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The Role of Knowledge Users in Energy Innovation Projects and Their Effect on Innovation Performance

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Abstract

Innovative collaborative partnerships and networks have been researched (Ahuja, 2000; Child & Faulkner, 1998; Gulati, 1998; Hagedoorn, 2002). The research has provided useful insights into the role of different partnership types in R&D networks, however the literature has widely neglected the characteristics and role of the users of knowledge created in network-projects. The paper defines knowledge users as those actors that utilize the knowledge created in specific phases of network-projects for innovation purposes and therefore are those actors that carry the knowledge from one phase in the project into the next technological phase. The paper will among other things identify the knowledge users, describe the different types and discuss their particular role in energy innovation in regards to the different technological phases. Furthermore, the paper will also examine the effect of knowledge users on innovation performance.

The present paper utilizes network-projects from the energy sector for the empirical analyses as these projects vary from basic research to commercialization and involves a multiplicity of user types. The network projects are constructed in such a way that there are different partners and often different user types in each project. The potential partner types are suppliers, universities, competitors, public and private research institutes, and consultants. Further the projects involve companies that apply the technology (users) and end-customers, who consume electricity (end-users). The paper is based on quantitative and qualitative data from a national energy program. The data consists of 401 network-projects that received public funding from 1998 to 2008, 19 interviews with three different actors within the funding system, and 34 observation studies of project evaluation. The preliminary findings are that the majority of

projects do incorporate the knowledge users, but incorporating the users do not automatically lead to innovative success. Technology phases as demonstration and commercialization tend to involve the users more, but user involvement tends not to contribute to new technologies. These results are further developed in the paper and discussed with special attention at how network programs should be designed to utilize the findings.

Keywords: Innovation, technology, network-projects and partner collaboration, energy programs, users.

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The role of the knowledge integrators in R&D projects

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Abstract

Knowledge integration in collaborative partnerships and inter-organisational relationships are of vital importance for utilization for R&D projects (Berggren et al., 2011; Enberg et al., 2010; Kogut, 2000). Despite of this, the recommendations as to how the knowledge can be integrated in collaborative R&D projects is thus far not well-understood (Lindkvist et.al., 2011; Tell, 2011). Once more than two actors are involved in the R&D projects, key actors known as the knowledge integrators are vital to the overall success of the projects. Such projects with multiple actors are often highly technical and demanding projects. The paper defines the knowledge integrators as actors that utilize the knowledge created in specific phases of inter-organizational R&D projects for innovation purposes, and hence these actors carry the knowledge from one phase in the project into the next technological phase. The knowledge created in these projects is developed by combining and integrating new knowledge from new sources with existing knowledge in order to develop technologies and perhaps even products or processes with significant improvements in performance. This paper contributes to the knowledge integration and creative accumulation literature by identifying the knowledge integrators in the R&D process of projects that have received public funding for energy technology projects. The data encompasses all applications for a particular program over a period of 18 years with projects ranging from basic research to demonstration. Based on the quantitative empirical results the paper discusses why the knowledge integrators might benefit the innovation process.

Keywords: knowledge integration, knowledge integrator, R&D projects, and creative accumulation

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Introduction

To understand why collaborative partnerships and inter-organisational relationships are beneficial for innovation (Ahuja, 2000; Child & Faulkner, 1998; Gulati, 1998; Hagedoorn, 2002), it is important to examine how knowledge is integrated and by whom in collaborative R&D projects. A crucial premise in R&D projects is the creation of knowledge that may create new solutions and technologies. But in large research-intensive projects such knowledge may not be created by one firm or research unit alone. Rather collaborative projects are most often the norm, and therefore to secure that the new knowledge is utilized the new knowledge must be integrated across actors in the projects for the development of new technologies. Fortunately, actors are typically the bearer and therefore the integrators of the knowledge, and to integrate knowledge means to include potential knowledge integrators in the projects. However, as argued by Tell (2011) little is known about who the knowledge integrators are and how they actually integrate the new knowledge.

This article investigates the role of knowledge integrators in collaborative projects, and how their role changes across different technological phases at the R&D program level. The interaction of a particular actor with a knowledge integrator in a project is expected to influence innovative performance positively by the means of appropriate knowledge transfer.

The paper builds on information obtained from 401 R&D project applications that were approved in the period from 1990 to 2008 when applying for funding. All projects address technology development through R&D within the Danish energy sector. The data is compiled by the national transmission company in Denmark, called Energinet.dk and has been verified by external examiners doing final evaluations of the projects according to their initial goals.

The research questions guiding the paper are as follows:

RQ1: *Who are the knowledge integrators?*

RQ2: *How does the involvement of knowledge integrators differ across technology areas?*

RQ3: What is the effect on project duration of involving a knowledge integrator?

RQ4: *How is the project composition when involving a knowledge integrator?*

The main argument for the formulation of the research questions is that little is known on how knowledge integrators contribute to R&D projects mainly because the exiting literature lack the focus on how the knowledge is integrated (Tell, 2011). The main reason for examining knowledge integrators is because they have a unique knowledge that may contribute to innovation. By integrating the knowledge integrators it might contribute to a better innovation process. But before integrating knowledge integrators in a R&D project it is important to consider implications from integrating a knowledge integrator. This paper shows that the when the complexity increases such as duration of the project and number of partners the tendency is that a knowledge integrator is incorporated in the R&D projects.

The paper therefore contributes to current literature on knowledge integration and creative accumulation by not only indicating the existence of knowledge integrators, but by presenting the concept in empirical research. This paper examines knowledge integrators on an organizational level implying that a knowledge

integrator can be a company or a university as contrary to other research projects that emphasized the individual's role as integrator (Anderson & Berggren, 2011). The importance of viewing organizations as knowledge integrators is important because that many public funded R&D project consist of different actors who bring specialized knowledge to joint R&D project. These actors are not only individual actor but organization/institutions who collaborate with other organizations/institution. The papers clarify how a R&D project can consist of different actors across diverse technical divisions and indentifies the knowledge integrator(s) in the projects.

The present paper investigates collaborative R&D projects from the energy sector and the projects vary from basic research to demonstration. The projects typically involve a range of partners that take on different roles like being suppliers, universities, competitors, public and private research institutes, consultants and companies that apply the technology (knowledge integrators) and end-customers who consume electricity (end-users). The knowledge integrator is therefore defined within each of the projects and coded as such using a conceptual model.

The paper presents a conceptualization of the knowledge integrator by discussing the knowledge integrator in the literature on knowledge integration and creative accumulation. A review of the literature will illustrate how knowledge integrators contribute to innovation. The data and the variables are then described. The paper addresses four research questions. Lastly, the paper discusses the results which lead to a final conclusion.

The theoretical background: Knowledge integration and creative accumulation

The literature on inter-organizational relationships has long claimed obvious benefits from incorporating external partners in the innovative project. One of the claimed benefits of working with external partners is exchange of knowledge for the benefits of learning and mutual innovation within the boundaries of the project (Tsai, 2001). However, in such projects one firm typically invites the partners to be involved, what Pisano & Verganti labels *consortium* (2008:4). However, more research and capital-intensive projects are formulated with a larger set of equal partners involved, because the ambition of the project transcends the capacities of single firms. Here there is not necessarily one key partner that coordinates all efforts, but rather a set of partners that interact according to e.g. a project description formulated for applying for public funds. A key activity in such projects becomes the exchange and integration of newly created knowledge with the differing insights of the individual project partners, and therefore implies a coupling of existing *actor-specific* knowledge with new *collective* knowledge and insights. Willem et al (2008: 371) define knowledge integration to:"*include sharing and transferring knowledge, but also the collective application of knowledge in cooperative activities. This integration exists on different levels in the organization; namely within teams, subunits, communities, or the organization"*.

An example of an intra-firm structure for knowledge integration is illustrated by the processes in cross functional teams, where the team structure stimulate knowledge flows among team members, as well as create a platform for changing and improving these knowledge flows (Magnusson & Lakemond, 2011). The same kind of processes are observed in inter-organizational projects where the team members are external partners with different backgrounds and competence and where the knowledge exchanges between the partners. While it is widely researched that companies should integrate knowledge from external partners to key actors within the firm (DeBresson & Amesse, 1991; Enkel et al., 2009;), it is a challenge to

understand how the knowledge and the interaction between different partners is integrated in the collaborations. (Tell, 2011).

Knowledge integration processes stimulate the combination and recombination of knowledge into new combinations. These new combinations are discussed in Schumpeter's analysis of innovation and economic change (Schumpeter, 1934). The new combinations create innovation, which are also called creative accumulations (Grandstrand, 1998; Bergek et. al, 2011; Breshni et.al., 2000). Creative accumulation is a process where companies explore innovation built on established knowledge. From a knowledge-based view the term, accumulation, implies that innovation is competence-enhancing rather than competence-destroying if it is created on previous knowledge rather than substituting for it (Grandstrand, 1997; Bergek et. al, 2011). Such processes are especially needed in research and capital-intensive R&D projects with high technological complexity that transcends technological disciplines and multiple areas of expertise where actors and areas of expertise are required to interact in new ways to develop improved technological performance.

Research and capital-intensive R&D projects often develop new technologies in networks where they rely on existing knowledge to develop new knowledge. Therefore, this paper argues that creative accumulation is the foundation of such research and capital-intensive R&D projects. It is also important to emphasize that creative accumulation cannot be accomplished in isolation (Bergek et al., 2011).

The above discussion implies that knowledge integration is about sharing and transferring knowledge, but also the application of knowledge for the collective, namely the joint R&D project. The processes of integrating knowledge are driven by key actors in each project. However, the knowledge integrator is not always a university or a customer, but may differ with the project description, the project aim etc. Part of the problems in researching knowledge integration is therefore linked to the problem of identifying the actual knowledge integrator.

Identification of the knowledge integrator

Powell et al. (1996) discuss inter-organizational collaboration and innovation with the main focus on organizational learning. They argue that sources of innovation can be found in the interaction between different actors such as universities, research institutes, suppliers and customers rather than only internally in a company. Research and capital-intensive R&D projects require involvement of a multitude of knowledge and actors rather than single firms R&D labs. Such collaborations therefore stress the needs of different actors with expert knowledge in order to innovate. Furthermore, the R&D project consists of a range of phases from basic research, over development to demonstration. At each development level, different actors understand and use the knowledge created in the particular technological phase and who are then able to integrate the knowledge into the next development phase. These actors are called knowledge integrators. Two important issues are therefore prevalent; each phase can therefore involve more than one knowledge integrator, and second, the knowledge integrator is also a university, a supplier, a customer or similar.

This paper therefore posits that knowledge integrators are *those actors that utilize the knowledge created in one specific phase of the R&D project, and that carry the knowledge from one development phase into the next technological phase*.

Figure 1a illustrates a combination of actors collaborating for a particular project, and *figure 1b* then uses this actor combination to illustrate the role of the knowledge integrator in a projects development phases.

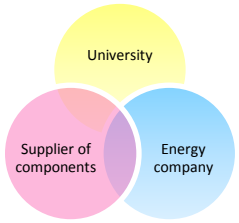

Figure 1a: An example of an actor constellation

Figure 1b illustrates a R&D project with actors found in e.g. energy projects (i.e. the empirical context of the paper). In the first stage of basic research, a knowledge integrator who is also involved in the applied research phase is involved illustrated by the arrow and the green bubble. In other words, to ensure knowledge integration, the actor responsible for utilizing the created knowledge in the subsequent phase must be part of the project from the beginning of the relevant innovation phase. As the project evolves into different innovation phases, the knowledge integrator, who is responsible for utilizing the knowledge created in the project, may change and often do. Hence, a key argument is that the knowledge integrator is not the same from the beginning to the end of the entire R&D process. Although not illustrated, the knowledge integrator in the research phase may be the yellow bubble, a university, whereas in the applied research phase, the knowledge integrator may be an energy company, a blue bubble. The same knowledge integrator may be found in the last phase as well.

An example could be illustrated by a project in applied research phase, which consists of different partners such as an electricity company, suppliers of equipment and a university. All the partners are potential users of the knowledge created, but there is only one actor that is responsible of employing the knowledge. In this example, the knowledge integrator is an electricity company, because it will implement the technology in their electricity system after the successful completion of the project. As the project evolves other knowledge integrators may become relevant for the project, e.g. a transmission company that is then incorporated in the demonstration phase of the project.

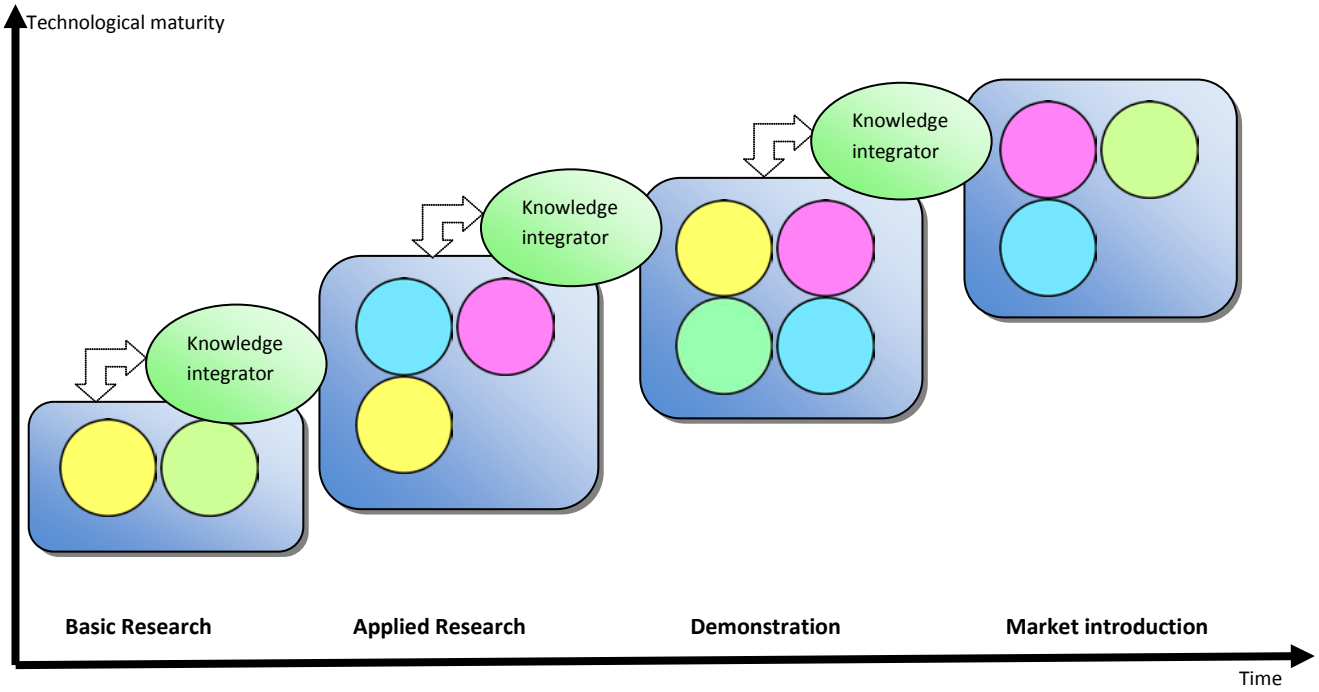

Figure 1b: The knowledge integration process across technological development phases

The partner types in a R&D project: yellow (university), green (XXX), blue (energy company like grid provider), pink (component supplier).

The R&D project

The knowledge integrator, who will integrate the knowledge created in the next phase

The knowledge sharing facilitated by the knowledge integrators involvement in both development phases

The importance of the knowledge integrator in inter-organizational R&D projects

When discussing the role of knowledge integrators in inter-organizational projects, it is pertinent to investigate whether knowledge integrators are significant in driving R&D projects towards innovation. To create innovation, the actors in a R&D project span different knowledge areas, and they combine their own knowledge with insights from other technical areas, but also with the knowledge created in the project. As a result the firms test and adapt their innovations by mobilizing the knowledge from the actors in the collaboration. To ensure the best possible result of the R&D process, one could argue that the combination of actors in the R&D project is highly relevant. This paper investigates who the knowledge integrator is and when the role of the knowledge integrator is important in regards to technology phases. Incorporating a knowledge integrator can result in an innovation process with technological phases that is not continuously interrupted or perceived as phases of entity, but more of a flow of knowledge where the knowledge

integrator integrates the created knowledge in every phase. By integrating the knowledge integrator in R&D projects, the innovations process might become more efficient and thereby more goal-oriented in a technical sense. As a result of the knowledge integrator, the technology might at the end of the innovation process be utilized, because the technology from the beginning is more focused and one may argue that the knowledge integrator keeps the innovation on the track.

Hypotheses

The research questions are analysed using four hypotheses:

> *H1: Projects incorporating knowledge integrators tend to have a longer duration than projects without knowledge integrators, i.e. involvement of knowledge integrators extends the project duration.*
>
> *H2: Projects incorporating more than one knowledge integrator have a longer duration than projects without the knowledge integrator*
>
> *H3: Projects within mature technology areas are more likely to incorporate knowledge integrators compared to projects in less mature technology areas*
>
> *H4: Projects incorporating knowledge integrators involve more partners than projects without knowledge integrators; i.e. when knowledge integrators are involved they are added to other partner types.*

The data set and variables

The whole energy system needs a transformation based on mainly renewable sources in order to reduce man-induced emissions (Buen, 2006). Significant technological change is necessary for this transformation to take place, and that is why it is important for energy companies to look beyond the short term and innovate new energy efficient solutions. By employing policy instruments and energy programs it can make it less of a burden for the energy companies to spend resources on R&D, and make it easier for them to invest in long term technologies.

The energy sector utilizes relative large and financial demanding projects where they are constructed in a way where there are different actors assembled in projects. These actors are partners in a project and together most of them finance half of the amount of the project and apply for funding for the rest of the amount. An example of this could be a project that wants to develop a new technology that can produce sustainable energy. When a project with this mission is formed, partners can often be universities with the latest knowledge about the technology, different suppliers of equipment and electricity companies that in the end has to use the technology and implement the innovation in the energy system.

Various governmental, research and support programs can have a major impact on innovation and development. Especially in the energy field, the programs have a substantial impact, since they help support research and development throughout the value chain from basic research to demonstration (Borup et al., 2009). The amount of public investments in R&D in new energy technologies has also played a crucial role in the development and proliferation of new innovative technologies (Borup et al., 2009). This is

especially relevant in the early stages of technology development, where uncertainty concerning the innovation is greatest[1].

The data employed in this paper is from an energy program called Energinet.dk whom administers a number of environmentally friendly research programs where the purpose is to support clean and environmental friendly energy. The program is funded by PSO (public service obligation) tariff. Energinet.dk is a public owned transmission company and is owned by the Danish Climate and Energy Ministry.

Data collection

The data used in this study consists of 401 funded projects from 1990 to 2008. The dataset was compiled in 2008 by the energy program with the purpose of evaluating the program and the funded projects. The aim of the dataset was to provide a comprehensive overview of all the projects that were initiated under the PSO program in its 10 year lifetime. Furthermore the overview should provide information about the amount of financial resources that were allocated to projects, which participants had been involved, and the maturity of the projects etc. PSO project was started by Elkraft (former Danish energy company) and Eltra (former transmission company), and at first the projects were imposed by the government. There is a series of projects that have started up before PSO funding was officially started. These are not all included in the final statement of PSO projects, and in the dataset. The list is updated to 2008 range and is not updated subsequently, as all entries in different context now occur electronically at the Energinet.dk.

The dataset's sources are released publications from Elkraft and Eltra. Energinet.dk publishes every year in collaboration with a number of other research programs the energy research report. It is only in recent years reports are available in an electronic version. Eltra and Elkraft's publications are available in paper format at Energinet.dk. The data collection is based on all these different publications where it is registered when the projects have started, completed, in how many years etc. The final list of projects in the dataset is compared with a computer file system located in Energinet.dk and compared to the research institution, Risø's list of PSO projects. There are a number of projects during their course has been merged with other projects - they act independently until the merger in the dataset.

Variables for the research questions

Knowledge integrator variable

The main dependent variable used to answer the research questions is the knowledge integrator variable. To identify based on actor names that were mentioned as partners in the project, if one or more of these were knowledge integrators, the researchers engaged an external expert to assist. The expert is very experienced with the PSO program and has also in earlier periods been associated with some of the projects on an administrative level. Today the expert is still working within some of the technology areas underlying the projects. The person therefore has the knowledge and expertise to evaluate if the knowledge integrator was in fact part of the projects. However, the researchers further cross-checked with a second expert to validate the codings of the expert.

The expert identified the knowledge integrator in a project by evaluating if there were one or more actors in projects, who would utilize the knowledge created in specific phases of the projects for innovation

[1] Report from Klimakommissionen: Nye energiteknologier – Forskning, udvikling og demonstration (2010:30)

purposes. Furthermore, to assist the expert a visual illustration of the phases and the role of the knowledge integrator was provided to the expert before the work commenced. The expert also evaluated *which* knowledge integrators were included in the projects.

Potential knowledge integrator	Description
Suppliers of energy	This category includes companies that supply materials to energy production. Some of the companies can also produce electricity. Examples of companies are Shell and DONG Energy A/S.
Producers of energy (electricity and district heating)	The category includes producers of electricity and district heating. Examples of companies are EPZ Holland, Vattenfall A/S, Nordborg Kraftvarmeværk etc. These companies produce electricity and district heating.
Transmission and distribution (energy companies – monopoly)	In this category includes utilities and transmission companies. E.g. Energinet.dk is a transmission company who owns all the natural gas transmission system and the 400 kV electricity transmission system.
Trade and sales (energy companies)	National utilities are included in this category. They trade and sell electricity on the market. E.g. Dong Energy A/S.
Suppliers of plant and components	Companies in this category are different suppliers of components and plants. It can be all from a national wind turbine producer to a local blacksmith shop.
Other private companies	This category includes companies that do not directly supply components but their service is still beneficial for the projects. An exampel is Eurofins Steins Laboratorium A/S which is an authorized an accredited to perform analysis in agriculture, dairy and food. Their service might be useful in bio fuel projects.
Advisers and consultants	Advisers and consultants are incorporated in the projects to supply their knowledge and expertise. The category includes normal consultant companies like Rambøll A/A to more specialized institutions with chemical expertise.
Universities and research institutions	The category includes national and international universities and research institutions.
GTS (Approved technological service institutes)	GTS – Advanced Technology Service Institutes is a network consisting of nine independent Danish research and technology organisations. They support innovation and constitute the core of the technological infrastructure in Denmark.
Public authority	This category includes public institutions like a municipality or DMI who provides meteorological information and forecasting in Denmark.
Politicians	Other national or international research programs are included in this category.
NGO (non-governmental organizations) and industry association	The category includes NGOs but also industry associations that supports the Danish energy industry.
Investors (funds etc.)	Investors like firms or fund who want to support projects are included in the category.
Other research programs	Other national or international research programs are included in this category.
Households	This category includes household and end users of electricity. Projects that are near market introduction can benefit from incorporating the end users.

Table 1: Description of the different potential knowledge integrators in the R&D projects.

Before the identification of the knowledge integrators was undertaken, a catalogue with all the actors in the dataset was produced. The following actors in the catalogue were divided into different groups: 1) Suppliers of energy, 2) Producers of energy (electricity and district heating), 3) Transmission and distribution (energy companies – monopoly), 4) Trade and sales (energy companies), 5) Suppliers of plant and components, 6) Other private companies, 7) Advisers and consultants, 8) Universities and research institutions, 9) GTS (Approved technological service institutes), 10) Public authority, 11) Politicians, 12) NGO (non-governmental organizations) and industry associations, 13) Investors (funds etc.), 14) Other research programs and 15) Households (see *table 1* for descriptions).

After coding each of the knowledge integrators in each project, the expert coded *who* the knowledge integrator is by applying the typology of knowledge integrators in the energy sector (*table 1*). The reason why the 15 categories were formed in such detail was to clarify the role of the knowledge integrator and to highlight the diverse nature of the knowledge integrator and that they vary depending on the technology phase and the technology area. After the expert coded the knowledge integrators into these 15 different categories, the categories were further summarized in three main categories: market integrators, science integrators and societal integrators.

Knowledge integrator groups	Individual knowledge integrator
Market integrators	Suppliers of Energy
	Producers of energy (electricity and district heating)
	Transmission and distribution (energy companies – monopoly)
	Trade and sales (energy companies)
	Suppliers of plant and components
	Other private companies
Science integrators	Advisers and consultants
	Universities and research institutions
	GTS (Approved technological service institutes)
Societal integrators	Public authority
	Politicians
	NGO (non-governmental organizations) and industry association
	Investors (funds etc.)
	Other research programs
	Households

Table 2: Three knowledge integrator categories

Market integrators include integrators with knowledge about and direct contact with the market; producers, suppliers and component companies in the energy sector.

Science integrators include integrators with knowledge about technical science and basic research; universities and other research institutes. Advisors and consultants are also included in this group because they often have an area of expertise that equals that of science institutions.

Societal integrators include a broader range of actors in the energy sector, including public authorities, politicians, NGOs etc. This group is characterized by their explicit role outside the technical field of the energy sector. They consume, regulate, lobby etc. Their interests are derived from a community-oriented perspective rather than technical or market perspectives.

For the first analyses, the dependent variable *knowledge integrator* is simply coded as a dichotomous variable to check the very nature of knowledge integration. The dependent variable *knowledge integrators* is an ordinal variable. To conduct regression analyses of the role of knowledge integrators, the paper applies logistic regression and ordered logit regression.

Independent variables

Partners

A majority of the projects in the dataset consist of collaboration with one or more partners (see table 3). These partners can have different backgrounds from producers of electricity to a university. This variable has registered the number of partners in each of the 401 cases.

University

University involvement in R&D projects is quite relevant in early stage R&D projects where the technology is relatively new. Many of the R&D projects in the energy sector incorporate universities because they have the newest research and technological expertise. This variable explains if a university is incorporated in a project and it is a dichotomous variable.

GTS

As mentioned before, GTS is Advanced Technology Service Institutes, i.e. a network which supports innovation and constitutes the core of the technological infrastructure. These institutes are incorporated in projects when the scope of the project is applied research or even commercial. The variable explains if a GTS institute is incorporated in the project.

Duration

The variable duration is based on the year of project initiation, subtracted the year the project ended. Some of the projects that started in 2005 or later are registered with the year that the projects were announced to finish in their application. So for some of the projects registered some years before 2008 it might be possible that the end year is the factual year if the projects experienced some problems that may have caused a delay, the end year might have been changed. The projects are registered in the dataset with the number of years of the project duration (see table 3).

Energy Biomass

This variable illustrates all the projects in the dataset that are in the area of biomass. Biomass is a renewable energy and a biological material. Biomass can be used directly or converted into other energy products such as bio fuel. Electric power plants can use biomass to generate electricity using steam turbines and gasifies or produce heat. Examples of materials are forest residues such as trees, branches and tree stumps, and municipal solid waste. Biomass technology is also what you can say is a mature technology compared to fuel cell or fossil energy, because it is a technology that is highly diffused in the energy sector, but not as commercial as fossil fuel. The variable is coded as a dichotomous variable that

illustrates biomass compared to other technologies (fuel cell, wave energy, wind energy, solar energy, bio fuel, fossil energy, and smart grid).

Energy fuel cell

This variable shows how many of the projects are in the fuel cell technology area. Fuel cell technology is a conversion of chemical energy into electricity. Hydrogen is a common fuel, but other fuel sources such as natural gas and alcohol (e.g. methanol) are also used. Fuel cell technology is different from normal batteries, because they can produce electricity continually if they are given constant source of fuel and oxygen to run. The technology is relatively new and immature compared to fossil fuel and biomass. The variable is coded as a dichtomous variable that illustrates fuel cell technology compared to other technologies (biomass, wave energy, wind energy, solar energy, bio fuel, fossile energy, and smart grid) .

Energy smart grid

This variable illustrates projects in the technology area called smart grid. This technology makes it possible to gather, distribute and act on information about the behavior of all participants in the energy sector from suppliers to consumers. This grid can contribute to improve the efficiency and sustainability of electricity services. The technology is quite young compared to biomass technology. The variable is coded as a dichotomous variable that illustrates smart grid compared to other technologies (fuel cell, wave energy, wind energy, solar energy, bio fuel, fossile energy, and biomass).

International partners

When talking about innovative R&D projects, the level of innovation and research can be so demanding that national sources are not enough. The energy program supports projects that have other partners than national ones especially if the partners' expertise is quite unique. This variable explains if an international partner is incorporated in the project. The reason why the number of international partners might be relatively low is because the projects are longitudinal. Before Denmark was a part of the European Union, the energy programs primarily supported national projects. The variable is coded a dichotomous variable (international partner/no international partner).

Responsible

This variable explains who the responsible for the project is. A private company, a GTS or a university can have the main responsibility of a project implying that they are the main organizer and applicant with regards to project management and financial resources. The variable used in the analysis is a dichotomous variable where university and GTS is one group and a private company another.

Competitor

In public funded R&D projects it is not unlikely that competing actors are part of the same project. This constellation is usually found in projects where the goal is to create a technological platform. This variable explains if there are competing actors in the project. The variable is dichotomous (competing actor(s)/no competing actor(s)).

	N	Min	Max	Mean	Std. dev
Knowledge Integrator	393	0	1	0.54	0.49
Partners	399	1	8	2.70	1.73
University	399	0	1	0.46	0.49
GTS	399	0	1	0.13	0. 37
Duration	397	1	12	3.56	1.62
Energy Biomass	393	0	1	0.40	0.49
Energy Fuel Cells	393	0	1	0.12	0.32
Energy Smart Grid	393	0	1	0.07	0.25
International Partner	400	0	1	0.11	0.31
Responsible	399	0	2	0.85	0.49
Competitor	397	0	1	0.06	0.23

Table 3: The descriptive statistics for the research questions 2-4.

Identifying the knowledge integrator and their role

The purpose of the section is to identify who the knowledge integrators are in R&D project in the energy sector. The empirical results show that a knowledge integrator is involved in 54.2 percent of the projects (*table 4*). The reminder of the paper focuses on projects incorporating knowledge integrators compared to projects that do not incorporate knowledge integrators.

As explained in the theoretical section, there is limited knowledge about knowledge integrators at an organizational level. The results here (*table 4*) show that R&D projects in the energy sector incorporate organizational knowledge integrators, but not who the knowledge integrators are. To identify who the knowledge integrators are, all potential knowledge integrators in the R&D projects were indentified (*table 5*). In the process of identifying the knowledge integrators, it was observed that a project as a maximum had three knowledge integrators.

Is there a knowledge integrator incorporated in the projects?	Frequency	Percentage
There is no knowledge integrator incorporated in the project	180	45.8
There is a knowledge integrator incorporated in the projects	213	54.2
Total	393	100.0

Table 4: Incorporation of the knowledge integrator

The reason why more than one knowledge integrator can be observed in a project is that the project can embrace different technological areas following different integrators. E.g. when producing an electrical car, three potential knowledge integrators can be identified: an electricity company produces the charger for the car; a supplier of car parts, and the end-consumer for the car. If the project is in the phase of applied

research, all the knowledge integrators can carry the knowledge to the next step in the technology phase, called demonstration.

The total number of knowledge integrators is 260 indicating that not all projects have knowledge integrators involved (on average 0.65).

As *table 5* illustrates, more than half of the knowledge integrators in the energy sector are mainly producers of energy (50.9%). A possible explanation for this may be that the before the liberalization of the Danish energy sector in 2003, only two energy companies (Elkraft and Elsam) were on the market, and they received a great amount of funding for their R&D projects. But, one may also argue that the producers of energy are a very natural knowledge integrator on an organizational level, because they are natural users of the innovations created in the R&D projects. They will and have implemented the R&D in the energy system, especially R&D projects that are politically regulated. Suppliers of plant and components are also a group that is relatively heavy represented (22.6%).

Identification of knowledge integrators	Number	Percent
Suppliers of Energy	4	1.9
Producers of energy (electricity and district heating)	133	50.9
Transmission and distribution (energy companies - monopoly)	10	3.8
Trade and sales (energy companies)	4	1.4
Suppliers of plant and components	59	22.6
Other private companies	4	1.5
Advisers and consultants	14	5.3
Universities and research institutions	23	8.8
GTS (Approved technological service institutes)	6	2.2
NGO and industry association	2	0.7
End users/Households	1	0.3
Total	260	99.4

Table 5: The total number of knowledge integrators divided into categories

	Frequency	Percent
Market integrators	214	82.3
Science integrators	43	16.5
Societal integrators	3	1.1
Total	260	99.9

Table 6: Knowledge integrators divided into groups

The majority of knowledge integrators are market integrators (*table 6*). The market integrators are the main drivers for production and selling of electricity in the energy sector, and they benefit by entering these kinds of R&D projects. Science integrators gain knowledge and research by entering into inter-organizational R&D projects, but they may not share the same need for participation since the universities are publicly owned and already has funding for some research activities. Societal integrators are represented with only 1.1 %, which is by far the smallest group compared to the other integrator groups.

The societal integrators may be less represented, because the majority of projects in the dataset are mainly basic or applied research projects. If the projects were orientated towards the end of the technological development phase such as market introduction (*figure 1b*) potentially the share of societal integrators would be larger. Another important point to address is that even though the societal integrators are less represented in projects, the Danish government can have an indirect effect by enforcing regulations that focus and support certain targeted energy areas above other energy fields.

Knowledge integrators across technological development phases

An interesting aspect that was raised with the market, science and societal knowledge integrators is whether these are in fact distributed equally across the technological R&D process. One could assume that science integrators would be more frequent in basic research whereas market integrators would be more prevalent in the demonstration phase. In the first part (*table 7*), the paper finds that in 56.2% of the projects in applied research a knowledge integrator is involved, and for basic research this is slightly higher (57.6%).

Presence of a knowledge integrator in the projects?	Basic research	Applied research	Demonstration	Total
No	**35**	**88**	**52**	**175**
	42.4%	43.8%	55.3%	46.3%
Yes	**48**	**113**	**42**	**203**
	57.6%	56.2%	44.7%	53.7 %
Total	**83**	**201**	**94**	**378**
	100%	100%	100%	100%

Table 7: Use of knowledge integrators in different technological development phases

In the demonstration phase the number of knowledge integrators is limited compared to other phases (*table 7*). The demonstration phase may be less inclined to involve knowledge integrators simply because these projects are represented by fewer partners (34.7% of the demonstration phase projects only have one partner).

	Basic Research		Applied Research		Demonstration	
Market integrators	37	71.1%	120	85.1%	48	85.7%
Science Integrator	15	28.8%	21	14.8%	7	12.5%
Societal Integrator	0	0	0	0	1	1.7%
Total	52	99.9%	141	99,9%	56	99.9%

Table 8: Integrator groups across different technological development phases

Table 8 show the knowledge integrators divided across the technological phases. Here it is observed that market integrators are presented in all the technological phases. One *market* integrator type that is strongly represented in the demonstration phase is energy companies within trade and sales taking 70% of the projects (not shown in the table). When private companies are close to commercialization the need to collaborate might weaken, because they want to protect valuable market-related knowledge and information. Other market integrators such as producers of energy, i.e. companies that produce electricity and district heating, are often represented in the applied research phase (61.7%), which implies that these companies are interested in relatively new upcoming energy research. Also market integrators such as suppliers of plant and components are heavily represented in applied research (48.5%). As expected above, *science* integrators are heavily represented in basic compared to applied and demonstration phase. GTS companies functioning as mediators between science and market are mostly represented in applied research. The societal integrators are represented in the demonstration phase with one case and this can be end-consumers that are integrated in the R&D project (*table 5*).

Knowledge integrators across technology areas

As described above, the energy sector is characterised by technical challenges demanding not only applied research, but also basic research. The sector develops both new and updated technologies based on existing technologies. Therefore, although a project is in the demonstration phase it does not automatically mean that the technology is mature.

In the following, *hypothesis 3* is tested using logistic regression analysis. The model has a good fit with a Nagelkerke R^2 at 0.38 and a significance level of the overall model at 0.000. The model includes duration of the project, presence of international partners, number of partners in total, involvement of science relationships by universities and GTS. As controls, the paper uses the technology areas. The Hosmer & Lemeshow test is not significant, meaning that the model is trustworthy.

The regression shows that projects in the biomass technology area positively raise the likelihood that a knowledge integrator is involved. This confirms *hypotheses 3*. Biomass technology is a mature technology in growth and is relatively widespread in Denmark[2]. A reason why biomass projects do incorporate knowledge integrators can be because the technology is relatively mature and the market integrators see the possibility of an immediate market introduction by entering projects in biomass.

[2] http://www.klimaogenergiguiden.dk/emne2_biogas-og-biomasse.html

	B	Exp(B)	Significance
Knowledge Integrator			
Constant	-2.963	0.052	0.000 ***
Duration	0.339	1.403	0.000 ***
International partners	-0.775	0.461	0.131
Partners	0.998	2.713	0.000 ***
University partners	-1.169	0.311	0.000 ***
Energy Biomasse	0.627	1.872	0.023 **
GTS	-0.855	0.425	0.027 **
Energy Fuel Cells	-0.285	0.752	0.496
Energy Smart Grid	-0.007	0.993	0.989
Nagelkerke R^2	0.386		
Cox & Snell R^2	0.289		
-2 Log Likelihood	396.440		
Hosmer & Lemeshow	0.408		
Number of observations	382		

Table 9: Logistic regression for projects incorporating a knowledge integrator

Furthermore, 56.3% of knowledge integrators in biomass projects are market integrators. Less developed technologies can be highly research intensive projects that might require the participation of only universities and research institutions. From this it can be discussed if the knowledge integrator is applicable in the immature technologies.

Table 9 also show that when a GTS company is in a project it is less likely that a knowledge integrator is incorporated in the project. The function of a GTS company is to act as a mediator between universities and private companies and therefore the project participants may consider GTS institutes as substitutes for knowledge integrators. The results also demonstrate that the likelihood of involving knowledge integrators increase with the number of partners, with the duration of the project, but is decreasing with the involvement of university and science partners. This confirms *hypotheses 1 and 4*.

Project duration and knowledge integration

Even though a knowledge integrator might contribute to the efficiency and goal-orientation of the R&D process, the knowledge integrator may also add complexity because the partners have to agree on common decisions. Therefore, the duration of a project might be affected when incorporating a knowledge integrator. The regression model (*table 9*) shows that a longer duration tends increase the likelihood that a knowledge integrator is involved in the project. However, the question remains whether this result is also valid for projects with more than one knowledge integrator.

Table 10 shows the results of an ordered logit regression to analyse *hypothesis 2*. The model has a good fit with a McFadden's R2 at 0.21 and a significance level of the overall model at 0.000. The variables; duration, energy biomass and partners has a significant effect (0.05) on projects with a number of knowledge integrators compared to projects on incorporated knowledge integrators. No effect can be detected by the variables competitor and energy fuel cells.

	Estimate	Std. Error	Significance	95% Confidence Interval
Duration	0.382	0.070	0.000 ***	(0,24;0,52)
Competitor	0.432	0.484	0.372	(-0,52;1,38)
Energy Biomass	0.656	0.235	0.005 **	(0,20;1,12)
Energy Fuel Cells	-0.619	0.388	0.111	(-1,38;0,14)
Partners	0.724	0.076	0.000 ***	(0,57;0,87)
MacFadden´s R2	0.216			
The overall model	0.000			
The number of observation	371			
The log likelihood	379.961			

Table 10: Ordinal regression on several knowledge integrators in a project

The results (*table 10*) show that increasing the duration of a project is positively related to the number of knowledge integrators in the project. The results also demonstrate that the number of partners raises the likelihood that more knowledge integrators are involved. This confirms *hypotheses 2*. Projects in the area of biomass area also raise the likelihood of having more than one knowledge integrator compared to fuel cells.

Discussion

This paper has demonstrated that organizational and institutional knowledge integrators are found in R&D projects in large energy programs. 54.2% of the R&D projects incorporate at least one knowledge integrator. Furthermore, the paper identified who the knowledge integrators are in the R&D projects in regards to energy. Three groups of knowledge integrators: market integrators, science integrators, and societal integrators were identified of which the largest group is market integrators (82.3% of the integrators). Market integrators are closer to the market than the other types and may be e.g. producers or suppliers of electricity. Societal integrators are represented with only 1.1 %, which is the smallest group compared to the other integrator groups. When studying knowledge integrators across the technological phases, the findings demonstrate that basic and applied research were represented by science integrators, whereas market integrators were heavily represented in applied research. Furthermore, the paper finds that projects referring to more mature technology areas integrate knowledge integrators to a higher

degree than immature technologies. The cause for this can be that mature technologies are more relevant for market integrators and that it could be a reason why they are involved in these projects. In more young technologies as fuel cells or the smart grid technology, it might not be possible to incorporate a knowledge integrator due to the immaturity of the technology and therefore the heavy involvement in early phases. A project's duration can vary dependent on the technology and the goal of the project. Results show that a longer duration tends to increase the likelihood that a knowledge integrator is involved in the project. The integration of more than one knowledge integrator in R&D projects does not alter the results. When discussing the number of partners in R&D projects, the results also demonstrate that the likelihood of involving knowledge integrators increase with the number of partners. Projects with many partners have the possibility to share knowledge and information and exchange knowledge that might benefit the project's goal. This may be the reason why the projects with many partners incorporate knowledge integrator.

Hypotheses	Description	Result
H1	Projects incorporating knowledge integrators tend to have a longer time period than projects not incorporating knowledge integrators	Positive significant
H2	Projects incorporating more than one knowledge integrator have a longer time period than projects not incorporating the knowledge integrator	Positive significant
H3	Projects within mature technologies tend to have incorporated knowledge integrators compared to projects in other technologies not incorporating knowledge integrators	Positive significant
H4	Projects incorporating the knowledge integrators have more than one partner compared to projects that have not incorporated the knowledge integrator	Positive significant

Table 11: Summery of the hypotheses

Conclusion

The paper started by stated by stating that the knowledge integrator in the literature is not well described when discussing knowledge integrator as an organisation or as an institution. The main purpose with this paper was to investigate the role of knowledge integrators in collaborative projects. The empirical results for research question 1 confirm the existence of knowledge integrators. The main findings of the descriptive analyses demonstrated that out of the three groups of knowledge integrators the largest group of knowledge integrators in the R&D projects is market integrators. The descriptive analysis also finds that the knowledge integrators identity changes along the technological phases. The empirical findings for research question 2 show that projects in the area of mature technologies tend to incorporate knowledge integrators more than projects in other technologies not incorporating the knowledge integrator. Furthermore, the empirical results for research question 3 confirm that a project's duration do have an impact on knowledge integrators. The longer a project is the more likely it is that a knowledge integrator or knowledge integrators are incorporated in the projects. When researching the construction of a project, the findings for research question 4 illustrate that when projects increase the number of partners it is likely that a knowledge integrator is incorporated in the project.

The paper is limited by a possible lack of important aspects or core aspects in the data collection. The data was firstly collected to other purposes than academic research. Furthermore, the paper does not consider the degree of involvement of the knowledge integrator in projects and it is not possible to compare these

results in international context or with other projects from other research programs. Further research should look more into how knowledge integrators affect innovative performance in R&D projects.

Recommendations

The paper presents three recommendations for potential partners in new projects. First, in the beginning of the process of establishing an inter-organizational R&D project, it is important for the potential partners to consider where the project is in the technological phase. Questions that need to be asked are e.g. if it is located in the applied research phase should there be a knowledge integrator involved in project? What are the consequences of involving a knowledge integrator and how does it affect the construction of the project? How does it affect the duration of a project etc. These are examples of questions that need to be asked before assembling the partners in the project. Second, a knowledge integrator may not benefit all projects and technologies. Results have shown that mature technologies have a tendency to integrate knowledge integrators and because of this, the projects should not integrate a knowledge integrator for any price. Partners in the project should carefully consider which role knowledge integrator should play in the project. Third, partners in R&D projects should be aware of that incorporating one or more knowledge integrators might increase the degree of complexity in the project.

In the further development of the paper the following research questions are considered:

- How are projects with universities and other research institutions incorporating knowledge integrators?
- How do knowledge integrators affect complexity in projects? Other measures than number of partners and project duration.
- How does knowledge integrators experience effect performance?

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