to be a mutual understanding that the purpose of the centre was to produce research relevant for the industry partners. However, the research partners seem to lack some knowledge regarding large-scale production, which is not surprising given that the majority of the researchers from the research partners primarily have worked for research institutions their entire career. This creates some barriers and limitations to their understanding regarding practical aspects of applying research results.

> *"There's a huge gap between mass producing something and having an idea for an industry process. [...] It's tough for researchers to conduct good innovation activities if they don't have strong connection to the context of their work."* Bob

> *"I wish there were more initiatives by the researchers to study what is happening in the factories, in order to bridge the gap between research and production. Our biggest challenge is to keep the direction the centre steady, so that the results and the research is purposeful." James*

The industry partners also pointed out that the research partners often were not as experienced with the different industry partners' technical equipment. Our informant, George, described knowledge on handling industrial production equipment as a craftsmanship. He also indicated that PhD candidates who are to conduct their experiments on such equipment spend large proportions of their research time just to make their equipment operational. He concluded that a tighter collaboration that allowed the research partners to utilize the industry partners' skills, would allow the research partners to hold an industrial standard in their facilities, allowing them to focus more on experimentation rather than system operation.

The research partners do not necessarily share this view. In fact, some research partners thought that the industry partners were holding back information, making it difficult to understand and plan research that met the industry partners´ needs. These companies were supposedly afraid of exposing trade secrets.

> *"The industry partners have to share [...] their actual problems so that we can plan how to resolve those problems in a given time frame. It is important that they give us a holistic understanding rather than just a small piece of the puzzle. Some give us more insight, but most often, they only show us a small piece. It's easier for us build the right competence if we have a complete understanding" Aron*

Despite the industry partners' critique of the research partners' knowledge on applying research, it seems that collaborating in the research centre have brought the involved partners closer. As the different industry partners have initiated more inter-firm collaborations after entering the research centre they have become closer organizationally, and to some extent cognitively as well as the involved partners are growing their knowledge bases through joint-research.

In sum, there is a consensus among the informants that the research centre has a positive effect to the further development of the solar industry in Norway. Two informants specified an increasing chance to work together in the future, while two other claims that their research project could be done outside the centre in the case of Solar United being shut down .

Working together in the centre brings research partners and industry partners closer together and gives them experience in large and complex collaborative projects, learning other organizations:

> *"Based on the experience we have now, I think it would be much easier to form a similar collaboration, or a continuation of this one. No matter what, if the centre is discontinued after 8 years of activity, the different industry partners will continue their collaboration with the research partners' binary projects." Andrew*

## 5.5 Innovation focus: evolution or revolution?

In this section, we first map how the different centre participants perceive innovation in the centre, and unravel what kind of innovations the different partners wish to focus on, which are: disruptive technologies, or incremental improvement of existing technologies.

The most abundant finding in relation to innovation in the centre is that the interviewees are quite uncomfortable with the term. However, all of them speak of getting an understanding of technical issues and generating research results in the shape of data or information, which matches our definition of innovation from section 2.1, actually most of our interviewees do not think innovation is a part of their activities. For instance, when asked how they work with innovation in the centre, an industry partner replied:

> *"I think innovation is a terribly difficult term. I don't know how to answer that question." Andrew*

Another replied the following on the same question, while referring to innovation as creation of new technologies:

> *"I never really had any expectations for innovation, and haven't experienced any innovation in the centre." Carl*

Summing up the interviewees' opinions on the topic, in addition to being a place for creating new relations, they want the centre to create knowledge in the shape of either competence and better understanding of fundamental problems, and/or improving their current processes, and/or developing new technology or processes. However, both industry partners and research partners have a common understanding for that the focus in the centres' innovation activities should be

creating a scientific foundation for developing innovations such as new processes and technologies:

> *"We don't work with innovation; we create the generic foundation for creating innovations" Henry*

Multiple of the research partners referred to the industry partners as their customers, as they often engage in binary projects as a result of projects in Solar United. In this respect, research partners often propose ideas for binary research projects to the industry partners. One informant pointed out that the industry partners strive to conduct as much as possible basic research within the centre in preparation for such binary projects, likely because the financial model of the centre reduces the cost of such projects:

> *"We've often had situations where we present ideas for innovation projects to the industry partners, and their response is that "this is very interesting, but let's start by conducting some of the necessary generic research in the centre first." Then, afterwards we start a binary project based on those results" Henry*

This allows the industry partners to use the competence accumulated in the research partners in binary projects outside the centre, which is "the preferred way of doing things." Regarding innovation in the form of new technologies and new companies is nonetheless said to be welcome by all the interviewees, but the dire state of the solar industry has made the centre focus extensively on strengthening existing companies rather than creating new ones:

> *"You can come up with some ingenious idea and work with it in the CEER and start a company. That is great and we should encourage it, but it is very tough if the industry is going bankrupt everywhere around you. The innovation and research results we develop in the centre should therefore be implemented in existing companies." Carl*

Though the focus in the centre is on developing competence that could be applied in existing business for the industry partners, there is also some focus on radical innovation. As mentioned in the centre description in section 4.2, the centre has a work package dedicated to developing new materials. If the centre obtains good results, these materials could pose as possible substitutes for silicon-based solar cells in the future. Though a breakthrough in this work package may greatly affect the industry in the future, only one of the largest industry partners has dedicated any time to the work package. This seems to be linked to the scope of R&D strategies in the different companies, where most of the companies have chosen a more narrow focus in their screening of new technologies.

# 6 Analysis - answering our sub-research questions

This chapter serves to answer our four sub-research questions by applying our literature review from chapter 2 to our empirical findings in chapter 5.

## 6.1 Answering sub-research question 1

> ***SRQ 1:*** *What outcomes do firms participating in Solar United expect from the collaboration, and what does the centre do to meet these expectations?*

We will in this section in order to answer this sub-research question we use theory from sections 2.2.6 and 2.3. As this SRQ consists of two parts, we will first answer the first part of the question using empirical findings outlined in section 5.1 regarding industry partners' motivations for participating in the centre. We then analyze findings from section 5.2 regarding industry partners' influence on centre activities to answer the second part of the question. We will also use outtakes from section 5.4 regarding mutual understanding between the partners in the centre, and some findings in section 5.5 regarding innovation focus in the centre to answer the second part.

### 6.1.1 Recapping the literature

The literature suggests that as organizations no longer possess all the knowledge necessary to innovate (Cohen and Levinthal 1990), implicating that they must interact in networks where they utilize diverse bodies of knowledge to enhance their innovation performance (Hislop 2005, p160). It has been found that collaborating in networks with different kinds of organizations contributes to better capabilities to absorb and utilize external knowledge (Grimpe and Kaiser 2010) which implies that research centres with partners along the entire value chain may yield a larger learning outcome for its participants**.**

Firms may participate in research centres for different reasons. Particularly, firms tend to participate in research centres to create knowledge necessary for developing innovations (Grimpe and Kaiser, 2010), to grow their network (Katz and Martin 1997) and some firms may participate solely to gain access to research government research funds (Rasiah and Govindaraju 2009). Some literature has found that large firms commonly participate more in research centres than small firms (Bayona Sáez and Huerta Arribas 2002). This may be because SMEs shun collaborations that are associated with bureaucracy, and which may require much management attention, or because they are not informed of the possibility to participate. It may also be because large firms have a stronger internal R&D capacity, enabling them to utilize external knowledge efficiently (Cohen and Levinthal 1989). Some large firms might also participate solely for keeping an eye on the state-of-the-art (Narula 2004).

### 6.1.2 Presentation and analysis of empirical findings on firms' expectations

We will now present and discuss the empirical findings most relevant to describing what outcomes firms participating in Solar United expect from the collaboration. As outlined in section 5.1, there are many reasons for the different firms' participation. Figure 5.1 sums up the main reasons and shows that there are relations between the firms' sizes, their position in the industry (i.e. core or supporting industry) and their main motivations. The large firms see the centre as a way to strengthen research communities which they may later hire for binary projects, and who they can call upon when they need to resolve issues. The smallest firms participating in the centre participate to verify their pre-commercial technologies. The research centre has provided conditions that have accelerated the technical development in these firms, as is clearly demonstrated by Jack's quote in section 5.1. Both large and small firms participate to build a larger network that includes both research partners and firms. However, some of the firms are only interested in establishing connections with the research partners that are CRTOs because of their focus on applied research.

The industry partners that belong to the supporting industry category are, as outlined in the final sections of 5.1, mainly involved to gain customer insight so they may improve their products according to customer needs. However, as their main network consists of organizations in many different industries, the centre also allows them to create much stronger bonds and relations to organizations that are peripheral in their network.

Recalling that sub-research question 1 is related to the firms' expectations, it is interesting to juxtapose the different groups' expectations to see if they interfere with one another. In this sense, firms' expectations interfere if they inhibit or weaken one another by drawing a disproportional amount of resources to some projects. We will answer this for each group of firms.

Firstly, the supporting industry partners' expectations are primarily interested in inter-firm collaboration and on networking, which are activities that require dedication from other participating firms as well. Hence, the activities supporting industry partners' expectations do not interfere with the other partners' expectations. We assume that the other firms' interest in networking will not interfere with other firm activities either.

For the large firms, the main motivation for participation in the centre is strengthening the research partners' competence in areas related their production. However, as is manifested in Henry's quote in section 5.5, the focus of the research in the centre is on creation of generic knowledge. In addition, as is shown in figure 4.3 most of the firms involved are not alone in their respective part of the value chain. Thus, when one of the research partners build competence on a particular topic, this may to some extent benefit the other firms in the same part of the value chain. We cannot see that this interferes with other firms' outcomes from the centre. In fact, a single firm was found to give an annual financial contribution without demanding any influence

on activities due to a restructuring of their organization. We see that this contribution matches the "listening post variety" described by Narula (2004) where a firm is present only to receive information on activities in the centre. Given the revenue model of the centre where a firm's contribution unlocks an additional threefold from the research partners and the NRC, this firm's participation actually enables other firm's activities in the centre.

The final category we will review is SMEs, whom mainly participate in the centre to verify their own technologies. Though this indicates that the SMEs mainly contribute to their own research, the annual reports show that they do not draw resources away from the other partners (SolarUnited 2011). Hence, we cannot find any conflicts of interest between the activities that the industry partners have initiated within the centre. Combined with the consortium agreement, which all the interviewees indicate has successfully dictated the outcome of all potential conflicts so far, we believe that all the participating industry partners may have their expectations fulfilled given successful management.

Now that we have reviewed the different firms' expectations and seen that they are not in conflict, we will compare them to the literature on why firms normally participate in research centres.

### 6.1.3 Comparison between empirical findings and literature

We will now review similarities and differences that we have found when comparing our empirical findings and our literature review. Our first findings are related to the firms' motivations. The literature states that basic research is a common motivation for participating in research centres (Grimpe and Kaiser 2010), which we can confirm for firms of all sizes in the case of Solar United.

The literature also points to networking effects as a possible motivation (Katz and Martin 1997), which we can confirm is a driving force for participation for every firm in the centre. We might specify that the participating industry partners primarily wish to establish relationships with certain other groups. More specifically, the small industry partners wish to become acquainted with the large industry partners as they all have pre-existing relations with the research partners, which they see as most relevant to them. On the other hand, large and medium size industry partners have a wider focus and wish for tighter connections with most firms and research partners. However, one industry partner explicitly pointed out that they have little interest in interacting with the universities. This indicates that the research coming from the universities is less applicable than the research from the CRTO's, which is not surprising given the CRTO's focus on user focused research.

Regarding participation for the sake of obtaining research funds (Rasiah and Govindaraju 2009), this seems to be the case for all the participating firms (except the one firm that deliberately does not influence the centre), and is a particularly important motivation for the small firms

participating as it greatly reduces their risk. We recall that the literature states that small firms often have higher R&D efficiency than large firms (Audretsch and Vivarelli 1996), which is perceived as the case for small industry partners in Solar United as well, though we do not have numerical evidence of this. This may be because the narrow scope of the small firms enables them to reach important milestones in their firms with the resources they invest. For instance, as mentioned in 5.1, one of the smaller firms in Solar United are resolving many technical issues essential to their core technology within the centre. Thus, we see that the combination of funds and competence that are available in research centres helps the small pre-competitive firms through the most risky parts of their development.

We will now compare literature to empirical findings related to the size of the participating actors. Though some literature states that most companies participating in research centres are large firms (Bayona Sáez and Huerta Arribas 2002), most of the firms participating in Solar United are SMEs. More specifically, two of the participating firms are large with more than 250 employees, five are medium size firms with between 50 and 250 employees, and the remaining three of the participating firms are micro-enterprises with less than ten employees. In the literature review in section 2.3.3 we saw that there are commonly two reasons for why SMEs do not participate in research centres, which are excessive bureaucracy and failure to communicate the centre to the SMEs (Bayona Sáez and Huerta Arribas 2002). The fact that most firms in the research centre are SMEs means that Solar United somehow have overcome these barriers. The industry partners' acquisition process outlined in section 5.1 showed that the centre management dedicated resources to recruiting industry partners by having a dedicated salesperson who properly communicated the centre to the industry partners, hence overcoming the communication barrier. We believe this process also enabled the centre to present itself in an unbureaucratic way to convince the industry partners, which largely seems to be true.

There are at least three possible reasons for why Solar United deviates from the literature on this topic. Firstly, many firms that are labour intensive also participate in research centres. The literature we have reviewed has used a large database over research centres where the participating firms are not necessarily as research intensive as the high technology firms participating in Solar United. For instance in the CEER for called Zero Emission Buildings collaborates with multiple construction contractors (ZEB 2014), which arguably are more labour intensive compared to any of the industry partners in Solar United. Such firms may have larger workforces than knowledge intensive firms, which may be a reason for why some other research centres have a larger share of large firms.

Secondly, as was stated in section 5.1, many of the interviewees pointed out Norway's unique position with steady access to energy, an educated labour force and high wages. Therefore, other countries are often more suited to conduct labour intensive production, whilst Norway is better fit to conduct specialized high margin niche work where automation may substitute for manual

labour. Hence, it may be in the nature of Norwegian industry to have a smaller share of large companies, particularly in an industry as young as the solar industry.

Thirdly, it may be that the literature is not wrong; but that the nature of research centres may have changed since Bayona Sáez and Huerta Arribas. (2002) conducted their research. We have, however struggled to find newer literature on the topic. As small firms have gained the capacity to innovate (Edwards, Delbridge et al. 2005) but must utilize external knowledge to do so (Audretsch and Vivarelli 1996), it seems natural for knowledge intensive SMEs in the contemporary knowledge society to participate in research centres where they may utilize diverse bodies of knowledge. These possible explanations does however require solid justification that exceeds the scope of this thesis.

Thus far, we have reviewed the industry partners' motivations for participating in the centre and compared them to the most common motivations in the literature. The motivations listed in the literature match Solar United well, but we have found some nuances. These nuances include that small firms primarily wish to network with large firms, and that large firms primarily use the centre as a government funded way to build competence in research institutions, which they later hire in binary projects. This constitutes our answer for *what outcomes firms participating in Solar United expect from the collaboration,* and we will now move on to present empirical findings to answer the second half of sub-research question 1: *what does the centre do to meet these expectations?*

### 6.1.4 Empirical findings on how the centre fulfill firms' expectations

As seen above, the different firms have multiple different expectations for the collaboration. In this section, we will direct extra attention to their expectations regarding knowledge creation. To answer how Solar United meets the participating firms' expectations, we will review how the industry partners influence the centres' activities and how their organizations respectively absorb knowledge created in the research centre.

#### 6.1.4.1 How industry partners influence centre activities

As presented in section 5.2, the industry partners decide the general direction of the research activities in the centre through the board. However, Arthur's quote in section 5.2 makes it evident that the centre management has the last say in many decisions, and that the board primarily makes recommendations for the direction of future research. Off course, if the centre management consequently defies the board's recommendations, then the industry partners may exit the collaboration, but this is not the case. From statements by the interviewees, e.g. Arthur's quote about the centre management's professional credibility in 5.2, we believe that there is trust between the board and the centre management, and that the industry partners believe that their expectations are realistic.

In addition to the board, the firm's influence the research topics on a project basis by suggesting projects and activities that somehow blend well with the other activities. This process seems to be unbureaucratic, and carried out in a way that the industry partners find reasonable. We have two quite different examples that describe flexibility of how research plans are decided. First, as seen in section 5.2, the company which our informant Joan represents attended work package meetings and conferences for more than half a year before they defined an activity which both fitted their R&D strategy and brought them into the network they desired. The second example shown in section 5.2, where the company represented by Jack had well defined needs even before they entered the collaboration. Thus, they could commence as soon as they joined the centre.

However, though the participating firms perceive that their most precarious activities are being carried out, they seem to be carried out over quite long periods. In the case of Jack's firm, the relevant research was carried out over a two-year period, though Jack's involvement in that period only made up a total of 4-5 months. If we recall section 5.2, we stated that there seems to be a general understanding among the industry partners that they will all get something from the centre, e.g. valuable data for their own factory process, but not necessarily all their wishes. We see that in practice, though they all may get something that they explicitly desire; they have to be prepared for not getting it right away.

If the case is that each firms only gets some of their demands carried out, then how do they justify the expensive participation in the centre? One possible answer to this question has already been outlined in section 6.1.2, as firm-specific research results are only one of many motivations for the firms. In addition we should keep in mind Gary's remark in section 5.2, which states that more than half of the activities in the centre are directly relevant to either current or future industrial solar activities. Seeing as the industry partners are financing only one quarter of the centres' budget, we see that they get quite some bang for their bucks. This implies that the industry partners actually perceive the research which Gary describes as "applicable for the future of the solar industry" as valuable. Hence, the trade-off from not getting their firm-specific activities conducted immediately is justified by other knowledge outputs and the other motivational factors listed in section 6.1.2**.**

This concludes our analysis of how the industry partners influence the research activities in the centre, and we will now focus on how the industry partners absorb the knowledge being created in the centre. We see that the industry partners absorb the knowledge in at least three different ways. We will review these methods one at a time before we compare them.

#### 6.1.4.2 How industry partners absorb knowledge from the centre

Before we outline the different ways in which the industry partners absorb knowledge, we briefly outline where the knowledge is created and accumulated. Our understanding is that knowledge is created primarily where the parties interact and carry out experiments, which is within the

research partners' facilities, the industry partners' production facilities, and to some extent the location of the general assembly. Hence, we assume that the knowledge created consists of an explicit component consisting of reports, papers, presentation documents and new computer programs, and a tacit component that accumulates within the researchers conducting the experiments, as illustrated in figure 6.1. If the results are not confidential, which may be the case e.g. if an experiment was conducted within an industry partners' facilities, the explicit component is made available for the other firms in the centre through the centres' e-room and/or by e-mail.

The transfer of tacit knowledge is much more intricate, and we have found that the different firms use different approaches to acquiring the tacit knowledge created in the centre.

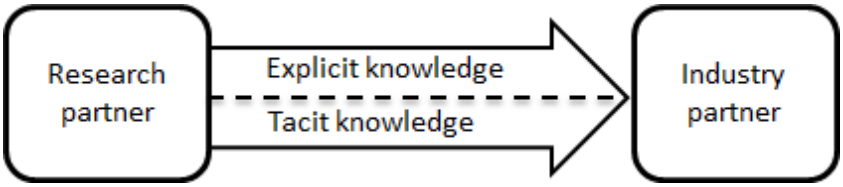



**Figure 6.1 Industry partners acquire both tacit and explicit knowledge from the research partners.**

The first way in which industry partners absorb tacit knowledge from the centre is through attending the different work package meetings, workshops and conferences arranged by Solar United. Here, researchers present and explain different results. Thus, some tacit knowledge may be transferred and explained in these settings. At least three of the participating firms, larger ones, do not participate in these meetings regularly, and they do hence assume that they are able to understand the context of the research from afar.

The second way is through active participation in the research conducted at the research partners' facilities. According to the empirical findings in section 5.1, researchers from at least four industry partners have actively participated in the centres' research at the centres' head quarter, which shows that the research centre is doing an effort to facilitate joint research at their facilities. In this way, the industry partners gain a better understanding of the conditions surrounding the research, and in addition they can influence the experiments so that they are more relevant for industry application. In this process, the industry representatives even have the potential to increase the research partners' understanding of their problems. In knowledge management terms, the tacit knowledge that provides an understanding of the context of the created knowledge is to a greater extent transferred to the industry partner through this method.

The final way that we have found that the industry partners absorb tacit knowledge is by conducting the centres' research activities internally. For instance, we might recall section 5.1 where industry partners would attempt to produce a number of their products using new equipment provided by another industry partner. In this setting, the industry partners are granted

insight that is as close to full-scale production as possible, and where they are able to absorb tacit knowledge well because the researchers will already understand the context that the machinery provides. We do not know what proportion of the research in the centre is carried out in the industry partners' facilities, but it seems about half of the medium size and large firms have used this approach.

Now that we have reviewed the three ways which firms use to acquire the tacit knowledge created in the centre, which includes attending meetings and participating in external and internal research, it is time to compare this with theory on knowledge external knowledge acquisition. Provided the taxonomy we presented in section 2.2.6.2, we see that the two latter ways of absorbing tacit knowledge are categorized as R&D collaborations. Conversely, if a firm only absorbs knowledge through the explicit knowledge component and the tacit knowledge transferred by presentations, it would be categorized as R&D outsourcing. From our literature review in section 2.2.6.3 we recall that it is a firm's internal R&D capacity and experience from other research collaborations which is determining for their ability to absorb external knowledge. From our empirical findings in 5.4, it is evident that at least two of the largest firms in the centre almost exclusively only receive the explicit knowledge component, as they rarely are able to participate in the centres' physical meetings. Still, they perceive the knowledge that they obtain as valuable. As these are large firms with strong internal R&D capabilities and several collaborative experience, this confirms the theories reviewed in the literature regarding external knowledge acquisition, and we have summarized this finding in figure 6.2.

Conversely, the small firms collaborate actively and intimately with the research partners. This is both due to their financial resources, which forces them to contribute in kind. This does however enable them to partake actively in the research, and we see that this supports Edwards et al. (2005) who state that small firms create knowledge through interacting in networks. This also supports the findings in figure 6.2 below.

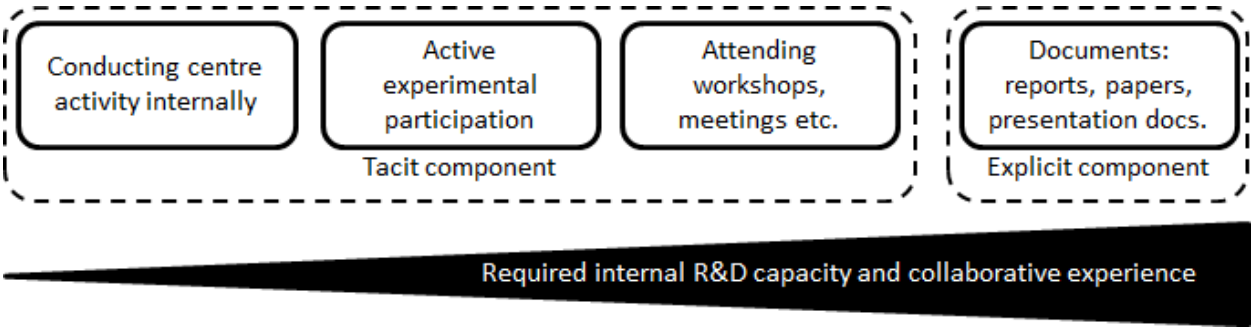



**Figure 6.2 Correlation between a firm's method of acquiring tacit knowledge and the two main factors influencing external knowledge absorption, which are the level of internal R&D capacity and previous collaborative experience. Lower levels of these factors require the firms to partake more actively in the research to absorb the tacit knowledge which is created.**

As most of the firms in Solar United are likely to benefit from absorbing the tacit knowledge component from the conducted research, it would seem advisable for the research partners to make the threshold for collaborative research as low as possible. We have found that multiple firms have been enabled to work collaboratively at the facilities of multiple research partners, and that some of the industry partners have carried out the research that is most central to them in their own facilities. Still, when asked how they acquire knowledge from the collaboration, most of the industry partners replied that it is primarily through meetings and emails. We believe that if the centre took measures to more active collaboration, for instance through dedicated work spaces, that the industry partners might create gain an even greater insight into the findings in the centre and a better common understanding with the research partners.

This concludes our assessment of the firms' expectations for the collaboration and the centres' effort to meet these expectations. In sum, we see that the research partners have different expectations, which include networking, generic knowledge creation, verification of their respective technologies and technical customer insight. We have seen that the process for defining research topics is unbureaucratic and that the different partners use different measures for carrying out collaborative research. Some of the industry partners have the research partners conduct relevant research on their own, while others participate more actively either in their own facilities or at the research partners' facilities. Different partners absorb the knowledge created in the centre in different ways, and these ways largely reflect these firms' capacity for absorbing external knowledge.

In the next section, we will look into how the firms in the research centre cope with the lack of geographical proximity with different types of proximity.

## 6.2 Answering sub-research question 2

> ***SRQ2****: How do firms cope with lack of geographical proximity when collaborating with other organizations in Solar United?*

This sub-research question relates to all four dimensions of proximity reviewed in section 2.4. To answer the above sub-research question, we therefore analyse our findings related to one dimension of proximity at a time, starting with geographical proximity. For each dimension, we first recap the relevant theory presented in section 2.4. We then apply this theory to analyse empirical findings related to this dimension from sections 5.1 on firms' motivations for participation, 5.3 on communication and ICTs, and 5.4 on mutual understanding.

### 6.2.1 Recapping the literature on geographical proximity

Face-to-face contact between personnel, which fosters knowledge transfer and innovation (Knoben and Oerlemans 2006), is practically difficult when partnering organizations in a research centre are not in close geographical proximity. The larger the geographical distance

between involved partners, the more difficult it is to transfer tacit and codified knowledge that a research partners, for instance other parties in a research centre, produces (Howells 2002, Boschma 2005). An alternative to geographical proximity is *temporary geographic proximity*, e.g. meetings, short visits, conferences and temporary co-location. This implies that partners do not need to be in constant geographical proximity when collaborating, since temporary proximity could be used to build other forms of proximity such as organizational, cognitive and social proximity (Boschma 2005).

#### 6.2.1.1 Presentation of empirical findings on geographical proximity

As shown in the empirical findings in 5.3, the industry and research partners involved in Solar United are geographically spread over such distances that meetings requires pre-planned visits, meaning it is unfeasible for the partners to meet face-to-face more often than they do today. The most common used meeting arenas are the work package meetings, which are arranged twice a year for each work package. There is also a yearly conference where all industry and research partners are asked to present their findings and results from the past year.

We have found that all of the industry partners view face-to-face meetings such as workshops and seminars to be a superior way of sharing knowledge, hence, the meeting activity is not seen as frequent. However, the industry partners seem to be the limiting party because they are already putting in quite some resources in terms of in-kind and capital. Recalling section 5.4 on relations and mutual understanding, we see that the research partners are responsible for arranging the WP-meetings. Even today, the research partners find it difficult to arrange the current number of WP-meetings due to the industry partners' tight schedules and limited flexibility. This forces the involved partners to have intense meetings, which has a negative effect on the knowledge transfer process between the partners. It also limits and even jeopardizes the new knowledge acquired by the industry partners at these meeting.

We have also found that if an industry partner for some reason is not able to attend a planned meeting, this partner will most probably not meet the rest of the work package until the next meeting or conference. Though summaries from the meetings are made available, in addition they have an e-room where documents like presentation slides and reports are supposed to be made available. As seen in section 5.3, most informants do not view distribution of documents as sufficient to stay up-to-date on the progress in the centre.

It seems that the involved partners would benefit from meeting more often, because it reduces the risk of missing meetings and hence tacit knowledge for the industry partner. We also believe they would benefit from more follow-up because it can make knowledge transfer less difficult by transferring knowledge with more iterations and in smaller bulks.

The empirical findings in 5.4 also show there are some working spaces available at the centre's main offices at IFE, which we know have been used by four of the industry partners while they

were conducting experiments at IFE. We see this as positive because it contributes to building relationships across organizations. However, this statement came from one of the research partners, while none of the industry partners mentioned these working spaces. In fact, one of the industry partners that supposedly had conducted their experiments at IFE could not recall this ever happening. Thus, given the potential benefits of collaborative R&D, this commodity might not be as well communicated to the industry partners as it potentially could have been. Such collaborative research spaces might lead to the partners getting a better understanding of each other's work practices. In addition, it may enable them to share transfer tacit knowledge by working together face-to-face and in the same research labs. We thus believe that such interaction is underestimated at Solar United.

We have now presented our findings relating to geographical proximity, and will now analyze these findings using theory from section 2.4.2.

#### 6.2.1.2 Analyzing of empirical findings on geographical proximity

The empirical findings show few arenas where the involved parties have geographical proximity, can transfer knowledge and build other forms of proximity, as the different arenas are not frequently arranged. Both industry partners and research partners seems to think that the industry partners are limiting the meeting frequency due to difficulties of prioritizing the meetings. The current amount of face-to-face time may be seen as sufficient as these sessions are supplied with follow by email and phone calls. This shows that there is organizational and social proximity has been built up from the temporary geographic proximity of the meetings (Boschma 2005). As these dimensions of proximity have emerged through initial meetings, there is no longer a need for as much geographical proximity in the centre, which matches literature on the topic (Rallet and Torre 1999). However, the literature consistently claims that face-to-face interaction is a superior way to transfer tacit knowledge (Hislop 2005), which matches the impressions of the industry partners. Thus, the centre should strive to maintain a fair amount of physical meetings.

### 6.2.2 Recapping the literature on organizational proximity

Complex knowledge transfer requires strong organizational such as organizational proximity because efficient collaboration requires feedback between the parties. This form of proximity can to a certain degree substitute for the lack of geographical proximity, for instance by applying strong control mechanisms in order to ensure ownership rights (IPR) and sufficient rewards for own investments (Boschma 2005).

Organizational proximity occurs through shared relationships between organizations, built by collaborating over time. This also indicates that it is more likely to initiate new collaboration with parties who have previously worked together, since they already have a mutual understanding (D'Este, Guy et al. 2012). Organizations that join a research centre should be prepared to invest resources into building organizational proximity, and the beginning of the

collaboration should be seen as learning and preparation for the collaboration rather than failure if things do not work as expected (Boschma 2005).

#### 6.2.2.1 Presentation of empirical findings on organizational proximity

Empirical findings in 5.1 and 5.4 showed that all of the industry partners except one have had binary research projects outside the centre with three of the research partners, including both CRTOs and one of the universities. Because of these past and present binary projects, there are organizational and social relationships built between the different organizations, which explains why these firms were asked to join Solar United.

Given that Solar United must attend the interest of all its' partners, it is not surprising that the partners spent much time formalizing their relationship through the consortium agreement. The routines, rules and organization of Solar United this provided a formalization which safeguarded their interests. After this slow start, the partners' attendance in the centre has normalized to attending meetings and follow-up by mail and phone. This normalization could be explained by trust-building and organizational co-experience from working together over time, including that from previous projects. The normalization may also explain why the industry partners do not prioritize more meetings, as they perceive some kind of togetherness between them and the research partners even though they are working over geographical distances.

Collaboration between the organizations in the research centre increases the chances for future collaborations, specified by two of the industry partners. In addition, the empirical findings in 5.4 show that two other industry partners claim that the research they conduct in Solar United could have been conducted in binary projects with one of the research partners if it were not for the research centre. Thus, the centre too enables close organizational collaboration in a way that does not require much follow up compared to a binary project.

#### 6.2.2.2 Analysing of empirical findings on geographical proximity

Because of organizational proximity between the industry partners and the two CRTOs from previous collaborations, their participation requires less follow-up than if it was the first time a firm and research institution collaborated. This initial organizational proximity was created before the start of the centre, is the result of an increase in shared relationships and mutual understanding. We hence confirm the literature, which states that pre-existing relations facilitate easier collaboration between the involved partners (D'Este, Guy et al. 2012).

Though there was organizational proximity between the involved partners prior to the establishment of Solar United, literature suggests that improving such proximity in a new project takes time (Boschma, 2005). This explains why it took as much as half a year to make the consortium agreement for Solar United, and makes sense, as there was no particular relation between most of the firms in the centre at that time. The consortium agreement made the organizational proximity stronger, and is a practical example how higher organizational

proximity can be obtained. This process even resembles the control mechanisms mentioned in the literature (Boschma 2005).

We have also found other phenomena, which point to the development of strong organizational proximity in Solar United. The regular attendance in the work package meetings show that industry partners are willing to adapting to Solar United´s organizational routines and share knowledge, demonstrating their wish for progression in their research projects, and that trust have been built between the involved partners. These are typical traits of collaborations with high organizational proximity (Boschma 2005).

The literature indicates that organizational proximity generates a capacity to combine information and knowledge from the collaborating parties, and to transfer tacit knowledge and other non-standardized resources between collaborating parties (Burmeister and Colletis-Wahl 1997 as cited by Boschma 2005). The collaborative projects described in 5.2 demonstrate this kind of combination of knowledge over large distances, and we therefore believe that organizational proximity has substituted some of the lacking geographical proximity between the partners in Solar United.

This concludes our assessment of organizational proximity in Solar United. The following section assesses cognitive proximity between the parties in the centre.

### 6.2.3 Recapping the literature on cognitive proximity

This section overlaps to some degree with section 6.4, as cognitive proximity will be discussed as a variable for knowledge integration. However, both sections include important findings regarding distribution of knowledge in the centre, and how this affects the collaboration between the involved partners. We will now present the most relevant theory regarding cognitive proximity presented in our literature review.

Cognitive proximity implies that organizations which have overlapping knowledge bases and expertise may learn from each other. It may to some extent seem reasonable to consider cognitive proximity as a part of organizational proximity, as sharing routines, cultures, values and norms may be viewed as an organization's knowledge base (Boschman 2005). Like organizational proximity, cognitive proximity is also seen as necessary to communicate and transfer knowledge between partners, and may also substitute geographical proximity in combination with other dimensions of proximity (D´Este, Guy et al. 2012, Knoben and Oerlemans 2006). To have a creative and productive collaboration, the partners in a research collaboration should not have too similar nor too different knowledge bases (Knoben and Oerlemans 2006), and should thus have a moderate level of cognitive proximity, as some cognitive distance increases the potential for learning (Boschma 2005).

#### 6.2.3.1 Presentation of empirical findings on cognitive proximity

The organizations involved in Solar United have different specializations, but still possess quite similar knowledge bases due to the specificity of knowledge required to compete in the solar industry. This cognitive proximity between the partners was one of the main reason of why these specific organizations became involved in the centre.

We have found that these cognitive similarities seem to support researchers when there is a geographical distance between the involved partners. For instance, one of the research partners states in section 5.4 that the people involved in the centre are competent which allows them to understand each other well. The industry partners perceive these cognitive similarities to be a prerequisite for collaborating productively, particularly since most of the work is conducted at different geographical locations. On the project level of collaboration, the researchers must work independently to codify and document the newly created knowledge in such a way, that this could be presented and transferred efficiently at the work package meetings. Cognitive proximity is a prerequisite to understanding the meaning of such codified documents, but is not necessarily a sufficient condition to understand such documents on their own, as a tacit knowledge component is not present in such documents. This component is however, transferred to some extent through the presentations at the work package meetings.

Thus far, we have provided a picture of cognitive similarity between the research partners and industry partners, but this is not the whole picture. Cognitive similarities are less than moderate within specific topics where the research partners lack insight, stated by multiple informants in section 5.4. Primarily this concerns specialized knowledge related to large-scale production, as the majority of the personnel from research partners have had no or limited work experience outside the academics. Their experience is often limited to experiments on industrial equipment in labs, in addition to experiments on industrial standard materials provided by firms. The lack of insight into the practical aspects of large-scale production may limits the applicability of the researchers' findings. This implies a need for more involvement of researchers at industry partners´ production facilities, in order to tighten the gap between experiments and large-scale production.

Our findings show that though some industry partners invite the research partners to their factories to bridge this gap, some research partners perceive the industry partners as private in the sense that they do not share all the information that the research partners require to conduct their research. These conflicting views indicate that the cognitive proximity between the partners is below optimal, which we will analyse in a more theoretical manner in the following section.

#### 6.2.3.2 Analysing of empirical findings on cognitive proximity

The level of cognitive proximity between the involved partners seems to have been an important motivational factor in the establishment of Solar United. The diversity of knowledge in the centre spans the entire value chain, providing a sufficiently large potential for learning (Boschma

2005). It seems that the level of cognitive proximity has laid a foundation for other dimensions of proximity to substitute for the lack of geographical proximity (D´Este, Guy et al. 2012, Knoben and Oerlemans 2006) in periods between meetings**.**

Though the level of cognitive proximity is overall somewhere just below moderate in the centre, we see a clear trend in that the research partners that are CRTOs, have a more optimal cognitive proximity to the industry partners than the universities. This is evident in that some of the industry partners do explicitly not engage in collaboration with the universities. The difference between the CRTOs and universities is their experience with applied research and thus industry relevant knowledge, which is not unexpected as they conduct contract based research. The difference between these organizational types illustrated in figure 6.3.

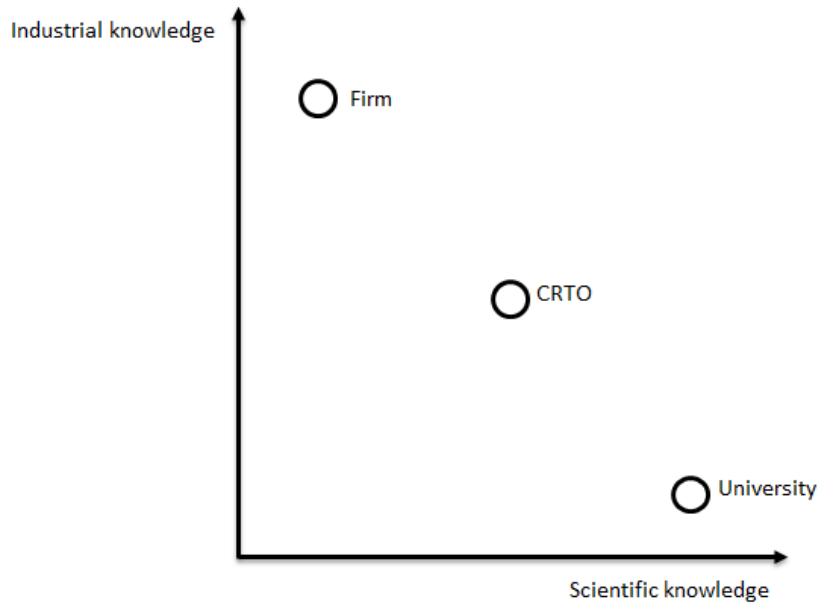



**Figure 6.3 Different kinds of organizations and their relative levels of scientific and industrial knowledge.**

### 6.2.3.1 Presentation of empirical findings on social proximity

As shown in the empirical findings in 5.1, all the industry partners except one have had past binary projects with at least one of the two CRTOs in Solar United. At least three firms have also collaborated with one of the universities prior to the establishment of the centre. This has lead to the development of social relations between the involved individuals in the organizations. Some of the firm representatives from the binary projects continued to represent the firms when they joined the centre, allowing them to utilize their pre-existing relations.

Both the research partners and industry partners perceived that existing social relations made picking up the phone or writing an email easier. This may be because their relation makes it more easy for the parties to understand each other's tones and moods, so that the words they

exchange. For instance, one of the informants seemed almost aggressive in his interview, but the other informants as if this was simply his way of being. Thus, the pre-existing relations allow the contact persons to understand their conversations as more than words.

Out informants hence perceived such relations as necessary to truly understand each other, both in formal meetings and informal follow conversations. In sum, social relations make it easier to communicate remotely by substituting face-to-face interaction to some extent. However, all our informants perceive physical meetings as important to allow flow of information about projects.

The informal arenas were appointed as the most important by the informants, is it allows them to discuss "of the job" topics. Our interviewees perceive these settings as valuable because they create connections between individuals to a much greater extent than the formal meetings. Particularly, the annual conference allows for much informal conversation as it allows industry and research partners to socialize and mingle between and after the conference sessions. Specifically, lunches, dinners and conversations at the bar were arenas with low thresholds for informal conversation. These informal settings are also arranged in connection to board meetings and work package meetings, where the list of participants is limited to those the firms formally collaborate with in the centre.

The appreciation that the informants expressed towards these events, indicates that it might be beneficial to arrange more of them. Events might include team-building workshops combined with cabin trips, or just informal social networks events, which the parties are urged, but not obliged to attend. Alternatively, the centre might utilize the current meetings even more by implementing some kind of social event at each formal meeting. These types of events would strengthen relationship between attendees, and at the same time provide arenas for those who seek more contact with the other involved partners. This is relevant because at least one of the smallest industry partners in the centre emphasizes networking as the most valuable outcome for their participation, as it provides opportunities for new business by creating relations to key individuals in other organizations.

Now that we have discussed the practical aspects of social proximity in the centre, we will compare the findings related to social proximity to the literature.

#### 6.2.4.2 Analysing of empirical findings on social proximity

Empirical findings show that social proximity has been developed through past collaborations with the two CRTOs and one of the universities. Thus, social proximity has been a foundation for creating new formal collaborations (Steinmo and Rasmussen 2013).

Recalling that the sub-research question concerns how firms cope with lack of geographical proximity, we see that social proximity has been developed through temporary geographical proximity at meetings. Those social arenas have led to relations, which allow the involved individuals to understand each other well without the presence of geographical proximity, and

have thus boosted the transfer of tacit knowledge (Boschma 2005, Balland 2012). Thus, our empirical findings indicate that knowledge diffuses between organizations more easily with high levels of social proximity (Boschma and Frenken 2009). However, our informants request more of these context, which may either indicate a need for better mutual understanding, or perhaps just a simple desire for more social interaction. Either way, we recommend that Solar United provide such informal arenas to further unite the community.

The empirical findings also show that the smaller industry partners use Solar United to gain access to key individuals from other industry partners by socializing. This has led to new businesses for these firms, implying that social proximity has led to innovative networks as the literature suggests (Oerlemans and Meeus 2005).

This section has discussed how social proximity has developed and substituted geographical proximity in Solar United. As social proximity was the fourth and last dimension that we were applying, we will now discuss the findings on proximity and how they interact.

### 6.2.5 Summarizing an answer

We have found that Solar United and its partners cope with lack of geographical proximity by using temporary geographical proximity, which has allowed them to develop organizational and social proximity. Most of the firms had collaborated with at least one of the research partners prior to the collaboration, indicating some social proximity and organizational proximity, which allowed the centre to initiate in a smoother manner than if there were no prior relations. Through meetings and events, the different partners who did not have prior relations have developed social proximity, particularly with those who participate in the same arenas. There are

Organizational proximity, on the other hand, has developed through the creation of the consortium, but has also developed through collaboration in the centre. There is, however, room for implementing stronger rules and routines regarding the centres e-room, which will be further discussed in section 6.3. Stronger digital infrastructure will provide even stronger organizational proximity between the partners in the centre.

Regarding cognitive proximity, this was largely present prior to the initiation of the centre. However, there is room for improvement, as it seems the level of cognitive proximity is less than optimal between research partners and industry partners. Particularly, the distance is large between universities and industry partners, which has lead us to the conclusion that it is most convenient for the centre to develop more cognitive proximity between industry partners and the CRTOs.

In sum, we believe the lack of geographical proximity is manageble, but that measures relating to better digital infrastructure, more social arenas, and more practical experience in production for the researchers will further improve the collaboration. Thus, we largely agree with the theory on this topic, as other kinds of proximity have reduced the need for geographic proximity (Steinmo

and Rasmussen 2013, Rallet and Torre 1999). This concludes our answer to sub-research question 2, and we will now go on to answer sub-research question 3 on how ICTs affect collaboration in the centre.

## 6.3 Answering sub-research question 3

> ***SRQ3****: How do ICTs facilitate the collaboration between individuals in Solar United, and how do ICTs facilitate organizational learning?*

This research question is practically quite important to Solar United due to the geographical spread of the partners in the centre. In order to answer this sub-research question we will start with a short review from chapter 2.2.5, before we review the empirical findings 5.3 and 5.4. We end this subchapter by answering the sub-research question through comparing our findings to the literature.

### 6.3.1 Recapping the literature

ICTs can help facilitate knowledge sharing and organizational learning in research centres when scientists cannot be collocated (Sonnenwald 2007). In this context, ICTs may improve coordination, communication and management across sites (Howells 1995), which further may facilitate knowledge creation and organizational learning for involved parties. The most frequently used ICTs to support research collaborations are e-mail, instant messaging, video conferencing, telephones, and shared data repositories (Sonnenwald 2007), illustrating a wide variety of tools for partners in research centres to apply when collaboration over geographical distances.

The different ICT-tools have different levels of information richness (Hislop 2005 p112), meaning that some tools are better than others regarding transfer or knowledge are. For instance, video conferences are richer than emails, as social cues that are transferred by video and audio can be lost when the information is converted to a written form (Ngwenyama and Lee 1997 p147).

Applying ICTs is not completely unproblematic, as removal of social cues and such means that the knowledge at hand loses some, or all of its tacit knowledge component (Hislop 2002). However, different conditions may contribute to efficient use of ICTs. For instance, ICTs can supply rich forms of communication in collaborations where ICTs are combined with face-to-face interactions (Nandhakumar 1999, Maznevski and Chudoba 1999). Others have found that the following factors are related to successful use of ICTs (Rogers 1995):

- ICTs should provide benefits over current practices for the users.
- ICT should be compatible with the users' values, experiences and needs.
- ICTs should be easy to try out and to use.

The different factors imply that the users of the ICT must make an effort to implement, adapt, learn and make good workflows for ICTs if the implementation is to be successful. For instance, training of personnel and creation of strategic guidelines for the use of ICTs may be a necessity.

In the following section we will present empirical findings from sections 5.3 and 5.4. These findings will be analyzed in section 6.3.3 with the above theory.

### 6.3.2 Presentation and analysis of empirical findings

The empirical findings in 5.4 shows that the geographical spread between the partners makes it difficult to meet face-to-face as frequently as desired. Some ICTs can substitute for this lack of proximity. For instance, we found that some follow-up meetings in each work were arranged as phone conferences. In 6.2.4, we argued that such non-physical communication may be carried out efficiently because of pre-existing social relations between individuals**.**

We have found that there are multiple areas of use for the different ICTs. The most common is emails and phone calls. The threshold for engaging in informal communications seem to be low as there is quite a lot of spontaneous follow-up communication by phone and emails between individuals from all partners in the time slots between physical meetings. As for shared repository systems, all of the partners have gained access to a digital repository referred to as the "e-room". The e-room contains presentations, research reports, papers and other documents that are uploaded and made accessible by the partners who may have interest of theses. The board members in Solar United's also use the e-room to censor results they wish to keep confidential.

The e-room theoretically works as a hub for information and knowledge sharing, and could potentially enable organizational learning for the involved partners. However, table 5.2 discloses that the e-room is not actively used by most partners in the centre, and is even unknown to some of the partners. The table shows that five informants think that the e-room functions well, though these informants are also the people with the best conditions for understanding the context of the e-rooms content through their active involvement in the centre. For instance, these informants have positions at the board or administrative posts in the research centre. The remaining 11 informants who had an opinion about the e-room, where of nine were industry representatives, had either not used the e-room or did not think it functioned well as a tool for sharing knowledge. Either this was due to lack of content of the e-room or that the informant did not have access to the e-room at all. This either implies that the industry partners have not gotten the right training for using the e-room, or that the e-room is formed in a way which is too complicated or cumbersome to learn how to use. It could also be that the industry partners have less interest in the data from the e-room, and do either not see it as vital for getting something out of the collaboration. It may also be that they do not have the tacit knowledge to understand the context of the explicit data in the e-room, as they had not been as involved in the centre as the informants who thought the e-room functioned well.

In addition, none of the interviewees had applied video conferences in the centre, which can be regarded as the ICT that is most similar to physical meetings, as participants can see each other. This is peculiar, as all the informants perceive face-to-face interaction in physical meetings as the most important form of communication. The interviewees particularly mentioned discussions about the continuation of current research as difficult through any ICT, and thus prefer to have such discussions in person. As there is surely need for such discussions in between the semi-annual work package meetings, we see that video conferences may provide a useful tool for follow-up discussions in between the regular meetings.

These findings will now be discussed, and compared to the literature on ICTs.

### 6.3.3 Comparison between empirical findings and literature

The empirical findings show that the most frequently used ICTs in Solar United are email and phone in addition to the shared data repository referred to as the e-room. These are all ICTs which are typical for research collaborations (Sonnenwald 2007). Phone and email can be seen as *active* ICTs as the individuals calling or emailing initiate contact in expectancy of response with the recipient, whilst the e-room is a *passive* ICT where individuals can share and access documents such as presentation, reports and papers. These ICTs seem to improve coordination in the centre, which matches the literature (Howells 1995), but that there is great potential for improving flow of knowledge through improving the e-room.

We have previously stated that emails and phone conference are being used to in between work package meetings. The informants perceive this as an efficient way to follow up in such projects. In these meetings, the topics are strongly related to topics already discussed in physical meetings, and we thus find that communication through ICTs indeed can be efficient if combined with face-to-face meetings (McLoughlin and Jackson 2002).

Regarding video conferences, we have not found any evidence of use of this kind of communication. Given the value that the interviewees have expressed towards physical meetings, we suggest that video conferences may improve the information richness of communication between work package meetings (Hislop 2005 p112).

We have thus far discussed the active forms of communication, and move on to discuss the passive form of ICT aided communication in the centre, namely the e-room. Such data-platforms are most often utilized to facilitate knowledge sharing and organizational learning for collocated partners (Sonnenwald, 2007). Officially, this is the function of the e-room, but it is not true in practice. Recalling table 5.2, the empirical findings show that the majority of the industry partners are either not using it or are not pleased with how it works, which we find alarming.

Recalling Rogers´ three criteria for successful use of ICTs (1995), we see that the e-room does not meet these demands:

- The e-room fails in being *easy to try out and use*, as there seems to be a high threshold for starting to use the e-room. Several industry partners do not know where to find it or that it even exists. Board members and administrator who claim they are pleased with the current solution have to learned to use the e-room in order to monitor and censor content, and some have even used the same system in other collaborations. Thus, they perceive the system as simple and expect others to have the same perception.
- The e-room fails to *provide benefits over current practices for the users*, as the majority of the potential users from the industry partners for several reason are not using it or do not think it works well. Some interviewees even used email consequently instead of the e-room as they thought it was a hassle. Thus, either the system should be redesigned to be simpler to use, or the users should be given sufficient training for using it.
- The e-room satisfies the criteria of *being compatible with researchers' values, experiences, and needs* to some extent, as only some of the research partners who have commented on the system find it compatible with their expectations.

In sum, we see that the e-room does not facilitate organizational learning to the extent that it potentially could. This would require that the industry partners used it and perceived it as a source of information. Some of the research partners also support this view, as is evident in table 5.2. The fact that only informants who are or have been heavily involved in the centre perceive the e-room as useful indicates a lack of tacit knowledge, which provides a holistic understanding of the content of the e-room. Thus, as ICTs fail to convey tacit knowledge, individuals who do not have sufficient understanding of the context of the e-room's content may not use it as a rich source of knowledge (Hislop 2002).

Now that we have compared our findings to the literature, we will sum up and answer our third sub-research question.

### 6.3.4 Summarizing an answer

We answer the two halves of this sub-research question one at a time, starting with how *ICTs facilitate the collaboration between individuals in Solar United.* We have found that individuals in the centre mainly use emails, phone calls and phone conferences as ICTs to facilitate the progress of their collaboration. These ICTs efficiently facilitate progress, as the different parties have already met and discussed the issues at hand in person. Thus, physical meetings enable them to use communication technologies efficiently. In order to improve collaboration between individuals, we suggest that video conferences should be considered as a more information rich substitute for phone conference.

We will now answer the second part of sub-research question 3, which regards *how ICTs facilitate organizational learning.* The e-room is intended as a platform, which enables all organizational members access to information that they need, thus contributing to organizational learning. However, our above analysis shows that the e-room largely fails to function in this

fashion, as it fails to meet Rogers' three criteria for successful ICTs. The short answer to the above question is thus that *ICTs do not facilitate organizational learning.*

In order to improve the use and quality of the e-room, the administration at Solar United should take action by dedicating resources to further development of the system as well as training for the users. This will allow the involved partners to adapt their workflows so that they more strongly embrace the repository system. The administration should make guidelines and routines for how the e-room should be used, making the data more attractive and valuable for those who wish to access it.

By executing the measures outlined in the above sections, we believe that communication between researchers in the centre will further improve and there will increasing organizational learning. The use of ICTs to aid communication in the centre is summarized in figure 6.4.

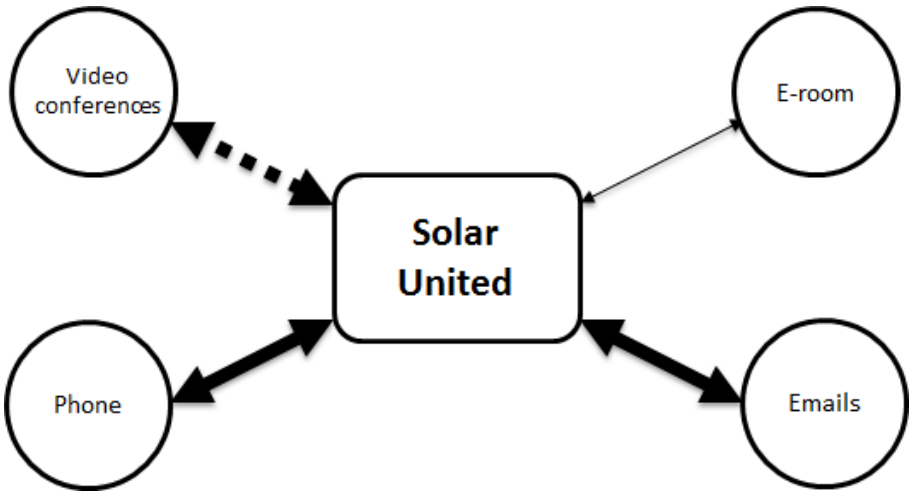



**Figure 6.4 The research centre and different kinds of ICTs that facilitate communication in the centre. Thicker lines represent more frequent use, and stippled lines represent potential use.**

We now move on to answering our fourth and final sub-research question.

## 6.4 Answering sub-research question 4

> ***SRQ4****: How is specialized knowledge from research institutions and firms integrated in Solar United?*

In this section we will answer the above sub-research question by discussing how the centre integrates knowledge and assess the centres' preconditions for knowledge integration. We will first briefly review the theory presented in section 2.2.4 on knowledge integration before we discuss management's influence on knowledge integration and mechanisms used to integrate

knowledge across locations, respectively. We will also apply some of the discussion from 6.2 on proximity and 6.3 on ICTs to provide new perspectives on the subject at hand.

The term knowledge integration is concerned with understanding the problem of coordinating highly specialized knowledge (Postrel 2002) and how differentiated knowledge can be effectively integrated in economic activities (Grant 1996, Roberts 2007**)** such as technological firms. Successful knowledge integration is associated with effective strategic response to fluctuations in the market (Lessard and Zaheer 1996) and enhanced product performance (Marsh and Stock 2006).

Knowledge integration has been described through three different processes which are to some extent complementary (Tell 2011): sharing or transferring knowledge, use of similar or related knowledge, and combination of specialized, differentiated but complementary knowledge. We are mainly interested in the latter, as knowledge integration should not allow an organization to necessarily transfer all knowledge from one unit to another in order to utilize it.

Grant (1996) provides a framework of mechanisms for integrating specialized knowledge, including rules, sequencing, routines and group problem solving. He also states that a common knowledge base is the most important prerequisite for efficient knowledge integration, where common knowledge might include language, numerical understanding, specialized knowledge, shared meaning, and recognition of different knowledge domains. These mechanisms and facilitating factors provide a framework, which we will apply later in this section.

### 6.4.1 Management's influence on knowledge integration

This section serves the purpose of evaluating whether the centre management provides good preconditions for integrating knowledge within the centre. We use empirical findings described in section 5.2 on firm influence and inputs, and 5.3 on communication.

There is a very small group of people who coordinate the research activities in the centre. As seen in section 5.2, the board sets the direction of the research activities, and the centre management consisting of the centre leader and work package leaders coordinate the activities. The industry partners seem to think that management has a holistic overview of the centre activities, which is evident in Joan's quote in section 5.2.

We might recall that one of the preconditions for successful knowledge integration is recognition of the knowledge residing in the different actors in the centre (Grant 1996). In section 2.2.4.2 we questioned whether the centre management might have this overview. The above section supports that centre management collectively has a firm overview, which allows them to connect and coordinate specialized knowledge within the centre.

In section 2.2.4.2, we also questioned whether the centre management had a holistic overview over the firms' knowledge base. Though there are many reasons for the firms to participate in the

centre, one of the most important is, as seen in 6.1, to utilize the research partners' diverse knowledge base. Thus, if the research partners are to coordinate the research centre to create knowledge relevant for the industry partners, they first need a good overview of the industry partners' potential contributions as well as an understanding of what results are valuable for the firms. We do believe this is the process described by Joan in section 5.2, where she states that her participation in meetings, workshops and conferences, gradually developed a mutual understanding between her and the other participants of what her firm needed and could contribute. The physical meetings were hence instrumental for the different parties to gain this recognition of mutual knowledge bases.

This process of gaining recognition of other centre participants' knowledge bases developed through the initiation of the collaboration, which if we recall section 6.2, is the same time in which they developed organizational and social proximity. Formal indoctrination into the centre happened prior to the development of this insight of each other's knowledge bases, and the correlation does thus seem strongest with social proximity. How do these insights develop in tandem? Does the one cause the other? These questions will now be discussed.

Recalling 6.2, social proximity develops through creating trust, friendship and common experience (Boschma, 2005), which enable the different parties to more easily transfer tacit knowledge. Recognition of individual knowledge domains, on the other hand, means having an understanding of other parties knowledge bases, which includes some understanding of both their tacit and explicit knowledge bases. If the research partners do not have the prerequisites to receive tacit knowledge from the industry partners, such as social proximity, then they may not understand the tacit knowledge embedded in the research partners. Thus, the research partners' individuals gain a better understanding of the industry partners' knowledge bases *after* they develop social proximity. This would imply that if a firm already had social proximity to the knowledge integrators at the centre (i.e. management) that they would more quickly outline the needs and possible inputs of the firm. We can put this implication to the test, and recall that Jack's firm joined and quickly defined their activities and inputs. Jack was acquainted with the research centre and many employees at the different research partners prior to joining Solar United. Thus, this particular example supports that social proximity facilitates a quick understanding of the industry partners' needs and knowledge bases.

Summing up the above sections, we believe that the centre management has a good overview of the knowledge embedded in the centre, giving them good conditions for integrating the knowledge in the centre. They also seem to develop recognition of the research partners' knowledge bases through the initiation of their partnerships. We argue that as social proximity develops between the individuals from involved partners, that the research partners become better fit to understand the industry partners' needs and knowledge bases. Thus, firms with pre-existing relations to the centre may more quickly plan and execute activities within the centre

than firms who first must develop social proximity to those who coordinate the research in the centre.

We will now direct our attention away from the preconditions for knowledge integration and over to the mechanisms used to integrate knowledge in the centre.

### 6.4.2 Integrating knowledge between remote locations

In this section, we will assess the difficulties of integrating knowledge given that the different organizations are spread over a large geographic area. We will first provide an overview of our on how this integration is carried out, by presenting findings from sections 5.2-5.4. We then analyze this by using a framework consisting of Grant's mechanisms and factors facilitating successful integration.

Regarding the arenas where the industry partners and research partners collaborate, we speculated in section 2.4.6 that sequencing may be applied as a mechanism for integrating knowledge. However, we have not found *any* evidence of sequencing, and as was illustrated in figure 2.2, it seems that the research is carried out either by research partners in their facilities or in the industry partners facilities.

Some of the research is, however, more collaborative than this in the sense that researchers from both industry partners and research partners work together in the same laboratory facilities. This has been done by at least four firms in periods of a few weeks at a time, according to Gary's statement in section 5.2. Most of the research is thus, carried out "uncollaboratively" in the sense that only one research partner conducts the research on behalf of the centre, which was described by Arthur in section 5.1. In this context, the knowledge of the industry partners is to a much lesser extent involved in the collaboration, and the potential for knowledge integration is thus much smaller and less interesting.

Regarding interorganizational communication, the partners mainly use direct communication through phone calls and emails to coordinate their research activities, as was described in section 5.3. However, some of the industry partners wish a larger proportion of communication did not require direct communication, because it makes the parties more dependent of each other. An example of this view, demonstrated by the fourth quote in table 5.2**,** where an informant suggests that a more systematic use of the e-room would allow him to keep up-to-date and follow other projects more easily. The last quotes in table 5.2 show that the research partner's believe a stronger routine regarding the e-room could improve the collaboration in general**.**

The fact that the research partners and industry partners rarely co-localize in their research activities means that the different parties are dependent of each other's common understanding of the context of the research. The research partners' understanding is, however, not always as good as is desirable. For instance, the industry partners perceive that the research partners have a limited understanding of how their research will be applied in large-scale production, as

illustrated by the quotes by Bob and James in section 5.4. To bridge this gap, the industry partners have suggested that the research partners should have their researchers spend time in their factories to gain such an understanding, which would enable them to make their research more applicable. The frustration we observed from these informants made it evident that the research partners do not prioritize factory visits and other activities that provide such insights.

When we asked the research partners how the collaboration could improve or yield more outcomes, none of them mentioned anything which even remotely involved improving their technical insight. In fact, as is evident in Aron's quote in section 5.4, some of the research partner's think that the industry partner's give the research partners too little insight into the firms' problems. These contradictory statements are likely to concern different industry partners, where some openly invite the researchers into their factories, whilst others are concerned with their intellectual property. It may also be a difference in perception, and that the research partners perceive the industry partners as private regarding their trade secrets despite their invitations to visit the factories. We will dig deeper into these conflicting statements in the next sections, where we will compare our findings to the literature outlined above.

We will now apply our framework to analyze the empirical findings presented above. Firstly, we see that the different mechanisms are applied to different degrees. Each mechanism will be discussed in the follow sub-sections. As we have found no evidence of sequencing, we will not apply this mechanism.

#### 6.4.2.1 Routines as a mechanism for knowledge integration

We have found that there are quite few routines related to collaboration in the centre. The ones we have found have all been related to the e-room, also discussed in 6.3, where we have two main findings. Firstly, researchers are required to upload research papers to the e-room in order for the board to sensor the reports' content if they should be confidential. Secondly, except for the explicit routines regarding publishing of research papers, routines concerning use of the e-room are non-existing or unclear to most of the centre participants, recalling table 5.2 in sub-chapter 5.3, and sub-chapter 6.3. Could the researchers and industry partners more efficiently integrate their specialized knowledge by strengthening routines in the e-room.

We believe the answer is yes, but only to some extent. As seen recalling 6.3, the majority of the industry partners do not utilize the e-room or are not happy with how it works. As table 5.2 in sub-chapter 5.3 shows, some wish to use the e-room to have easy access to an overview of progress in the research; some think there is too little content; some even do not know that it exists. If routines which reverse these issues with the e-room are introduced, in addition implement the measures recommended in 6.3, then there may be more industry partners using it.

Then it would be easier access to overviews of progress as all parties would actually know where and how to access papers, results etc. in the e-room.

Does this however facilitate knowledge integration? As most industry partners participate meetings and are connected with the centre management, whom we have stated have a good overview of the competence in the centre, then this use of the e-room becomes redundant. They are, however, useful to all participants who do *not* participate in the arranged meetings. For instance, as seen in section 5.3, we found that different representatives from one of the larger partnering firms participated different work package meetings, and afterwards briefed each other. In this briefing process, the representatives may put the explicit content collected from the e-room into context, but only if they actually have the explicit material at all. In this process, individual knowledge is converted to group knowledge which is a necessity for organizational learning (Zietsma, Winn et al. 2002). In this context, the routines may strengthen knowledge integration in the form of knowledge sharing rather than knowledge use and combination. This is nonetheless valuable to the participating firms, and we thus propose that these routines should be strengthened.

This is as mentioned the only form of routine identified from our interviews. Moving on, we will now discuss the final two mechanisms for efficient knowledge integration: group problem solving and and rules.

#### 6.4.2.2 Group problem solving and rules as mechanisms for knowledge integration

We start with group problem solving, which was described by the literature as a "last resort" mechanism because it is exposed to faults during improvisation. From our understanding, all board activity, meeting activity and research is dominated by this kind of problem solving which is central in the centre. Thus, group problem solving naturally dominates as a way of combining knowledge in the centre. This activity should be more difficult if the people participating in the given activity are not co-localized, as this requires a constant transfer of both explicit and tacit knowledge between the participants. However, as we saw in section 5.3, meetings in the centre are largely carried out in person, and phone meetings are carried out between people with strong social bonds and relations. Hence, this activity is managed as optimally.

Regarding rules and directives as an integration mechanism, we have not found any other than those embedded in the consortium agreement. These few rules do, however, provide frames for the collaboration and contribute to organizational proximity. Thus, as seen in section 6.2, they are a prerequisite to efficient remote collaboration in the centre for two reasons. Firstly because the consortium is mandatory for the CEERs, and secondly because we found that organizational proximity contributes to trusty relationships between the participating organizations.

#### 6.4.2.3 Centre wide knowledge integration

As was described above, few mechanisms of knowledge integration have been applied in the research centre. However, with exceptions of the mechanisms outlined above, we do not believe that there is potential for more robust integration mechanisms either due to the diversity of the research. The nature of the activities in the centre requires the researchers to be flexible and change their research focus if the direction of the research changes, mechanisms are thus tough to apply.

Is knowledge integration still possible given that there are almost no mechanisms to help with the integration process? Recalling that the purpose of knowledge integration can be seen efficient combination of knowledge while minimizing knowledge transfer through cross learning by organizational members (Grant 1996), we see that knowledge integration may still be efficient despite the absence of integrating mechanisms. This is because the researchers may, under coordination from the board and management, synergize their research. By this, we mean that the researchers can utilize their specialized competences to conduct different kinds of research, and the product may have a greater value to the partners than the sum of each single research result. Thus, we argue that integration of knowledge in Solar United is possible, but we have not argued whether the necessary preconditions are present.

According to Grant (1996), the researchers and industry partners should have a sufficiently similar knowledge base to achieve efficient knowledge integration. If we crosscheck the different kinds of common knowledge, we see that language, numerical kinds of understanding, and recognition of individual knowledge domains seem to largely be present. However, the fact that the researchers from the research partners are not familiar with the production facilities means that they lack some specialized knowledge, and that they may not have a shared meaning of the applications of the research. According to this framework, which is supported by James' and Bob's quotes in section 5.4, the only way to further improve the relevance of centres' research is to increase the research partners' knowledge which relates to large scale production.

Recalling section 2.4.6, we stated that these kinds of common knowledge may be said to describe cognitive proximity, which is defined as similarities in the way actors perceive, interpret, understand and evaluate the world (Wuyts, Colombo et al. 2005). Arguably, if the researchers gain a better understanding of how their research may be applied in large-scale production, then they will increase the similarity in how they and the industry partners understand and evaluate the world. The research partners and industry partners may thus have a more optimal cognitive proximity if the research partners gain more insight into how their research can be applied in the industry partners' factories. Figure 6.5 illustrates how the industry partners' knowledge bases should evolve to improve the collaboration.

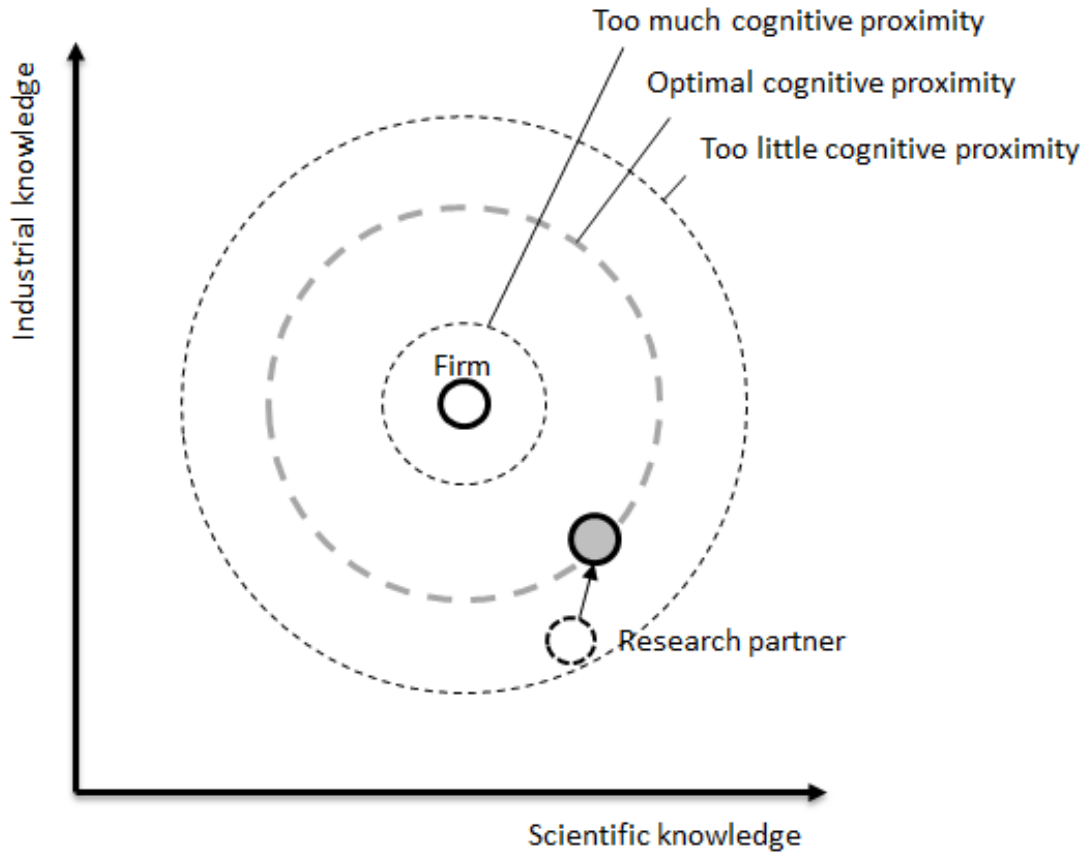



**Figure 6.5 If research partners develop more understanding of industrial practices, they will become more relevant to the industry partners.**

This concludes our analysis of our sub-research questions. In the following chapter, we apply this analysis to answer how knowledge intensive firms benefit from collaborating in research centres.

# 7 Discussion

This chapter is dedicated to answering our main research question:

> ***MRQ**: How do knowledge intensive firms benefit from collaborating in research centres?*

We will answer this question by synthesizing a model that describes how knowledge intensive firms benefit from collaborating in Solar United, based on the findings in chapter 6. We start with describing the background for Solar United in order to provide a better understanding of our final model. We then synthesize the first part of the model from our analysis of different firms' expectations, and crosscheck this model with the other firms' expectations to see whether it is general enough to fit all the firms participating in Solar United. Finally, we discuss whether this model may apply for research centres in general.

## 7.1 Answering our main research question

As was mentioned in 5.1, the firms and research institutions that make up Solar United already had collaborations and activities organized prior to the establishment of the centre, shown in the empirical findings in 5.1 and 5.4. These activities included binary projects, and to some extent a specialization of the different research communities to avoid their specialized competences to be overlapped. As the CEER scheme was announced, and the firms and institutions agreed to apply for support in order to start a research centre, they began creating the borders of the collaboration entering in a consortium, which finally were formalized by a consortium agreement. Figure 7.1 illustrates the initiation process where the stippled line represents the centres "walls" formalized by the consortium agreement ,symbolizing the organizational proximity between the involved partners.

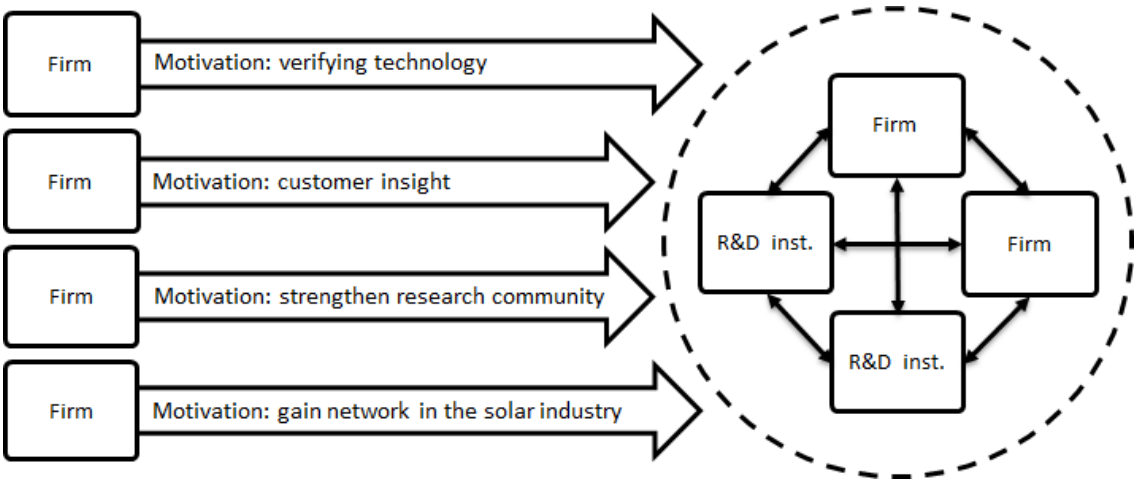



**Figure 7.1 Firms enter Solar United with different expectations of outcomes. The black arrows between the boxes to the right represent communication and knowledge transfer.**

**Correlations between firms size, industry position and their expectations for the centre.**

**Table 7.1 Correlations between firms size, industry position and their expectations for the centre.**

| Expectation | Group of firms |
|---|---|
| Networking | All industry partners |
| Strengthen research communities competence to create binary projects later | Larges industry partners |
| Test and improvement of technologies | SMEs in the core industry and supporting industry |
| Customer insight | Supporting industry |

Following this initiation process, the different partners became acquainted, established social proximity in form of personal relations between their representatives, and gained insight into each other's' motivations and needs. As illustrated in figure 7.2, the centre became more clearly defined. The partners were not just a group of organizations, but a network that could integrate their activities for common goals. As we argued in section 6.1, the centre does indeed have the potential to integrate the partners' specialized knowledge in order to create new knowledge that is relevant to their operations. In theoretical terms, the involved partners in the research centre have used temporary geographical proximity in form of physical meetings to gain organizational and social proximity, which allows them to collaborate more easily over large distances. Table 7.2 briefly reviews the different kinds of proximity, how they are made in the centre, and why they are beneficial to the industry partners.

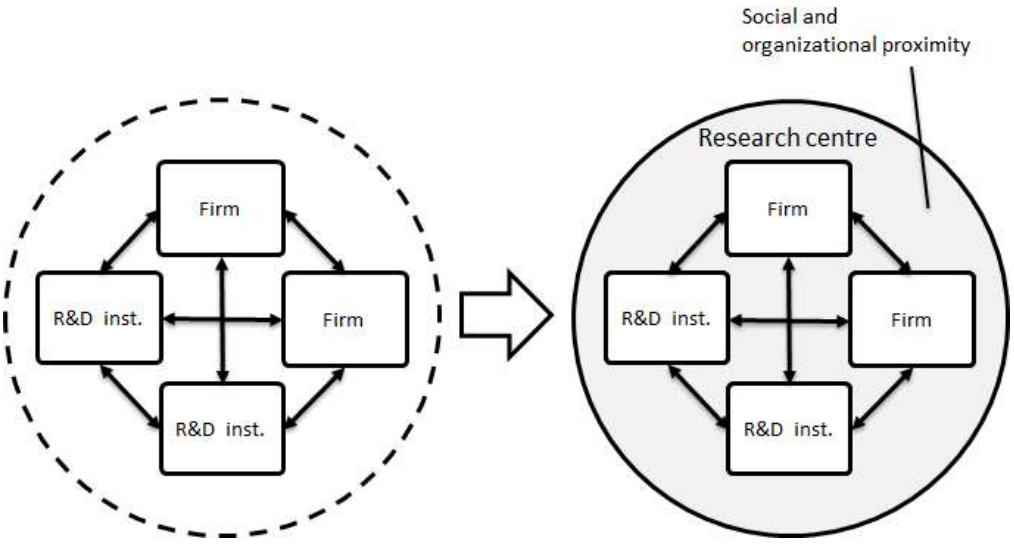



**Figure 7.2 Formalization of the research centre.**

**Table 7.2 Summary of different types of proximity which have been established in Solar United.**

| | Where its created in the centre | Related benefits for industry partners |
|---|---|---|
| Temporary geographical proximity | WP-meetings, workshops, yearly conference | Allows other types of proximity to develop (Boschma, 2005).<br><br>Arenas for transfer of tacit knowledge (Knoben & Oerlemans, 2006) |
| Organizational proximity | Signing the consortium agreement; collaboration in the same work packages over time; board meetings | Important for the formalization of the research centre. Builds capacity to transfer tacit knowledge between the collaborating parties (Burmeister and Colletis-Wahl 1997 as cited by Boschma, 2005). May lead to future collaborations (D'Este, Guy et al. 2012) |
| Cognitive proximity | Projects where industry and research partners actively collaborating | Important for common understanding between the partners, should not be to high, but moderate. Builds common understanding between partners, leading to more relevant results from the centre (Knoben & Oerlemans 2006) |
| Social proximity | Face-to-face meetings, conference dinners, after-meeting-beers | Is important for communication and diffusion of knowledge between individuals (Boschma and Frenken 2010). Better communication and trust between partners, possibilities for new collaborations (Boschma, 2005) (Balland 2012). May lead to new innovative networks (Oerlemans and Meeus 2005) |

With the boundaries of the centre in place, research activities commenced and the research partners started building new competence. The direction of the research is set by the board, while the management and work package leaders set the research plans in collaboration with the different firms. Due to the geographical spread of the partners, the majority of communication is assisted by ICTs. The black arrows in the above figures thus represent both face-to-face communication and ICT aided communication. As seen in 6.3, this communication is to a very low degree aided by an e-platform, which limits the different parties' access to relevant documents. The diffusion of knowledge within the centre is thus limited to that, which is dispersed through face-to-face interaction, phone calls and emails.

The research activities yield a lot of generic knowledge, but as shown in section 5.2, the research partners also develop firm-specific competences. This knowledge is financed through the centre, but is not completely disclosed to all partners and hence makes up a foundation for binary projects. Thus, firms that have resources for binary projects (i.e. large firms) benefit from collaborating in Solar United because the centre finances the development of competence which they may apply in such binary projects. This mechanism is illustrated in figure 7.3.

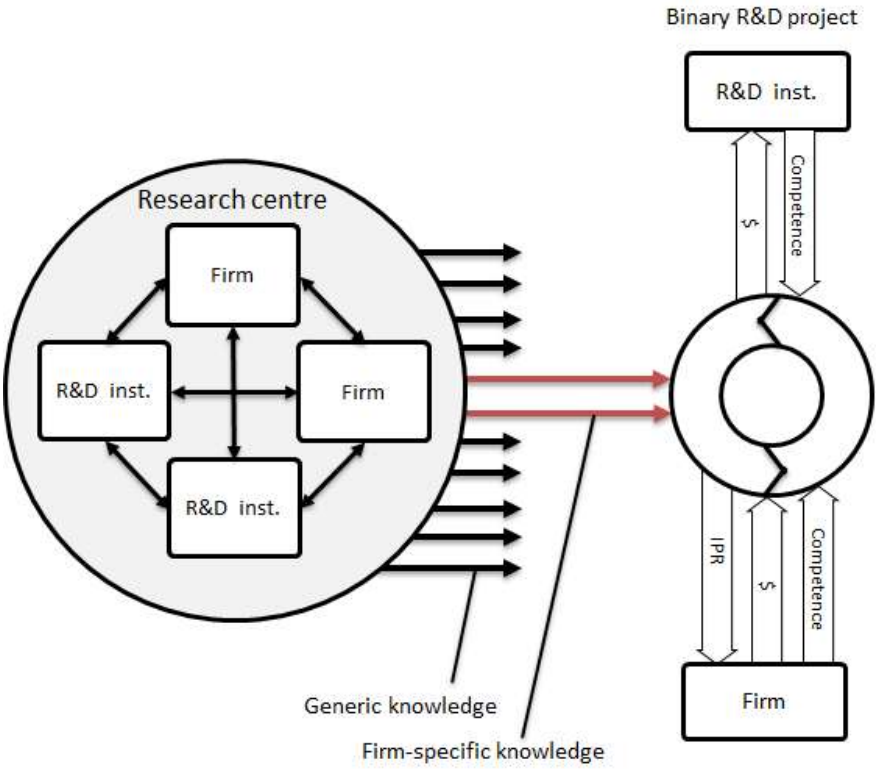



**Figure 7.3 Spin-off projects. Firm-specific knowledge created in the centre is applied to binary projects with a stronger innovation focus.**

We will now test the validity of this model to other segments of industry partners, starting with firms that do not have resources for binary projects (i.e. small or pre-competitive firms), we have found that the centre provides a network of resources which they may utilize from. For instance, in section 5.1 Jack explained that his firm was able to conduct experiments with the research partners, which allowed them to reach new milestones in their product development. Small and pre-competitive firms may hence benefit from collaborating in research centres as it allows them to develop their technologies by utilizing resources and competence that they do not possess. Reaching such milestones may unlock new funding, either private or public, which may further allow the firm to enter in collaborative research, for instance with an industrial partner or in a binary project with a research institution. For the sake of our model, we generalize such collaborative research projects as binary projects.

Supporting industry partners, however, have somewhat different motivations for participating. As was outlined in section 5.1, supporting industry partners primarily participate to gain better insight into their customers' needs, though they also participate in binary projects with research institutions. As discussed in section 6.1, supporting industry partners are often suppliers to different industries, limiting their attention to each industry. Research centres provide an arena to get up close and personal with a particular industry, and gives them insight into how the firms in that particular industry think. Thus, their main benefits from collaborating in the Solar United is

the participation itself, and not necessarily the binary projects that spin out from the centre. Nevertheless, as they also interact actively within the centre and attend partake in binary research projects, supporting industry firms fit the model illustrated in figure 7.3.

We have thus far reviewed how knowledge created in Solar United is being transferred to firms and how this knowledge is utilized in binary projects, but what is the outcome of such projects? The primary outcome is firm-specific knowledge, which is applied in the client firms' production or other practical applications. However, there is also a secondary outcome. As stated by Henry in section 5.1, many such collaborative research projects both yield knowledge spillovers that are not sufficiently relevant to be followed up by the firm alone. These spillovers work as new impulses for the research centre. As most of the industry partners have binary projects with one or more of the research partners, there is quite a lot of input from binary projects to the centre. Thus, the output from binary projects close a loop which feeds the centre with firm-relevant input; which constantly develops the research partners' competence on industry; and which generates firm specific knowledge that spin out of the centre as binary projects. This loop is illustrated in figure 7.4.

In this loop, the firms absorb knowledge both directly from the centre and in the binary projects. Recalling figure 7.3, which outlined how firms absorbed tacit knowledge from the centre, we see that the large firms primarily absorb knowledge from the centre by attending meetings and reading documents extract more knowledge from the binary projects. On the other hand, the small firms who partake more actively in the research at the centre do not have as many binary projects. Thus, firm size affects the point where firms absorb knowledge: small firms absorb directly from the centre to a greater extent than large firms, and large firms from binary projects than small firms. The position of medium size firms is, however, less clear from our findings, but we see a clear trend on a simplified scale where we oppose small and large firms. This scale is illustrated in figure 7.5.

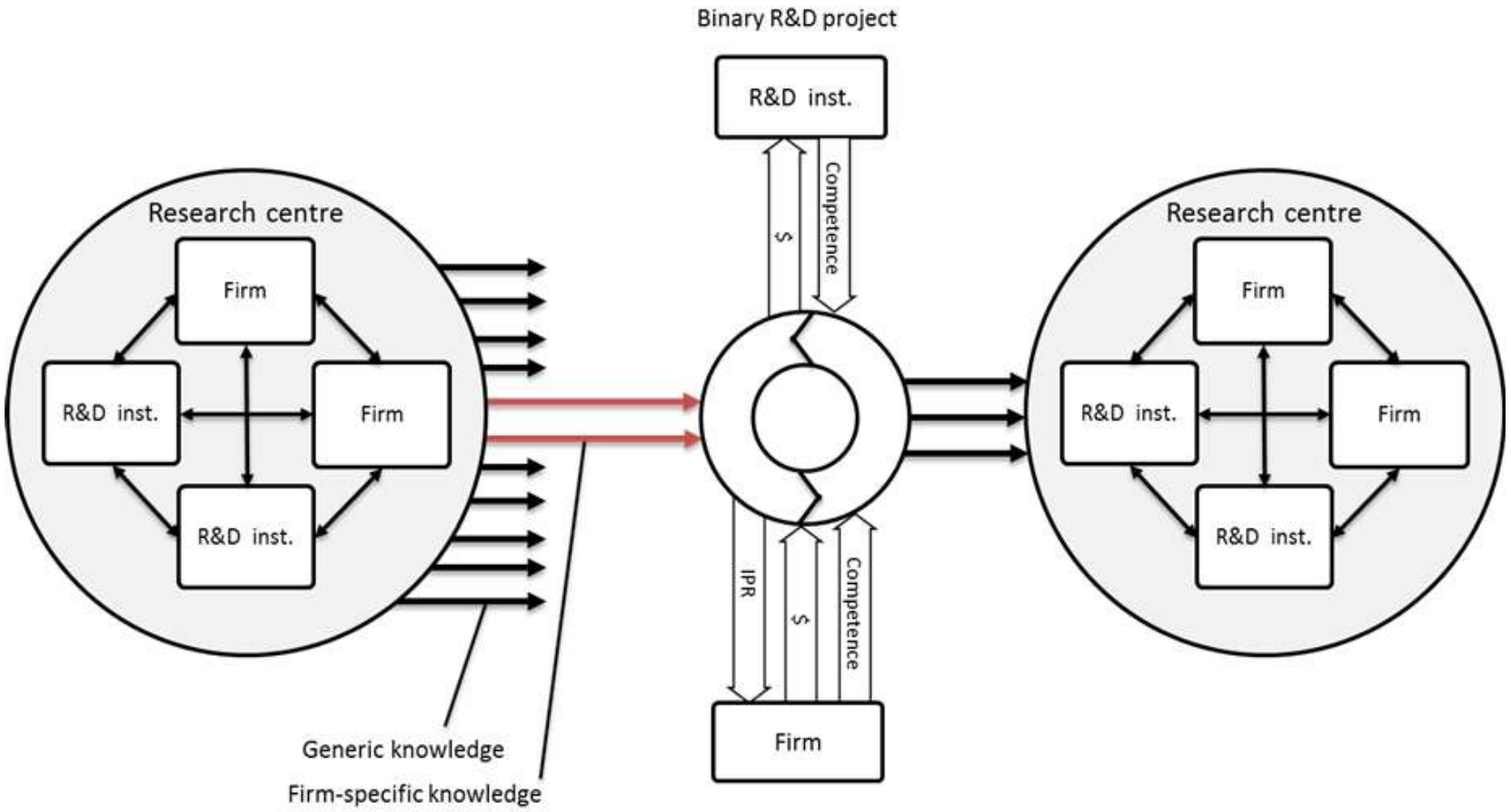



**Figure 7.4 Model of how knowledge intensive firms benefit from collaborating in research centres.**

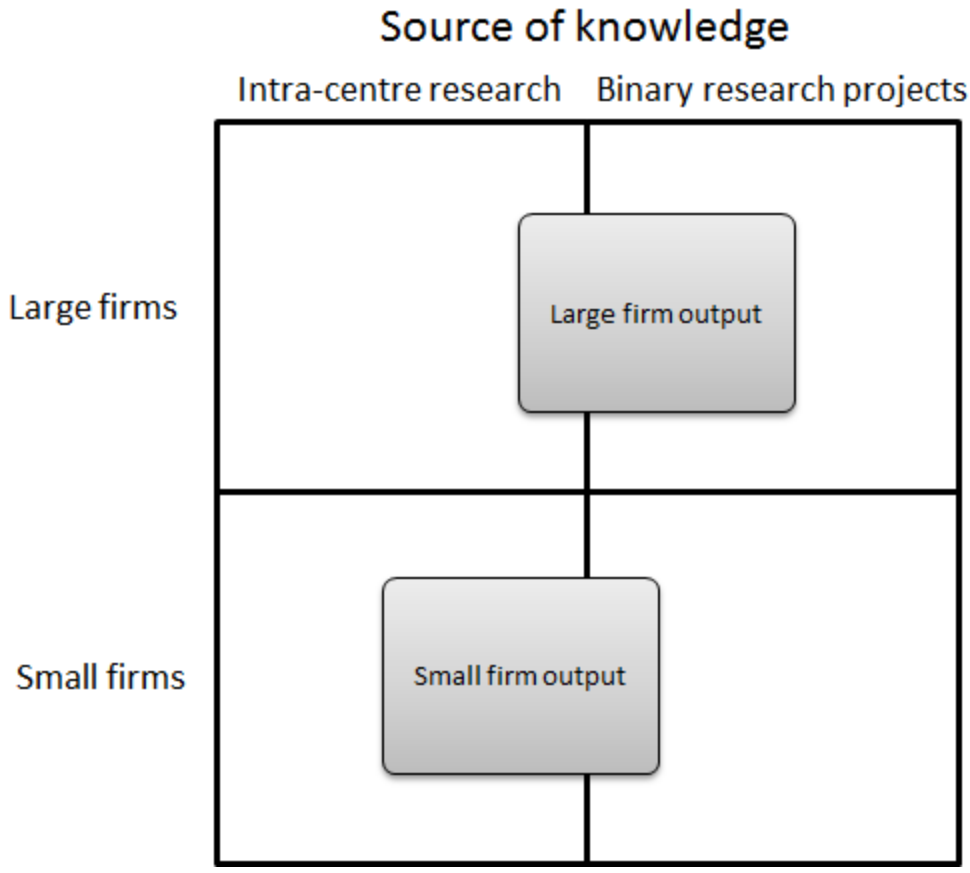



**Figure 7.5 Correlation between firm size and location of their knowledge acquisition.**

## 7.2 Transferability of the model

This section evaluates the transferability of the model in figure 7.4 by applying the literature on the topic presented in section 3.4. As we have conducted a single-case study of a research centre, one might attempt to generalize our model to be valid for knowledge intensive firms and research centres outside of Solar United as well. Though some of our findings are consistent with findings in the literature, for instance those relating to proximity, many also conflict with the literature. Particularly, the research results concerning firms' expectations regarding outputs from the centre diverge from other literature (e.g. Bayona Sáez and Huerta Arribas 2002). Thus, to confirm the transferability of these results and their validity in our model in figure 7.4, we see that further research is required. Specifically, further research might compare the expectations of firms participating in research centres where only knowledge intensive firms participate with research centres where some firms are less knowledge intensive. This will provide perspective on the validity and transferability of our analysis.

# 8 Conclusions

In this final chapter, we will give a brief overview of the findings and conclusions that we have obtained in this thesis. We will then review theoretical and practical the implications that have been found throughout the thesis. The chapter ends with recommendations for further research.

## 8.1 Main findings

In this master thesis, we have answered how knowledge intensive firms benefit from collaborating in Solar United. We have cross-linked several concepts in the knowledge management literature that to the best of our knowledge, have not been combined as we have done in this thesis. This cross-link has granted us novel insight into how proximity, knowledge integration and ICTs influence the outcomes for industry partners in research centres. Our primary findings and conclusions are presented in table 8.1 below.

**Table 8.1 Primary findings and conclusions**

| | **Findings and conclusions** |
|---|---|
| **MRQ** | *How do knowledge intensive firms benefit from collaborating in Solar United?*<br><br>● Knowledge intensive firms benefit from collaborating in Solar United in different ways depending on their financial status and position in the industry.<br>○ Large firms with funds for R&D have the research partners develop firm-specific competence. The firm can thus start binary projects at a lower cost than if they had to pay for the development of the research partner's competence by themselves.<br>○ Smaller firms with lower R&D capacity and less funds, particularly pre-commercial firms, conduct research that advances their technological development within the centre. These findings may be applied in binary projects outside the centre.<br>○ Supporting industry partners primarily benefit by gaining insight into the state-of-the art and customer insight, enabling them to create superior supporting products. Thus, the knowledge created in the centre is their primary benefit, but this group has also started binary projects as a result of the research centre.<br>● Thus, all industry partners benefit from different kinds of knowledge creation. Knowledge spillovers from binary projects are channeled back to the centre, creating a cycle. In this way, the research partners' competence constantly builds and the industry partners develop new knowledge and technology at a lower cost than if the firm conducted all the R&D themselves. |
| **SRQ1** | *What outcomes do firms participating in Solar United expect from the collaboration, and what does the centre do to meet these expectations?*<br><br>● There is a correlation between firms' size and position as core or supporting industry, and their main motivations for collaborating in research centres.<br>○ Large firms in the core industry want to strengthen the research community's competence to create binary projects later.<br>○ SMEs in the core industry want to test and improve their technologies. |

| | |
|---|---|
| | ○ Supporting industry wants customer insight.<br>○ All participating firms are interested in the networking aspect of the centre.<br>● All the firms are to some extent motivated by knowledge acquisition. Knowledge is transferred through different arenas summarized in figure 7.4. Tacit knowledge is particularly difficult to transfer continuous due to the partners' geographical spread.<br>● Our findings support that firms' internal R&D capacity and experience with R&D collaborations allows firms to absorb knowledge despite lack of physical presence. |
| **SRQ2** | *How do firms cope with lack of geographical proximity when collaborating with other organizations in Solar United?*<br><br>● The firm representatives and researchers rarely met face-to-face, mainly limited by industry partners' flexibility and geographical distance.<br>● The centre participants meet periodically, and this temporary geographical proximity contributes to building social, cognitive and organizational proximity between partners in the centre.<br>● Our findings are largely consistent with the literature, as these kinds of proximities between the partners seem to facilitate mutual understanding despite lack of geographical proximity. |
| **SRQ3** | *How do ICTs facilitate the collaboration between individuals in Solar United, and how do ICTs facilitate organizational learning?*<br><br>● Strong social proximity enables researchers in the research centre to collaborate efficiently by communication technologies such as phone and email, which is consistent with the literature (McLoughlin and Jackson 2002).<br>● There is unrealized potential in the use of ICTs in Solar United, e.g. the e-room solution barely fulfills one out of three of Rodgers' criteria for efficient use of ICTs (1995). Thus, organizational learning is limited by the e-room, because plans and other documents are not present to the extent that they could be.<br>● The centres' partners, particularly the industry partners, may benefit from replacing phone conferences with video conferences to a larger extent. This may increase knowledge transfer and decrease the possibility for misunderstandings as the parties can have interactions that are more illustrative in these meetings. |
| **SRQ4** | *How is specialized knowledge from research institutions and firms integrated in Solar United?*<br><br>● Few of Grant's integration mechanisms (1996) are present in the centre. Still, there is still great potential for integrating knowledge between the researchers and industry partners in the centre.<br>● Regarding Grant's conditions for successful knowledge integration, the researchers in the centre seem to lack some specialized knowledge related to large-scale production, and hence lack shared meaning with the industry partners when addressing applications of their research.<br>● We have drawn a connection between cognitive proximity and Grant's conditions for successful knowledge integration. A better understanding of large-scale production will provide a more optimal cognitive proximity between research partners and industry partners, hence allowing more relevant research results to emerge from the centre. |

## 8.2 Theoretical implications

In addition to the findings summarized in table 8.1, our cross-linking of theoretical perspectives has yielded a novel implications for theory. The first concerns proximity and knowledge integration, where we have proposed a link between cognitive proximity and Grant's factors that facilitate knowledge integration (1996). We found that cognitive proximity facilitates knowledge integration between organizations. Furthermore, we found that Grant's factors may be seen as sub-factors for cognitive proximity, thus higher levels of Grant's common knowledge variables also provide higher levels of cognitive proximity. This is particularly interesting because cognitive proximity concerns the organizational level of analysis, whilst Grant's factors are described as kinds of common knowledge, which may be understood at both the group and organizational level. Thus, we propose that these factors may be used as observable variables to assess cognitive proximity.

In the next section, we direct our attention to the managerial implications that have resulted from our analysis.

## 8.3 Practical implications

We will now review the four main implications for management that have become evident throughout our analysis. The first two regard mutual understanding between the partners in the centre, the second two regards use of ICTs as a way of sharing knowledge throughout the centre.

### 8.3.1 Measures for mutual understanding

We have two propositions which may improve the mutual understanding between industry partners and research partners, but which also may foster better understanding between the industry partners as well. The first concerns the research partners' insight into large-scale production. This will allow the research partners a better understanding of the industry partners' needs, which may lead to a stronger demand from the industry partners for consultancy by the research partners both within and outside the centre. Thus, research partners may benefit greatly from increasing their relevance to the industry partners.

The second proposition relates to social arenas. The solar community already arranges social events after conferences and meetings, and our recommendation is to not underestimate the value of these settings. In fact, these settings may provide an arena for further expanding the circle of acquaintances. These settings serve as a way to share tacit knowledge and develop social proximity, which we have argued to be a core necessity for a productive collaboration. Thus, maintaining and strategically using these settings to create bonds between the organizations in the centre may facilitate new collaborations and efficient diffusion of knowledge throughout the centre.

### 8.3.2 Measures for knowledge sharing

We have dedicated much attention in this thesis to evaluating the tools that are used for sharing knowledge across remote locations in the centre. In this process, we have highlighted two tools as potent. The first is video conferences, which not used in the centre at all. A large proportion of formal meetings which today are arranged in phone conferences could benefit from including video because it grants the participants greater possibilities to utilize social cues and illustrations to explain their opinions. This however has practical limitations due to the need for hardware that allows such videoconferences, and the costs and benefits of investing in such equipment must naturally be evaluated.

Our final practical implication is also the one we have emphasized most heavily throughout our thesis, and concerns the centres' e-room. We have clearly seen that such a platform is desired among the different parties in the centre, but that the current solution and the routines that surround it are not sufficient. Keeping in mind that only a single informant thought that the technical structure of the e-room was problematic, the current solution may practically be improved with two measures. The first is giving each new partner and partners who have not used the platform a firm introduction. Preferably, they should also get a walkthrough of the database that resides in the e-room, as this will allow them to "see the forest and not just a group of trees". Secondly, they should establish firm routines, which makes it easy for the partners to always upload their presentations, papers and documents. A person dedicated to collecting such material after meetings may support such routines and conferences, assuring that someone at all times is responsible for the routines.

## 8.4 Implications for further research

There are several perspectives that have been mentioned or applied in this thesis, which may be applied to gain even better insight into how firms benefit from collaborating in research centres. Firstly, the part of our framework that concerned knowledge integration was quite narrow, and we believe there is potential for greater insight into knowledge integration in research centres. Secondly, we purposefully opted out communities-of-practice as a perspective in this thesis. As one of our primary findings is that tacit knowledge accumulates within the research partners of the centre, the communities-of-practice perspective and its strong connection to the practice-based view may be quite applicable in the context of research centres.

In addition to these other perspectives, we are curious as to the transferability of the model presented in figure 7.4. There are two levels where the model may be validated. First, in the same context as our thesis, i.e. for centres where all industry partners are knowledge intensive firms. Second, if the model withstands this test, then its transferability to research centres in general, where participating firms are not necessarily knowledge intensive, may be tested. In that case, new insight into the location of firms knowledge absorption (i.e. directly from the research centre or from binary projects) from participation in research centres may be obtained.

# 9 References

Aftenposten (2012). "REC legger ned på Herøya." 2014, from http://www.aftenposten.no/okonomi/innland/REC-legger-ned-pa-Heroya-6813798.html#.U9FS7_mSyTs.

Argote, L. and E. Miron-Spektor (2011). "Organizational learning: From experience to knowledge." Organization science **22**(5): 1123-1137.

Arita, T. and P. McCann (2000). "Industrial alliances and firm location behaviour: some evidence from the US semiconductor industry." Applied Economics **32**(11): 1391-1403.

Audretsch, D. B. and M. Vivarelli (1996). "Firms size and R&D spillovers: Evidence from Italy." Small Business Economics **8**(3): 249-258.

Balland, P.-A. (2012). "Proximity and the evolution of collaboration networks: evidence from research and development projects within the global navigation satellite system (GNSS) industry." Regional studies **46**(6): 741-756.

Bayona Sáez, C. and E. Huerta Arribas (2002). "Collaboration in R&D with universities and research centres: an empirical study of Spanish firms." R&D Management **32**(4): 321-341.

Boschma, R. (2005). "Proximity and innovation: a critical assessment." Regional studies **39**(1): 61-74.

Boschma, R. and K. Frenken (2010). "The spatial evolution of innovation networks. A proximity perspective." The handbook of evolutionary economic geography: 120-135.

Bougrain, F. and B. Haudeville (2002). "Innovation, collaboration and SMEs internal research capacities." Research policy **31**(5): 735-747.

Boyatzis, R. E. (1998). Transforming qualitative information: Thematic analysis and code development, Sage.

Broekel, T. and R. Boschma (2012). "Knowledge networks in the Dutch aviation industry: the proximity paradox." Journal of Economic Geography **12**(2): 409-433.

Brown, J. S. and P. Duguid (1991). "Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation." Organization science **2**(1): 40-57.

Brown, J. S. and P. Duguid (2001). "Knowledge and organization: A social-practice perspective." Organization science **12**(2): 198-213.

Bryman, A. (2012). Social research methods, Oxford university press.

Burmeister, A. and K. Colletis-Wahl (1997). "Proximity in Production Networks The Circulatory Dimension." European Urban and Regional Studies **4**(3): 231-241.

Busenitz, L. W. and J. B. Barney (1997). "Differences between entrepreneurs and managers in large organizations: Biases and heuristics in strategic decision-making." Journal of business venturing **12**(1): 9-30.

Cassiman, B. and R. Veugelers (2006). "In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition." Management Science **52**(1): 68-82.

Chatterji, D. (1996). "Accessing external sources of technology." Research-Technology Management **39**(2): 48-56.

Cohen, W. M. and D. A. Levinthal (1989). "Innovation and learning: the two faces of R & D." The economic journal **99**(397): 569-596.

Cohen, W. M. and D. A. Levinthal (1990). "Absorptive capacity: a new perspective on learning and innovation." Administrative science quarterly: 128-152.

Cohen, W. M. and D. A. Levinthal (1994). "Fortune favors the prepared firm." Management Science **40**(2): 227-251.

Czarnitzki, D., et al. (2007). "The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany." Journal of applied econometrics **22**(7): 1347-1366.

D'Este, P., et al. (2012). "Shaping the formation of university–industry research collaborations: what type of proximity does really matter?" Journal of Economic Geography: lbs010.

D'Este, P. and S. Iammarino (2010). "The spatial profile of university-business research partnerships." Papers in Regional Science **89**(2): 335-350.

David, P. A. and D. Foray (2002). "An introduction to the economy of the knowledge society." International social science journal **54**(171): 9-23.

Edmondson, A. C., et al. (2007). "6 Three Perspectives on Team Learning: Outcome Improvement, Task Mastery, and Group Process." The academy of management annals **1**(1): 269-314.

Edwards, T., et al. (2005). "Understanding innovation in small and medium-sized enterprises: a process manifest." Technovation **25**(10): 1119-1127.

Fichman, R. G. and C. F. Kemerer (1997). "The assimilation of software process innovations: An organizational learning perspective." Management Science **43**(10): 1345-1363.

Freeman, C. (1991). "Networks of innovators: a synthesis of research issues." Research policy **20**(5): 499-514.

Frost, T. S. and C. Zhou (2005). "R&D co-practice and 'reverse'knowledge integration in multinational firms." Journal of International Business Studies **36**(6): 676-687.

Gassmann, O. (2006). "Opening up the innovation process: towards an agenda." R&d Management **36**(3): 223-228.

Gertler, M. S. (1995). "" Being There": Proximity, Organization, and Culture in the Development and Adoption of Advanced Manufacturing Technologies." Economic geography: 1-26.

Gibbons, M., et al. (1994). The new production of knowledge: The dynamics of science and research in contemporary societies, Sage.

Gill, J. and R. J. Butler (2003). "Managing instability in cross-cultural alliances." Long range planning **36**(6): 543-563.

Grant, R. M. (1996). "Toward a knowledge-based theory of the firm." Strategic management journal **17**: 109-122.

Greunz, L. (2003). "Geographically and technologically mediated knowledge spillovers between European regions." The Annals of Regional Science **37**(4): 657-680.

Grimpe, C. and U. Kaiser (2010). "Balancing internal and external knowledge acquisition: the gains and pains from R&D outsourcing." Journal of Management Studies **47**(8): 1483-1509.

Hagedoorn, J., et al. (2000). "Research partnerships." Research policy **29**(4): 567-586.

Hislop, D. (2002). "Mission impossible? Communicating and sharing knowledge via information technology." Journal of Information Technology **17**(3): 165-177.

Hislop, D. (2005). Knowledge management in organizations: A critical introduction, Oxford University Press.

Howells, J. (1999). "Research and technology outsourcing." Technology Analysis & Strategic Management **11**(1): 17-29.

Howells, J. R. (1995). "Going global: the use of ICT networks in research and development." Research policy **24**(2): 169-184.

Howells, J. R. (2002). "Tacit knowledge, innovation and economic geography." Urban studies **39**(5-6): 871-884.

Ingram, P. (2002). "Interorganizational learning." Companion to organizations: 642-663.

IPCC (2014). Climate Change 2014: Impacts, Adaption, and Vulnerability.

Jacquier-Roux, V. and B. Bourgeois (2002). "New networks of technological creation in energy industries: reassessment of the roles of equipment suppliers and operators." Technology Analysis & Strategic Management **14**(4): 399-417.

Jaffe, A. B., et al. (2005). "A tale of two market failures: Technology and environmental policy." Ecological Economics **54**(2): 164-174.

Johnson-Laird, P. N. (1983). Mental models: Towards a cognitive science of language, inference, and consciousness, Harvard University Press.

Katz, J. S. and B. R. Martin (1997). "What is research collaboration?" Research policy **26**(1): 1-18.

Kirat, T. and Y. Lung (1999). "Innovation and proximity territories as loci of collective learning processes." European Urban and Regional Studies **6**(1): 27-38.

Knoben, J. and L. A. Oerlemans (2006). "Proximity and inter-organizational collaboration: A literature review." International Journal of Management Reviews **8**(2): 71-89.

Kogut, B. and U. Zander (1992). "Knowledge of the firm, combinative capabilities, and the replication of technology." Organization science **3**(3): 383-397.

Landry, R. and N. Amara (2003). "Effects of sources of information on novelty of innovation in Canadian manufacturing firms." Understanding innovation in Canadian industry: 67-110.

Laursen, K. and A. Salter (2006). "Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms." Strategic management journal **27**(2): 131-150.

Lee, S., et al. (2010). "Open innovation in SMEs—An intermediated network model." Research policy **39**(2): 290-300.

Leonard-Barton, D. (1995). Wellsprings of knowledge: Building and sustaining the sources of innovation, Harvard Business Press.

Lessard, D. R. and S. Zaheer (1996). "Breaking the silos: Distributed knowledge and strategic responses to volatile exchange rates." Strategic management journal **17**(7): 513-533.

Lundvall, B.-A. (2009). "Innovation as an interactive process: user-producer interaction to the national system of innovation: research paper." African journal of science, technology, innovation and development **1**(2 & 3): 10-34.

Malterud, K. (2001). "Qualitative research: standards, challenges, and guidelines." The lancet **358**(9280): 483-488.

Marsh, S. J. and G. N. Stock (2006). "Creating dynamic capability: The role of intertemporal integration, knowledge retention, and interpretation." Journal of Product Innovation Management **23**(5): 422-436.

Maznevski, M. L. and K. M. Chudoba (2000). "Bridging space over time: Global virtual team dynamics and effectiveness." Organization science **11**(5): 473-492.

McLoughlin, I. and P. J. Jackson (2002). "11 Organisational learning and the virtual organisation." Virtual Working: Social and Organisational Dynamics: 178.

Meeus, M. T., et al. (2001). "Patterns of interactive learning in a high-tech region." Organization Studies **22**(1): 145-172.

Mengis, J., et al. (2009). "Working together in the space between expertise and ignorance." Management Learning.

Merton, R. K. (2008). Focused interview, Simon and Schuster.

Miles, M. B. and A. M. Huberman (1994). Qualitative data analysis: An expanded sourcebook, Sage.

Mitchell, V. L. (2006). "Knowledge integration and information technology project performance." Mis Quarterly: 919-939.

Nadiri, M. I. (1993). Innovations and technological spillovers, National Bureau of Economic Research.

Nandhakumar, J. (1999). Virtual teams and lost proximity: Consequences on trust in relationships. Virtual working: Social and organizational dynamics. P. Jackson.

Narula, R. (2004). "R&D collaboration by SMEs: new opportunities and limitations in the face of globalisation." Technovation **24**(2): 153-161.

Newell, S., et al. (2002). "Managing Knowledge Work."

Ngwenyama, O. K. and A. S. Lee (1997). "Communication richness in electronic mail: Critical social theory and the contextuality of meaning." Mis Quarterly: 145-167.

NIFU (2010). "FoU for en grønn energisektor."

Nonaka, I. (1994). "A dynamic theory of organizational knowledge creation." Organization science **5**(1): 14-37.

Nonaka, I., et al. (1994). "Organizational knowledge creation theory: A first comprehensive test." International Business Review **3**(4): 337-351.

> Confirmatory factor analyses were conducted to test Nonaka's ((1994) Organization Science, Vol. 5, No. 1, pp. 14-37) a priori model of organizational knowledge creation with data collected from 105 Japanese middle managers. The results provide strong support for viewing organizational knowledge creation as a higher-order construct comprised of four knowledge conversion processes: socialization, externalization, combination, and internalization. © 1995.

NRC (2008). FME - beskrivelse av ordningen.

NRC (2014). "http://www.forskningsradet.no/."

Ocasio, W. (1997). "Towards an attention-based view of the firm." Strategic management journal **18**(S1): 187-206.

Oerlemans, L. and M. Meeus (2005). "Do organizational and spatial proximity impact on firm performance?" Regional studies **39**(1): 89-104.

Patel, P. and K. Pavitt (1998). "National systems of innovation under strain: the internationalisation of corporate R&D." Science Policy Research Unit **19**: 1-25.

Plewa, C., et al. (2013). "The evolution of university–industry linkages—A framework." Journal of Engineering and Technology Management **30**(1): 21-44.

Postrel, S. (2002). "Islands of shared knowledge: Specialization and mutual understanding in problem-solving teams." Organization science **13**(3): 303-320.

Rallet, A. and A. Torre (1999). "Is geographical proximity necessary in the innovation networks in the era of global economy?" GeoJournal **49**(4): 373-380.

Ranga, L. M., et al. (2003). "Entrepreneurial universities and the dynamics of academic knowledge production: A case study of basic vs. applied research in Belgium." Scientometrics **58**(2): 301-320.

Rasiah, R. and C. V. Govindaraju (2009). "University-industry R&D collaboration in the automotive, biotechnology and electronics firms in Malaysia."

Rietzschel, E. F., et al. (2007). "Relative accessibility of domain knowledge and creativity: The effects of knowledge activation on the quantity and originality of generated ideas." Journal of Experimental Social Psychology **43**(6): 933-946.

Roberts, J. (2007). The modern firm: Organizational design for performance and growth, Oxford University Press.

Rogers Everett, M. (1995). "Diffusion of innovations." New York.

Schulz, M. (2002). "Organizational learning." The Blackwell companion to organizations: 415-441.

Shane, S. A. (2000). A general theory of entrepreneurship: The individual-opportunity nexus, Edward Elgar Publishing.

Simon, M., et al. (2000). "Cognitive biases, risk perception, and venture formation: How individuals decide to start companies." Journal of business venturing **15**(2): 113-134.

Singley, M. K. (1989). The transfer of cognitive skill, Harvard University Press.

SolarUnited (2011). Annual report 2011.

Sonnenwald, D. H. (2007). "Scientific collaboration." Annual review of information science and technology **41**(1): 643-681.

Steinmo, M. and E. Rasmussen (2013). How firms collaborate with public research organizations: the evolution of proximity dimensions in successful innovation projects. 35th DRUID Celebration Conferance, Barcelona, Spain, June 17-19.

Stensli, M. (2013). Bedrifters utbytte av deltagelse i FME (Forskingssenter for Miljøvennlig Energi), Norwegian University of Science and Technology.

Teece, D. J. (1987). Technological change and the nature of the firm, Produced and distributed by Center for Research in Management, University of California, Berkeley Business School.

Tell, F. (2011). "Knowledge integration and innovation: a survey of the field." Knowledge integration and innovation: Critical challenges facing international technology-based firms: 20-60.

Tjora, A. (2012). Kvalitative forskningsmetoder i praksis, Gyldendal Akademisk.

Tsoukas, H. (1996). "The firm as a distributed knowledge system: a constructionist approach." Strategic management journal **17**(S2): 11-25.

TU (2009). "Umoe Solar dropper Norge." 2014, from http://www.tu.no/industri/2009/02/02/umoe-solar-dropper-norge.

Vie, O. E. (2012). "The need for knowledge integration in renewable energy innovation projects." Energy Procedia **20**: 364-376.

Von Zedtwitz, M. and O. Gassmann (2002). "Market versus technology drive in R&D internationalization: four different patterns of managing research and development." Research policy **31**(4): 569-588.

Weigelt, C. (2009). "The impact of outsourcing new technologies on integrative capabilities and performance." Strategic management journal **30**(6): 595-616.

Wenger, E. C. and W. M. Snyder (2000). "Communities of practice: The organizational frontier." Harvard business review **78**(1): 139-146.

Williamson, O. E. (1985). The economic intstitutions of capitalism, Simon and Schuster.

Winter, S. G. and R. R. Nelson (1982). "An evolutionary theory of economic change." University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.

Wuyts, S., et al. (2005). "Empirical tests of optimal cognitive distance." Journal of Economic Behavior & Organization **58**(2): 277-302.

Yin, R. K. (2009). Case study research: Design and methods, Sage.

ZEB (2014). "The research centre on Zero Emission Buildings." from http://www.zeb.no/.

Zietsma, C., et al. (2002). "The war of the woods: Facilitators and impediments of organizational learning processes." British Journal of Management **13**(S2): S61-S74.

# Appendix II: Interview guide research partners

**Informanten**

- Hva gjorde du før du startet her, hvilken utdanning og bakgrunn har du?

- Hvilken rolle har du i forskningsinstitusjonen i dag?

**Bakgrunnen for senteret**

- Kan du begynne med å si litt om bakgrunnen for at du er med i senteret?
    - Hva var din rolle i forhistorien til senteret?
        - Hadde du noen påvirkning?
    - Springer din deltakelse i senteret ut fra tidligere samarbeidsrelasjoner? Om så hvilke da (forskningssamarbeid, undervisningssamarbeid, bedriftssamarbeid)?
    - På hvilket tidspunkt ble vedkommende involvert i senteret (idefasen, søknadsfasen, etter finansiering)?
    - Hvordan ble du involvert, og hvor mye? (Tilfeldig, invitert, aktiv jobbing fra egen side)?
    - Fortell litt om hvordan dere gikk fram for å involvere bedriftspartnere.
    - Hvordan ser du for deg fremtiden din i senteret? (Endring i stilling, fortsette, spin-off, prestisje?)
- Kan du si litt om hva det å være [rolle] går ut på for din del? **(**Ansvar, rutiner**)**
- Hvordan, og i hvilken grad har du mulighet til å påvirke hvilke prosjekter som gjennomføres? **(**kan du starte et selv? Bestemmer du ressursfokus, eller hvem gjør egentlig det?)
- Kan du si litt om hvordan du viderefører det akademiske arbeidet ditt gjennom senteret? (Hvordan overføres taus kunnskap? Prosedyrer, normer, hvem overføres det til?)

**Bedriftsinvolvering**

- Var du involvert i arbeidet med å få partnerbedrifter inn i senteret? (Hvis nei, hvem burde vi snakke med?)
    - Kan du si litt om forhistorien for å trekke inn bedrifter i senteret? (Tidligere relasjon, partner blinket ut fordi passer inn tematisk i senteret, hva har vært hovedfokus? Penger, andre?)

- Fortell litt om hvordan dere gikk fram for å få de med som partner, krav fra begge parter

- Hvordan er bedriftene involvert konkret på aktivitetsnivå i din SP/oppgaver?
    - Hvilken kunnskap og kompetanse kan bedriftene bidra med? (Bidrar de med dette i det hele tatt?
    - Hvor ofte møtes dere? (Faste tider) Hvilken kontakt har dere med bedriftspartnere utenom formelle møter?
    - Hvordan fungerer ordningen med å ha forskningsfaddere? Fortell litt om ordningen.
    - Har du opplevd at en bedriftspartner har mistet interessen (Hvordan merket du det? Hva tenker du om det, hva var begrunnelsen? Har forventningene deres stemt med resultatene?)
    - Har dere opplevd å miste partnere, er det noen fellestrekk mellom de dere har mistet?
    - Hvordan går dere frem for å rekruttere ny partnere? (Hvem bidrar i denne prosessen, hva bidrar du med og hvem synes du burde bidratt?)
    - Hvordan jobber du for å holde bedriftspartnerne involvert i senteret og dine SP/oppgaver/aktiviteter?
    - Gjør de krav på den beste/mest anvendelige/ mest lovende og lønnsomme teknologien? Er fravær av" de beste ideene" som gjør at noen trekker seg?

**Innovasjonsaktivitet**

***Kommentar:*** *Vi ønsker å kartlegge innovasjonsaktiviteten i senteret samt eventuelle aktiviteter som er spunnet ut av senteret.*

- En del av formålet med FMEene er å utvikle innovasjoner, kan du si litt om hvordan dere i din gruppe jobbet med innovasjon?
    - Er innovasjon en integrert del av aktiviteten eller en "tilleggsaktivitet"?
    - Hvor opplever du at ansvaret for innovasjonsaktiviteter ligger? Pådrivere? Hvordan prioriteres innovasjon? Hvor mye av din og dine underordnedes tid brukes på dette? Prosjekter eller noen timer i uka?

- Hvilke innovasjoner kan knyttes til din gruppe/WP?
    - Har bedriftspartnere benyttet seg av resultater/kunnskap fra din SP/oppgaver (konkret)?

- Hvordan arbeider dere for å" oversette" kunnskap til bedriftspartnerne? Må noen bidra til erfaringsoverføring i person? Midlertidig ansettelse etc.?
- Hva er senter-deltakernes rolle etter aktiviteter har blitt spunnet ut?
- Hvordan har dere løst spørsmålet om "eierskap" av resultater fra prosjektet? Opplever du IP som problematisk?
- Har du andre eksempler på spin-off som har sprunget ut av miljøet (men ikke nødvendigvis senteret)? Kjenner du til forskere (ikke privat sektor) som har bidratt til eller blitt med i en spin-off Hva skjedde med spin-offene?

- På hvilken måte har deltakelse i senteret bidratt til samarbeid mellom bedriftene som deltar?
  - Samarbeid på andre områder, nye forskningsprosjekter?
- Hva tenker du om at innovasjon er et krav som stilles i FME instrumentet? (vs kompetansebygging)

**Avsluttende spørsmål**

- Har du noen erfaringer eller tips til hvordan man kan få til gode samarbeid mellom bedriftspartnere og akademia i slike prosjekt? Hva må til?
- Vi ønsker å nøste videre i dette med innovasjon som kommer ut av FMEer. Hvilke personer er det relevant å snakke med i Solar United eller i samarbeidsbedriftene/forskningspartnerne i neste omgang?
- Vi ønsker også å studere konkrete eksempler der samarbeidet mellom akademia og bedriftspartnere har fungert veldig godt (spennende historier, solskinnshistorier eller sammenbrudd), hvem i Solar United kan vi prate med for å nøste mer opp i dette?

Kommentar:

- Få frem folks opplevelse av samarbeidet.
- Vi må forsøke å få frem de gode eksemplene. Still spørsmål underveis og be om eksempler dersom noe bør tydeliggjøres (eks. dersom en bedrift opplever samarbeid med FoU som vanskelig, kan man si: «Den utfordringen du snakker om nå, kan du knytte det til et eksempel»).

# Appendix II: Interview guide industry partners

## Informanten

- Hva gjorde du før du startet her, hvilken utdanning og bakgrunn har du?
- Hvilken rolle har du i bedriften i dag?
- EVT: Mer om bakgrunn: erfaring fra andre bedrifter, erfaringer og avdelinger?)
- EVT: Vurdere å stille spørsmål om bedriftsstørrelse og– enhet

## Bakgrunn for samarbeidet og involvering

- Kan du si litt om bakgrunnen for din bedrift er/var med i samarbeidet?
    - Incentiv og formål?
    - Forventning om avkastning?
- Hvordan var (og er) deres bedrift med på å definere tema (og aktiviteter)?
    - Eksempler?
    - Er det et sideprosjekt eller hovedprosjekt?
    - (I hvilken grad har bedriften/nøkkelpersoner hatt samarbeid med FoU-miljøer før FME-prosjektet?)
    - Hvem er beslutningstaker for å bli med i eventuelt prosjekt?

## Deltakelse

Involverte personer

- Hva er/var dine oppgaver og ansvar i forbindelse med Solar United?
- Hvem andre i din bedrift har tilknytning til Solar United? (Formelt eller uformelt)
- Hvor store ressurser har dere investert i prosjektene (Finansielle, menneskelige timer etc.)
    - (Får dere igjen det dere forventet for investerte ressurser?)

Rutiner og kommunikasjon

- Hvordan følges samarbeidet opp fra de involverte partene?
    - Hvor ofte møtes dere, hvem er tilstede? (Fastsatt?)
    - Hva besluttes i disse møtene?
    - Kontakt med forskerne/forskningsmiljøene utover formelle møtene? Hvem kontakter i så fall hvem og hvorfor?
- Hvordan påvirker strukturen til Solar United dette arbeidet?

Bruk av kunnskap

- Hva er det viktigste dere har lært/erfart av å jobbe sammen med Solar United?
- Vil dere fortsette med denne typen samarbeid med FoU-miljøene (eventuelt andre FoU aktører) på andre områder?

**Samarbeidets dynamikk**

- Hvordan foregår samarbeidet? Workshops, prosjekt, fysisk vs virtuelt, grupper vs 1-til-1 etc.?

Relasjoner

- Hvor viktig og hvordan er personlige relasjoner/nettverk (For samarbeidsdynamikken)
- Opplever du at dere og forskerpartnerne/Solar United har god kommunikasjon?
    - Mener du det er felles forståelse mellom de ulike partene som er involvert?
    - Hvordan kunne dette eventuelt blitt bedre? Hva mener *du*?

Deling og IKT

- Hvordan deles kunnskap med de andre i prosjektet? (ERP/CMS)
    - Har dere en systematisk måte å gjøre kunnskap fra forskningssamarbeidet tilgjengelig for andre i din bedrift?
    - Hvordan deles taus vs. eksplisitt kunnskap?
- Hvordan lærer dere av hverandre? (Evt. hvorfor, hvorfor ikke? Overføring av taus kunnskap)

**Innovasjonsaktivitet**

Et viktig formål med FMEene er at de skal bidra til mer innovasjon

- Opplever du at innovasjon er en integrert del av samarbeidet eller mer en" tilleggsaktivitet"?
- Føler du at strukturen til senteret er optimalt i forhold til dette?
    - Hva kunne eventuelt vært annerledes?
- Hvilke potensielle resultater fra senteret vil være mest nyttige for dere?
    - Har du noen konkrete eksempler?
    - Hvem andre drar eventuelt nytte av resultatene?

    - Hvordan benytter dere resultater (f.eks.) kunnskap fra senteret?
- Har du tanker rundt spin-offs basert på forskningsresultatene fra samarbeidet?
- Er det noen problematikk rundt IP i samarbeidet?
- Åpner samarbeidet for nye muligheter (Business og samarbeid)?
- Hvordan har resultatene og utføringen av samarbeidet innfridd forventningene?

**Avsluttende spørsmål**

- Har du tanker rundt hvordan man kan få til godt samarbeid mellom bedriftspartnere og forskningspartnere i slike prosjekt?
    - Ideer til hvordan det kan skapes mer? Arbeidsplasser, innovasjon, spin-offs etc.
- Norge er i posisjon til å være ledende i solenergi. Burde vi være et kompetansesenter selv om det ikke er lønnsomt å produsere solceller her? Tanker? Er dette et alternativ dere har hørt om eller vurdert tidligere?
- Hva tenker du om at Solar United blir "lagt ned" i 2017, hvilke konsekvenser får det for dere?
- (Hvem andre burde vi snakke med?)

Kommentar:

- Få frem folks opplevelse av samarbeidet.
- Vi må forsøke å få frem de gode eksemplene. Still spørsmål underveis og be om eksempler dersom noe bør tydeliggjøres «Den utfordringen du snakker om nå, kan du knytte det til et eksempel»).