

# FME HighEFF

## Centre for an Energy Efficient and Competitive Industry for the Future



### Deliverable D5.1\_2020.03

#### Barriers, drivers, innovation, Book Chapter

Delivery date: 2020-10-30

Organisation name of lead partner for this deliverable:

**NORD Universitet**

**HighEFF- Centre for an Energy Efficient and Competitive Industry for the Future is one of Norway's Centre for Environment-friendly Energy Research (FME).  
Project co-funded by the Research Council of Norway and Industry partners.  
Host institution is SINTEF Energi AS.**

#### Dissemination Level

PU	Public	x
RE	Restricted to a group specified by the consortium	
INT	Internal (restricted to consortium partners only)	

<b>Deliverable number:</b>	D5.1_2020.03
<b>ISBN number:</b>	
<b>Deliverable title:</b>	Barriers, drivers, innovation, Book Chapter Steinmo, M. The role of research centers in developing radical innovation for sustainability. Sustainable Innovation: Strategy, Process, and Impact, ed. Voinea, C.L., Roijakkers, N., Ooms, W. Routledge/Taylor & Francis.
<b>Work package:</b>	WP5.1
<b>Deliverable type:</b>	Book Chapter
<b>Lead participant:</b>	Marianne Steinmo at Nord university

<b>Quality Assurance, status of deliverable</b>		
Action	Performed by	Date
Verified (WP leader)	Jens Røyrvik	2020-11-06
Reviewed (RA leader)	Ingrid Camilla Claussen	2020-11-06
Approved (dependent on nature of deliverable)*)		

\*) *The quality assurance and approval of HighEFF deliverables and publications have to follow the established procedure. The procedure can be found in the HighEFF eRoom in the folder "Administrative > Procedures".*

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<b>Abstract</b>
<p>Radical innovation is a key to sustainability and to firms` long-term competitive advantage because this type of innovation involves the development of technologies that represent a fundamental change from firms` existing practices, knowledge, principles and ideas. Different types of innovations require various knowledge bases and types of expertise. Incremental innovation requires a deep and refined understanding of existing knowledge, whereas radical innovation requires entirely new knowledge and skills that may introduce substantial changes to a firm`s existing knowledge, capabilities and routines. To obtain access to the knowledge needed to develop radical innovation for sustainability, firms can be involved in research centers where firms collaborate with a diverse set of partners, such as universities and R&amp;D organizations. This chapter addresses the role of research centers in developing radical innovation for sustainability and discusses firm enablers for managing innovation development during three phases of a research center: the establishing phase, the performance phase and the end phase. This chapter provides important implications and guidelines for firms on how to manage radical innovation for sustainability in research centers.</p>

## The role of research centers in developing radical innovation for sustainability

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### Abstract

Radical innovation is a key to sustainability and to firms' long-term competitive advantage because this type of innovation involves the development of technologies that represent a fundamental change from firms' existing practices, knowledge, principles and ideas. Different types of innovations require various knowledge bases and types of expertise. Incremental innovation requires a deep and refined understanding of existing knowledge, whereas radical innovation requires entirely new knowledge and skills that may introduce substantial changes to a firm's existing knowledge, capabilities and routines. To obtain access to the knowledge needed to develop radical innovation for sustainability, firms can be involved in research centers where firms collaborate with a diverse set of partners, such as universities and R&D organizations. This chapter addresses the role of research centers in developing radical innovation for sustainability and discusses firm enablers for managing innovation development during three phases of a research center: the establishing phase, the performance phase and the end phase. This chapter provides important implications and guidelines for firms on how to manage radical innovation for sustainability in research centers.

### 1.0 Introduction

As the mitigation of environmental degradation gains prominence on the policy agenda, firms' innovation activities play a vital role in the transition to a more sustainable society (Cainelli et al., 2015). At the same time, firms must constantly create new products, services and processes to acquire competitive advantage and survive in the long term (Kodama and Shibata, 2014). If firms are to contribute to sustainability, they need to improve their existing products and processes by making them more efficient (incremental innovation) (Schmidt and Calantone, 1998). However, radical innovation is the key to sustainability (Cainelli et al., 2015) and to firms' long-term competitive advantage (Kodama and Shibata, 2014) because this type of innovation involves the development of

technologies that represent a fundamental change from firms' existing practices, knowledge, principles and ideas (Dewar and Dutton, 1986).

Different types of innovation require various knowledge bases and types of expertise. Incremental innovation requires a deep and refined understanding of existing knowledge (Tsai, 2001), whereas radical innovation requires entirely new knowledge and skills that may introduce substantial changes to a firm's existing knowledge, capabilities and routines (Laursen and Salter, 2006, Benner and Tushman, 2002). To access new knowledge, firms can engage in different types of innovation collaboration, defined as *"co-creation with (mainly) complementary partners through alliances, cooperation, and joint ventures during which give and take are crucial for success"* (Enkel et al., 2009, p. 313).

Although some firms succeed in capturing value from the strategies and capabilities associated with innovation collaboration, firms often fail to successfully implement innovation through collaboration (Knudsen and Mortensen, 2011, Laursen and Salter, 2006), and researchers have suggested that it is far from easy to identify and assimilate relevant external knowledge sources (Cohen and Levinthal, 1990). Moreover, firms find it difficult to implement comprehensive changes that will drive sustainability (Ionescu-Somers, 2012). Hence, more research is needed on the "determinants of successful open innovation" (Lichtenthaler, 2010, p. 86) and on how firms can invest and build competencies and capabilities that are focused on the exploration and exploitation of external knowledge (Lichtenthaler, 2009). This conceptual paper responds to these knowledge gaps by discussing the role of research centers for firms seeking to develop radical innovations focused on sustainability. Research centers are joint ventures among university, industry and governmental funding organizations (Lind et al., 2013). They have become one of the predominant policy responses aimed at facilitating research solutions that require scientific and technical input from multiple disciplines and perspectives to address challenges that organizations are unwilling to address alone due to resource need and risk (Boardman, 2011). Research centers are therefore a unique setting in which firms might foster radical innovation for sustainability. Hence, this chapter addresses the following questions: (1) How can firms manage to develop radical innovation for sustainability? (2) What is the role of research centers in stimulating the development of radical innovation for sustainability?

To address these questions, this chapter first presents the literature on sustainable innovation, followed by a discussion of the role of incremental and radical innovation in sustainability. Then, the paper discusses the knowledge needed to develop different types of innovation (radical, in particular)

and how firms can access that knowledge through different types of collaborations. The paper ends with a discussion of the role of the research center and how to enable firms to generate sustainable radical innovations in research centers. Radical innovation is the focus of this chapter, but discussions of incremental innovation are used for comparison.

## 2.0 Theoretical framework

### 2.1 Sustainability-oriented innovation

As environmental degradation demands increasing policy attention, firms' innovation activities play a vital role in the transition to a more sustainable society (Cainelli et al., 2015, Seebode et al., 2012). Innovation (together with infrastructure) is strongly emphasized as one of the sustainable development goals adopted by the UN's General Assembly for the "2030 Development Agenda", in which 17 sustainability goals were announced as part of the vision for a sustainable future for humans and our shared planet (UN, 2015). Sustainability-oriented firms have shown that it is possible to be simultaneously socially responsible and profitable through sustainable innovation (Thu et al., 2018).

Many studies still emphasize the intersection of the environmental and economic dimensions of the widely used "triple bottom line" framework (Rennings, 2000), often employing innovation in terms of "eco-innovation", "green" or "environmental" innovation (e.g., Horbach et al., 2012, Schiederig et al., 2012). This chapter follows the definition of sustainability-oriented innovation provided by Arnold and Hockerts (2011), "*realized ideas that improve environmental and/or social performance compared with the current situation*" (p. 394), which implies products and processes that seek to improve environmental and/or social performance (Hansen and Grosse-Dunker, 2013). This term considers both the environmental and social dimensions of innovation and suggests that the performance improvement of both is necessary for the sustainable innovation performance of firms (Kennedy et al., 2017).

Sustainability-oriented innovation remains understudied (Hansen and Grosse-Dunker, 2013), and scholars often fail to differentiate between radical and incremental innovation (Dangelico et al., 2013). Both types of innovation are important for sustainability and involve a continuum ranging from minor improvements of existing products and processes to a total change in their nature (Dodgson et al., 2008). Hence, the role of different types of innovations for sustainability is discussed.

### 2.2 The role of incremental and radical innovation in sustainability

As shown in Table 1, incremental innovation involves cumulative improvements based on existing technological principles and continual changes in technologies and products (Schmidt and Calantone, 1998). Incremental innovation involves “*relatively minor changes in technology and provide relatively low incremental customer benefits per dollar*” (Chandy and Tellis, 1998, p.476), and the knowledge and skills embodied in incremental innovation are mostly present within the firm (Robertson et al., 2012). Firms benefit from incremental innovation because they produce more efficient products and processes that enhance and increase consumption experiences without disrupting customers’ prior knowledge or requiring new learning (Menguc et al., 2014).

**Table 1** Distinction between incremental and radical innovation

	Incremental innovation	Radical innovation
Definition	Cumulative improvements based on existing technological principles and continual changes in technologies and products (Schmidt and Calantone, 1998).	Development of technologies representing a fundamental change from firms’ existing practices, knowledge, principles and ideas (Dewar and Dutton, 1986).
Knowledge & skills	Deep and refined understanding of existing knowledge (Tsai, 2001), mostly present within the firm (Robertson et al., 2012).	New and broad set of knowledge and skills that may introduce substantial changes in a firm’s existing knowledge, capabilities and routines (Laursen and Salter, 2006, Benner and Tushman, 2002).
Risk	Less risky (Yamakawa et al., 2011).	Highly risky (Yamakawa et al., 2011).
Time of diffusion	Short-term performance impact for firm (Yamakawa et al., 2011).	Long-term performance impact for firm (Yamakawa et al., 2011).
Type of collaboration	Deep collaboration with actors providing similar knowledge (Katila and Ahuja, 2002).	Collaborative breadth with a diverse set of resources providing new knowledge (King et al., 2003).
Central collaborative partners	Suppliers (Sobrero and Roberts, 2002), customers (Von Hippel, 2007), and competitors (Gnyawali and Park, 2011).	Universities and public research organizations (Hall and Bagchi-Sen, 2007).
Potential for sustainability	Low potential for sustainability (Hellström, 2007) and failure to address the causes of unsustainable global problems (Whiteman et al., 2013).	High potential for sustainability (Hellström, 2007).

Conversely, radical innovation involves the development of technologies that represent a fundamental change from firms’ existing practices, knowledge, principles and ideas (Dewar and Dutton, 1986). Ahuja and Morris Lampert (2001, p. 253) define radical innovation as “*those foundational inventions that serve as the basis for many subsequent technical developments*”, thereby defining radical innovation as a source for the subsequent development of incremental innovation (Schoenmakers and Duysters, 2010). Unlike incremental innovation, which mainly applies existing knowledge, radical innovation requires firms to come up with novel ideas that address customer problems through technologies that are distant from existing approaches (Zhou and Li, 2012). Well-known examples of radical innovation include the shift from pistol aircraft engines to turbojets and the

change from steam to diesel electric locomotives (McDermott and O'Connor, 2002). Radical innovation is critical to long-term firm success and competitiveness because the potential rewards are much higher (McDermott and O'Connor, 2002). Furthermore, firms that create radical innovation are able to deliver breakthrough technologies that benefit customers and alter the ways new products and processes are experienced and used (Chandy and Tellis, 1998).

Different levels of risks and diffusion time are associated with incremental and radical innovation. Because radical innovation requires new knowledge and represents a departure from existing practice, they tends to be more costly and associated with higher risks compared to incremental knowledge, which relies more on existing knowledge and existing markets (Germain, 1996, Yamakawa et al., 2011). Incremental innovation tends to take a shorter time to diffuse because it is more predictable, less risky and more proximate to previous innovation compared to radical innovation, which takes more time to diffuse (Yamakawa et al., 2011).

In the context of sustainability, the changes that characterize incremental innovation mostly relate to add-on or end-of-pipe improvements to existing technologies and to reductions in resource inputs, materials and waste, often referred to as “eco-efficiency” (Szekely and Strebel, 2013). Examples of incremental innovation for sustainability exist in a range of industries, such as building, manufacturing, electricity and heat generation, and they are important for firms’ competitiveness sustainability. However, while incremental innovation reduces waste and costs, they fail to address the causes of unsustainable global problems (Whiteman et al., 2013). Firms that only concern themselves with incremental innovation can suffer from a “carbon lock-in,” where they repeatedly return to their fossil-fuel path dependency (Arthur, 1994, Unruh, 2000). This lock-in situation might lock out more radical innovation, which is essential for sustainability (Könnölä and Unruh, 2007) and for long-term firm success and competitiveness and has much higher potential rewards (McDermott and O'Connor, 2002).

Radical innovation for sustainability is key to achieving the UN goal of sustainability because such innovation often arises from changes in technological paradigms and is a driving force of technological, industrial and societal change (Schoenmakers and Duysters, 2010). Hence, radical innovation for sustainability is needed to manage sustainability transitions, such as the shift from fossil fuels to solar energy (Fischer-Kowalski, 2011), the replacement of toxic substances, the creation of cradle-to-cradle loops, and the transformation of supply chains (Young and Tilley, 2006, Braungart et al., 2007). Because radical innovation is increasingly apparent in sustainability debates (Tukker and Butter, 2007) and is found to have higher potential for sustainability compared to incremental

innovation (Hellström, 2007), this chapter further discusses the *knowledge* needed for radical innovation, which is recognized as one of the most important antecedents of innovation processes (Darroch and McNaughton, 2002).

### 2.3 Knowledge needed for the development of sustainability-oriented radical innovation

Although there are many arguments that innovation is necessary for a sustainable transition, it is less clear what skills, techniques and approaches firms should use to develop radical sustainability-oriented changes (Seebode et al., 2012). The development of incremental innovation relies mainly on internal knowledge sharing, individually held know-how and the construction of deeper and more refined understandings of existing knowledge (Tsai, 2001) and is “*associated with recombination that consists of combining improved components that are already connected within a technological domain or from technologically proximate domains*” (Keijl et al., 2016, p. 1026). In contrast, radical innovation requires an entirely new set of knowledge and skills that may introduce substantial changes in a firm’s existing knowledge, capabilities and routines (Laursen and Salter, 2006, Benner and Tushman, 2002) (see Table 1). Firms’ abilities to respond to market opportunities for radical innovation are enhanced by a broad knowledge base with varied accumulated observations and understandings of new information and knowledge (Chesbrough et al., 2006). Diverse knowledge often stimulates various ideas that only touch the surface of emerging breakthroughs instead of digging down to their core, a situation that likely promotes incremental innovation (Laursen and Salter, 2006).

This chapter mainly explores radical innovation, which has strong potential to contribute to sustainability (Hellström, 2007). Therefore, the next issue to address is how firms can *obtain access* to a new set of broad and diverse knowledge bases and skill sets required for radical innovation for sustainability. Firms’ access to the knowledge needed for radical innovation for sustainability relates to the UN’s 17<sup>th</sup> sustainability goal, which indicates that collaboration plays an essential role in setting the world on a sustainable path (Schaltegger et al., 2018, UN, 2015). Several sustainability researchers also consider the benefits of open innovation (Keskin et al., 2013) and collaboration (e.g. Lang et al., 2012, Wiek et al., 2012) to be critical to solving the complex challenges of sustainability.

### 2.4 The role of collaboration for radical innovation for sustainability

Considering the importance of going beyond the firm’s organizational boundaries to gain access to the knowledge needed for innovation, collaboration with external actors is at the heart of the open



innovation perspective (Von Hippel, 2007, Chesbrough et al., 2006). The idea that openness is beneficial for innovation is based on the premise that a single firm cannot innovate in isolation but must engage external actors (e.g., customers, suppliers, competitors and R&D organizations) to obtain access to ideas and resources that enrich and expand its technological resource base (Dahlander and Gann, 2010). Scholars have identified collaboration as important to sustainable innovation because of its complexity and uncertainty (De Marchi, 2012, Adams et al., 2016) and have begun to consider the synergy between open innovation and sustainability (Slotegraaf, 2012).

Open innovation exists along a continuum that represents various levels of collaboration breadth and depth – in terms of knowledge and partnership – that might also influence the outcome of innovation (incremental vs. radical) (Kobarg et al., 2019). Collaboration depth refers to the intensity and extent of the interaction between firms and their collaborative partners and determines opportunities for knowledge transfer and learning (Kobarg et al., 2019). Greater collaboration depth can facilitate trust between collaborative partners and ease both knowledge transfer and the acquisition of complex external knowledge (Lane et al., 2006).

Incremental innovation is driven by improvements in existing knowledge, and the knowledge and skills embodied in these innovations are usually *close to the firm's knowledge bases* (Yamakawa et al., 2011). Therefore, repeated, deep collaboration can be used to develop incremental innovation because it gives firms access to familiar knowledge (Katila and Ahuja, 2002). Examples of collaborations where external partners possess similar knowledge include collaborations among suppliers, which often trigger improvements to existing products and processes (Sobrero and Roberts, 2002); collaborations with customers, who can be knowledge sources for new ideas about existing practices (Von Hippel, 2007); and collaborations with competitors, which give firms access to industry-specific knowledge (Gnyawali and Park, 2011).

Conversely, the breadth of collaboration for innovation can be defined as *“the number of external sources or search channels that firms rely upon in their innovative activities,”* and depth can be defined as *“the extent to which firms draw deeply from the different external sources”* (Laursen and Salter, 2006). Collaboration breadth can therefore be determined by the number and diversity of external partners, the variety of shared experiences (Kobarg et al., 2019), and the complexity of knowledge transactions (Sirmon et al., 2011). Because radical innovation is primarily characterized by the newness of knowledge, is complex in nature and requires multiple connections to internal and external actors in the value chain (Dewar and Dutton, 1986), this type of innovation requires collaborative breadth (Kobarg et al., 2019). Moreover, greater collaborative breadth indicates diverse

resources (King et al., 2003) that expand the resource base to share the risk associated with radical innovation (Green et al., 1995).

Universities and R&D organizations are essential collaborative sources for firms seeking to develop radical innovation (Hall and Bagchi-Sen, 2007) because they provide firms with specialized and broad knowledge and give firms access to fundamental knowledge and the opportunity to conduct high-quality research (Laursen and Salter, 2006).

#### 2.4.1 R&D collaboration for radical innovation for sustainability

Perkmann and Walsh (2009) identify four types of collaboration between firms and universities and R&D organizations (henceforth, R&D partners): knowledge generation, idea testing, technology development and problem solving. The goals of these collaborations can range from basic research projects steered by researchers to applied projects that solve firms' problems. These collaborations aim to develop new scientific and technical knowledge and involve different types of R&D partners (e.g., R&D organizations and universities) and firms of different sizes. The R&D partners are focused on the development of new knowledge, while firms explore and exploit the knowledge through innovative opportunities created through collaboration for economic benefits (McKelvey et al., 2015). Research centers represent one essential type of collaboration between firms and R&D partners that aims to cover the range of activities from knowledge generation to problem solving and thereby involves both firms' aim of developing innovation and R&D partners' aim of developing new knowledge. The next section discusses the role of research centers as instruments for radical innovation in sustainability.

#### 2.4.2 The role of research centers for sustainable radical innovation

Research centers have become one of the predominant policy responses that facilitate research collaboration spanning the boundaries of government, R&D organizations and industry. By joining firms with universities and R&D organizations, research centers aim to develop solutions that require scientific and technical input from multiple disciplines and perspectives to address challenges that organizations are unwilling to address alone due to resource requirements and risk (Boardman, 2011). A research center can be defined as a *“joint venture between the university, industry and governmental funding organisations, identifying some domain of research where industry and*

*academy can benefit from collaborating*” (Lind et al., 2013, p. 910). Bringing together R&D partners and firms in research centers is an attempt to stimulate the production of academic research and radical innovation (Ponomariov and Boardman, 2010, Styhre and Lind, 2010) and to address social and economic problems (e.g., sustainability) that cannot easily be addressed by R&D actors, firms or the government (Stokols et al., 2008).

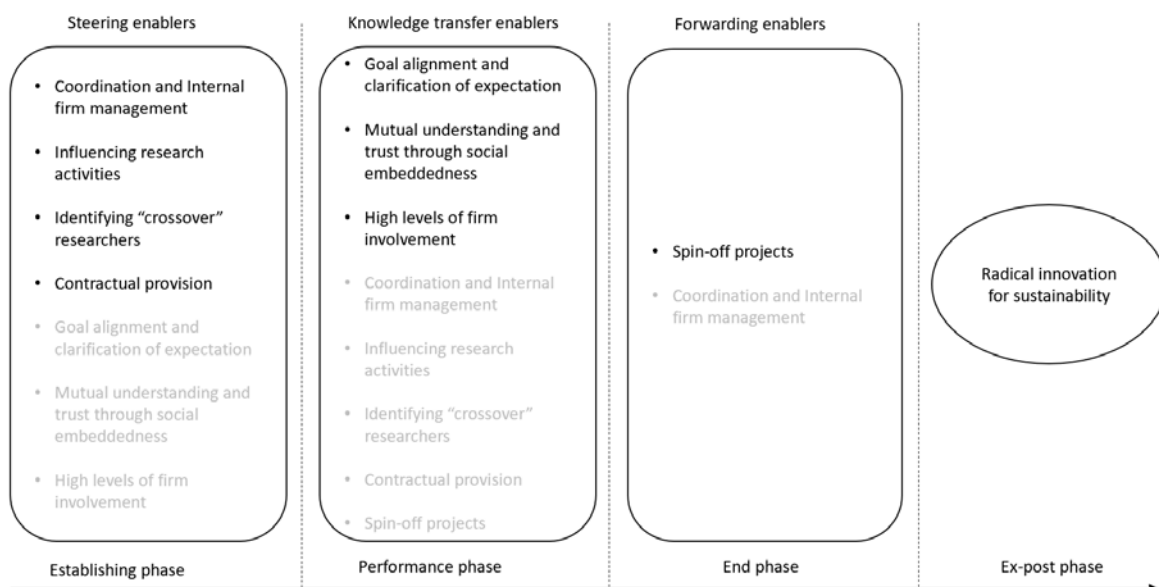
Research centers are a key solution to support sustainable development because they often focus on research and development that aims to be “transformative” and “paradigm-shifting”; their research is characterized as “blue-sky” or as having a “high risk-high yield” (Boardman and Gray, 2010). With a broad and diverse set of collaborative partners, research centers provide firms with the specialized knowledge bases (Gulbrandsen et al., 2015) required for radical innovation (Kobarg et al., 2019). Moreover, R&D partners deliver scientific knowledge and highly skilled labor to the collaborative firms, which in turn provides R&D partners with funding, equipment and a range of research projects to pursue (Feller and Roessner, 1995). Research centers are also a valuable source of radical innovation collaboration due to their time horizon (usually 5-8 years) (McKelvey et al., 2003), which supports the idea that radical innovation takes time to develop and that the partners (both R&D partners and firms) will most likely benefit from the results in the long run by identifying possible future economic applications of the innovations and deriving returns (O'Connor et al., 2008).

Research centers are university-based; they have clear, predefined tasks, obligations and divisions of labor (Ménard, 2004) and represent higher structural levels of scientific and technical research compared to university-based research units in general, such as department laboratories (Friedman, 1982). Moreover, research centers can be relatively hierarchically structured. They may have a manager representing an R&D partner that establishes the overall goals, evaluates performance, and selects projects for the research activities within the centers, which are typically supported and controlled by an advisory board (Bozeman and Boardman, 2003).

In sum, research centers are a valuable source of radical innovation for sustainability. Their value stems from “structural reasons”, such as their long-term orientation, focus on “blue-sky” innovation and access to a diverse and broad set of actors with the specialized knowledge bases required for radical innovation. Moreover, because firms find it difficult to implement a comprehensive change to drive sustainability (Ionescu-Somers, 2012) and to obtain support for long-term radical innovation that carries high risks (McDermott and O'Connor, 2002), research centers are a unique way for firms to share the risk with several actors and to obtain access to the resources needed to develop radical innovation.

## 2.5 Key enablers of firms seeking to develop radical sustainable innovation in research centers

Although research centers are a valuable tool for firms seeking support for radical innovation for sustainability, there are significant institutional and knowledge boundaries between firms and R&D partners that make such collaborations challenging (Steinmo, 2015, Miller et al., 2016, Galán-Muros and Plewa, 2016). The next section discusses key enablers for firms to overcome potential challenges and thus manage long-term radical innovation development for sustainability in collaboration with R&D partners in research centers. Figure 1 illustrates the enablers of three central phases of a research center, (1) “steering enablers”, (2) “knowledge transfer enablers” and (3) “forwarding enablers”, which involve the establishment (before and when entering the collaboration), performance (during the collaboration) and end (last year(s) of collaboration) of research centers, respectively. It is worth noting that each of the discussed enablers is important throughout all the phases of a research center, but these enablers are of the utmost importance during the phase under which they are presented in the figure. Hence, in Figure 1, the most important enablers for each phase are marked in bold type.



**Figure 1** Firm enablers for managing radical innovation for sustainability in research centers

### 2.5.1 Establishing phase – steering enablers

There are four aspects in particular that firms should consider when establishing a research center but that are also important in the performance phase: (1) coordination and internal firm management of involvement in the research center, (2) influencing research activities, (3) identifying crossover researchers, and (4) contractual provision. These enablers mostly pertain to important internal aspects of how the firm steers the research center at the very beginning to manage long-term radical innovation for sustainability.

### ***(1) Coordination and Internal firm management of involvement***

Schoenmakers and Duysters (2010) suggest the need for more coordination of internal firm management to acquire the knowledge necessary to develop radical innovation. This is an important requirement to consider when firms are invited by researchers to become partners in a research center. To this end, firms should ensure that the firm's strategy is in line with the firm's involvement in the research center and that the owners of the company have the patience to be involved in long-term radical innovation development. In this situation, an in-depth presentation of the aim and potential benefits of the research center to the firm's board of directors is essential. Such a presentation can ensure that board members dedicate the necessary resources to reap long-term benefits from the collaboration and that board members have the understanding and patience needed for radical innovation because a successful radical innovation will most likely benefit the firm in the long run. The board's resolution of the firm's involvement in the research center and its commitment to resource allocation will secure long-term involvement and prevent the firm from dropping out of the center prematurely.

Firms could also create a strategic plan for firm involvement and goals for their involvement in the research center. These plans and goals should articulate the firm's level of involvement as well as the personnel and resources required to achieve radical innovation development in the long run.

### ***(2) Influencing research activities***

Because the research center's application often sets the agenda for the collaboration and acts as the foundation for continuing collaboration, firms should ensure that they obtain a complete overview of the thematic and working tasks of the research center, and they should influence and suggest user-oriented research activities that are in line with the interests of the firm. This influence on research activities is also important in the performance phase to increase the usefulness of the knowledge and research results developed. Therefore, firms should conduct thorough internal discussions to highlight

themes relevant to the research center both in the application phase and during the collaboration to provide benefits to the firm.

However, because the outcome of radical innovation can rarely be anticipated and often requires a new set of knowledge and skills provided by universities and R&D organizations (Laursen and Salter, 2006), it is crucial that firms attend to their research partners' suggestions for long-term research activities to foster radical innovation and avoid excessive steering of the research activities, which may result in incremental innovation outcomes. Finding a balance between activities driven by researchers and by firms can be accomplished by including projects within the center with different time horizons (short and long term) and research orientations (basic and applied research). Some short-term applied research projects (1-2 years) will likely contribute to more frequent research results for firms and greater motivation and patience to be involved in long-term research activities driven by researchers, thus preventing unsatisfied firms from dropping out of the center.

### ***(3) Identifying the crossover researchers***

Because research centers often consist of a large range of diverse researchers (representing universities and R&D organizations), they usually include researchers with different academic orientations, such as those with an orientation toward a “fundamental understanding” or the “utility” of their research (Tijssen, 2018). Tijssen (2018) capture the use-inspired identity of researchers in three archetypes: (1) “science-oriented” researchers who perform scientific research with high levels of knowledge production, (2) “application-oriented” researchers who are highly concerned with technological development, and (3) “user-oriented” researchers who have high levels of interaction with users outside the research community who will use and/or benefit from the research results through commercialization and innovation. However, user-oriented researchers have been found to provide lower rates of academic output (Tijssen and Yegros, 2017). Tijssen and Yegros (2017) have identified a fourth type, “crossover” researchers, who tend to combine these three orientations. Crossover researchers often have prior employment experience in the business sector, are engaged with firms through joint research and commercialization activities, and show better research performance than their non-entrepreneurial peers (Abramo et al., 2012, Tijssen and Yegros, 2017). Several studies suggest that crossover researchers act as exchange agents between the worlds of science and the business sector (Mangematin et al., 2014). Therefore, crossover researchers are of

special importance for research centers that merge these two worlds to achieve long-term innovation goals by including numerous firm and R&D partners.

Arguably, firms involved in research centers should be attentive to the different research orientations of researchers to be more strategic about those with whom they establish research projects in the establishing phase (and in the performance phase) because researchers are likely to shape their research to achieve a particular outcome. Research projects shaped by application-oriented and user-oriented researchers will most likely yield development projects with incremental innovation outcomes because these types of researchers likely hold knowledge bases quite similar to those of firms. Hence, to promote long-term radical innovation performance as well as user-oriented research, firms mostly engage in projects with crossover researchers, which supports a threefold research orientation of scientific research, technological development and user orientation. Firms should therefore invest time in getting to know the researchers in the research center by asking questions about their research interests and orientations and their prior experience to identify and capitalize on relationships with crossover researchers.

#### ***(4) Contractual provisions***

Academic research conducted in research centers has limitations regarding the disclosure and further development of research results, methods or materials (Lerner and Merges, 1998). Hence, the utilization of research results developed in a research center depends on contractual provisions – devised by the owners – that govern the access to and openness of the results and technologies. Because firms often strive to secure private financial results and universities and R&D organizations seek to commercialize research results, contractual agreements between the partners are important to control intellectual property (IP) (Czarnitzki et al., 2014). A collaboration agreement that governs how the involved partners address research results and IP in a way that conforms to the regulations of the research center's funding is also important to build trust-based collaboration between firms and R&D organizations (Rappert et al., 1999), which is a prerequisite of knowledge sharing (Steinmo and Rasmussen, 2016).

Hence, firms should consider and decide what research activities they can conduct in open innovation projects where the research results can be made publicly available for all partners as well as the activities and results that must be confidential and/or controlled through IP. Firms' ability to distinguish between knowledge and research results that should be open or secret requires internal

discussion within the firms and thorough negotiations with the research partners early in the collaboration. These decisions should not be left to external actors (such as lawyers). Firms need control over specific research activities, and results can be achieved by negotiating contractual agreements that feature at least one research partner early in the collaboration that works with firm-specific research activities. These activities could also be addressed through parallel projects conducted outside the research center that translate the publicly available knowledge developed in the center to more specific and applied results that are useful for individual firms.

However, firms' demand for control is likely to hamper long-term radical innovation processes that require broad knowledge bases from different sources and openness from different firms during the knowledge-creation process. Firms should therefore be as open as possible in sharing the knowledge that contributes to a collective knowledge development process, which is required to achieve the goal of radical innovation for sustainability. This can be done by engaging in formal and informal meeting arenas in the research center where firm-specific knowledge and experience decided by the firm is shared. As such, the firm representatives who engage in the research center should be given a mandate from the firm to not only consider their operations and short-term benefits but also use their knowledge to identify and explore research possibilities with their partners, which is the likely starting point to develop radical innovation for sustainability. To secure an open knowledge-sharing process, contractual agreements that regulate access to and ownership of potential future innovation outcomes should be negotiated and established early in the collaboration to secure the firm's benefits of the knowledge it has contributed in the beginning of and during the innovation process. Such agreements will likely contribute to a more open knowledge-sharing process because the firms ensure long-term benefits of their contributions of "intellectual" assets. Such contractual agreements are typically negotiated at the end of R&D collaborations when solutions and research results are developed, but it is strongly recommended that they should be considered in the early phases of collaborations because it is easier to negotiate the IP of potential outcomes prior to its existence.

Because the knowledge and results developed in research centers cannot always be anticipated, continuous awareness of open vs. firm-specific knowledge and results is also important in the performance phase of a research center, when substantial research activities are established.

### 2.5.2 Performance phase – knowledge-transfer enablers

Firms should focus on three aspects during the performance phase of a research center: (1) goal alignment and clarification of expectations, (2) mutual understanding and trust through social



embeddedness, and (3) high levels of firm involvement. These enablers mostly focus on how firms manage efficient knowledge transfer processes with R&D partners, which is a prerequisite for the enhancement of radical innovation for sustainability.

### ***(1) Goal alignment and clarification of expectations***

Differences in organizational structure, management, goals, and problem solving sometimes hinder collaborations between academic and commercial entities (Ambos et al., 2008, Bjerregaard, 2010) and can lead to goal conflicts (Bozeman and Boardman, 2003). Whereas the aim of universities and R&D organizations is to educate and perform fundamental academic research, firms seek to develop commercially valuable products and services (Ambos et al., 2008). Furthermore, universities and R&D organizations often have a long-term orientation, whereas firms are more oriented toward short-term, applied research that can lead to solutions to current problems (Spithoven et al., 2011). These differences might hamper the performance of radical innovation in research centers. Hence, to avoid goal conflicts, it is important that the partners conduct in-depth conversations to understand each other's interests and how they can contribute to radical innovation performance. These conversations can ease the process of formulating shared goals for the collaboration that are beneficial to both partners' involvement in radical innovation.

Because radical innovation requires time to develop, it is important to facilitate effective dialogue early in the collaboration process so that the partners can clarify their expectations, ask questions and develop an understanding of the different goals and requirements of their work in the research centers. Firms should also address unrealistic expectations and be patient because it takes time to manage a successful and vigorous collaboration with research partners to develop radical innovation.

### ***(2) Mutual understanding and trust through social embeddedness***

As evidenced by the many unsuccessful attempts at knowledge transfer between firms and R&D organizations, it can be challenging to develop trust and establish a common understanding in communications and interactions between firms and academics (Steinmo and Rasmussen, 2016, Santoro and Bierly, 2006). Trust and common understanding are typically developed when firms are socially embedded (Boschma, 2005) in the research center and engaged with researchers in both formal (e.g., meetings and workshops) and informal arenas (ad hoc contact). Because similar partners

are better able to transfer knowledge (Nooteboom et al., 2007), social embeddedness is of the utmost importance to the development of a radical innovation that requires that *different* and often unknown partners collaborate. Hence, firms should understand how to manage and organize their social relationships with researchers and dedicate considerable time to engaging with unknown researchers when they begin collaborating and over time (Steinmo and Rasmussen, 2018).

### **(3) High levels of firm involvement**

Firm involvement is an important premise for successful university-industry collaboration (Santoro, 2000, Mora-Valentin et al., 2004, Núñez-Sánchez et al., 2012). Due to the challenge of collaborating with a diverse set of actors, as is required for radical innovation, high levels of interaction and firm involvement are needed in research centers (Gulbrandsen et al., 2015).

When research centers are established and when firms have signed collaborative contracts and received grants from the support schemes, some firms might expect to have already achieved the “golden ticket” to innovation without making any appreciable contribution. Nevertheless, collaboration between firms and R&D organizations is a two-way engagement and requires contributions from both partners. When entering a research center, firms should therefore dedicate the resources needed to involve several employees (from the strategic to the more operative levels) to ensure successful collaboration with the research center. As such, firm leaders should explicitly focus on motivating and dedicating several employees to engage in frequent interaction with the research center. In particular, leaders should dedicate a boundary spanner who acts as the main firm representative in the research center. This person functions as the “link between a unit and its environment” (Haas, 2015, p. 1034) and works in the interfaces with R&D partners (Santoro and Chakrabarti, 2002), thus contributing to transferring new knowledge (Haas, 2015). The boundary spanner could be used to transfer the knowledge accessed in the research center to the firm level, which would likely strengthen firms’ R&D robustness and reduce the potential vulnerability of relying solely on individuals who have acquired knowledge through the research center. The boundary spanner of the firm can discuss with firm employees the research results achieved by the research center and suggest research activities to the center based on the firm’s needs. Moreover, firms should dedicate a boundary spanner with the skills to interact and create external relationships and with prior experience in collaborating with researchers, which has been shown to be an enabler of successful R&D collaboration (Steinmo and Rasmussen, 2016).

### 2.5.3 End phase – forwarding enablers

Because radical innovation for sustainability takes a long time to develop, firms should ensure that the knowledge and research results developed in the research center are developed further in new spin-off projects during the last year(s) of a research center's existence (ex-post phase).

#### ***Spin-off projects***

Because radical innovation for sustainability takes time to develop, the innovation processes that unfold in a research center most likely need to continue after the work of the research center ends if their full implementation potential is to be realized. Hence, in the last year(s) of the research center's existence, firms should make sure that they continue the innovation processes by applying for subsequent projects that integrate the knowledge and learning derived from specific research center activities into new R&D funded projects (Georghiou, 2002). Previous research shows the value of prior contacts (Slavtchev, 2013) with common understanding (Steinmo and Rasmussen, 2016) for successful collaboration between firms and universities or R&D organizations. Therefore, firms should capitalize on the relationships developed within the research center to kick-start new overlapping innovation projects for radical sustainable innovation.

### 2.6 Concluding remarks

To address the issues of how firms can develop radical innovation for sustainability and the role of research centers in that process, this conceptual chapter contributes by increasing our understanding of how radical innovation can be developed by accessing new knowledge from a diverse set of actors through collaboration with R&D partners in research centers. Furthermore, this chapter contributes to increased knowledge of how firm enablers can manage this process during the three phases of a research center.

First, in the establishing phase, firms should *coordinate a long-term radical innovation approach* to sustainability within the firm and *influence research activities* in line with the firm's needs while attending to R&D partners' thematic and long-term orientation. Finding this balance can be accomplished by including some short-term applied research activities based on the firm's needs and some long-term activities driven by researchers that support radical innovation performance. Some applied activities will likely produce more frequent research results for the firm and the motivation and patience to become involved in long-term research activities, which may prevent firms from

dropping out from the center. Firms should also be strategic regarding the type of researcher with whom they establish research projects because researchers hold different research orientations that are likely to influence the research activities and potential results. As such, through close dialogue and interaction, firms should aim to identify and *establish research projects and activities together with “crossover” researchers* that support a threefold research orientation of scientific research, technological development and user orientation, which are all important to foster long-term radical innovation performance and provide firms with user-oriented research results. Finally, from the very beginning, firms should formulate contractual provisions of potential research results and innovation outcomes. As such, firms should consider what research activities they could conduct in open innovation projects where the research results could be made publicly available for all partners and the activities and results they need to keep secret and/or maintain control over through IP. However, to support long-term radical innovation processes, firms should be as open as possible in sharing the knowledge that contributes to the collective knowledge development process. This can be done by giving the firm representative a mandate from the firm to use his or her knowledge to identify and explore research possibilities with partners, which is likely to be the starting point to develop radical innovation for sustainability. To ensure an open knowledge-sharing process, contractual agreements that regulate access to and ownership of potential future innovation outcomes should be negotiated and established early in the collaboration.

In the performance phase, firms should be particularly attentive to knowledge-transfer enablers by *aligning goals and clarifying expectations* with R&D partners in a way that attends to both partners’ interests. Firms should also accept R&D partners’ long-term goals and orientations, which are essential for radical innovation. Moreover, *developing mutual understanding and trust through social embeddedness* and a high level of firm involvement are essential to managing knowledge transfer in the performance phase of a research center because radical innovation development requires collaboration with diverse partners who are often unknown. In the end phase, firms should ensure that they continue their innovation processes by *applying for subsequent projects* that integrate knowledge and learning from specific research activities from the center into additional R&D projects.

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