EIS – Strategic research alliance for Energy Innovation Systems and their dynamics – Denmark in global competition

1. Summary

Changing the energy systems to climate friendly and sustainable systems is one of the largest challenges facing society today. The characteristics of the innovation systems with respect to new and renewable energy technologies are central for how well countries perform and are able to contribute to the needed changes, in a strong international competition. The impact of energy technology, equipment and know-how on the Danish economy has been growing fast during the latest decade. But as the international competition increases continuous, ambitious and intelligent innovation is needed to maintain a strong Danish position. However, the understanding and the analytically-based knowledge of the energy innovation systems are still scattered and limited on many points.

The purpose of the strategic research alliance is to analyse the nature of the energy innovation systems in Denmark, seen as part of an international context, and to connect leading Danish and international researchers analyzing energy innovation systems. Through the analyses the alliance will critically assess the characteristics of the innovation system and the innovation dynamics with respect to individual areas of energy technology. The alliance activities will feed into strategic planning and innovation in individual areas of energy technologies as well as to development of policies and institutionalisations in the energy area more generally and within innovation and research policy. In addition, the alliance will assess to what extent the ambitious visions and plans about green growth, competitiveness and innovation for sustainability are realistic.

2. Objective of the project

The objective of the strategic research alliance is to analyse the nature of the energy innovation systems in Denmark, seen as part of an international context, and to connect leading Danish and international researchers analyzing energy innovation systems. Through the analyses the alliance will critically assess the characteristics of the innovation systems, the innovation dynamics with respect to individual areas of energy technology, and the efficiency of the innovation systems for moving towards the long-term goal of renewable and sustainable future energy systems.

The alliance will contribute to the leading international scientific knowledge on energy innovation systems, contribute to training of young researchers in the field, and facilitate the use of the knowledge from this knowledge community by Danish actors. The communication of knowledge and results will feed into strategic development for companies, policy makers and interest organisations.

As part of the overall objective, the research activities will compare the energy innovation system in Denmark with other countries, develop new quantitative indicators of innovation systems for sustainable energy systems, and monitor the energy innovation systems in general and with respect to selected energy technologies. In addition it will analyze whether energy innovation is part of a new paradigm of innovation (‘eco-innovation’) that differs from traditional innovation.

3. The main results of the project

As a strategic research alliance the main result of the project is the creation of novel scientific synergies between the existing but scattered research groupings in Denmark and abroad concerned with energy innovation system research. This is anticipated to advance the international quality of activities of the involved participants. The alliance will contribute to advance the international research and doctoral education in the area and form a platform for additional international cooperation. The alliance results in 5 PhD students, 2 post-docs and a biennial doctoral summer school. The scientific output falls in two main fields:

1) the alliance contributes to a more advanced understanding of the nature of the energy innovation systems in Denmark and especially of these systems’ challenges and possibilities for

becoming among the most effective intelligent systems in an increased global competitive context and for contributing to the energy systems of the future.

2) the alliance will result in a significantly improved statistical and methodological foundation for further research and for policy making, which should prove effective means to reach the policy aims on energy, environment and industrial competitiveness of the country.

The results in the first field will have direct relevance for policy making and especially the energy industry and its individual firms (e.g. firms in the energy efficiency sector, the venture and financial sector, and sub-suppliers for the more established part of the energy sector). The latter will be fed directly to the involved private and public-sector users' own statistical analyses and method development. These partners include Danish and Nordic institutions such as Statistics Denmark, Danish Energy Agency (incl. Greenlab DK and the Energy Technology Development and Demonstration Programme (EUDP), Danish Energy Industries Federation, Energinet.dk, Energitjenesten and Nordic Energy Research). Other institutions include the Danish Agency for Science, Technology and Innovation and international institutions such as IEA, OECD, EU (Set Plan and ETAP) and the World Bank. Finally, the project also results in contributes to inform the general debate on the opportunities of energy technologies.

4. Background and hypothesis of the project

Through the liberalisation, opening of markets and internationalization of the energy systems in the latest decades, market-based interaction and engagement by private companies in making new energy technology products have become more central to the development of the energy systems. The dynamics for moving towards low-fossil, renewable and sustainable energy systems have changed, not least in areas where the energy technology supply industry has grown markedly and developed to larger economic fields with many organisations, multiple activities and much manpower. The tendency is further reinforced by a pronounced policy focus on commercialisation, private-public partnerships and innovation in some countries, e.g., Denmark. Creating advanced, viable, intelligent sustainable energy systems are increasingly considered a vital foundation for economic and societal development and an important driver of economic growth and transformation. The global 'race' to create the most effective energy technologies and energy systems is intense.

In order to understand the dynamics of energy technology development towards renewable and sustainable energy systems today, there is need for research analyses that can embrace the industrial perspectives of energy innovation together with the more traditionally addressed perspectives of market development, energy system planning, energy policy and technological-scientific research.

In this connection, innovation system analyses make up a promising theoretical-analytical approach. The analyses of innovation systems have showed that the innovative performance and capabilities differ widely from country to country and are a result of the specific constitution of the innovation systems in the individual countries. The research tradition became well-established through the 1990s, with focus primarily on general national innovation systems, but also to some degree on individual industry sectors (Lundvall 1992, Nelson 1993, Edquist 1997, Malerba 2002). Through the 2000s, innovation system studies that focus on dynamic phenomena as, e.g., establishment of new technologies and sectors' change and development in new directions, appeared (Jacobsson & Bergek 2004; Hekkert et al. 2007, Markard & Truffer 2008).

On the energy area, a limited number of innovation system studies have appeared in recent years. For Denmark there exist one general study that compares five areas of renewable and efficiency technologies plus a number of more selective studies on individual technology areas (Borup et al. 2009, Andersen & Drejer 2008). Among the main findings of the existing studies are that the energy innovation systems differ considerably from country to country and that they despite globalisation and considerable international activities are anchored on national level. They also point out that there is need of more knowledge about amongst other things the relationship between domestic, national activities and international connections and networks.

The analytical knowledge of the energy innovation systems is hence still scattered and limited on many points. The reason for establishing a strategic research alliance on energy innovation systems is that there is need for a stronger degree of continuity in the research activities on the topic and an establishment of a fuller and more comprehensive picture of the dynamics of the energy innovation systems building on a cross-going gathering and discussion of knowledge from individual analysis projects.

Only a few international comparisons of energy innovation systems exist. Among the exceptions are the work by Hekkert, Negro and Raven on bioenergy (e.g. Negro & Hekkert 2008) and Jacobsson et al. (e.g. 2004) on renewable energy technologies in primarily Germany and Sweden. (Klitkou et al. 2008) and (Borup et al. 2008) compare the energy innovation systems in the Nordic countries. The research alliance will support further analytical comparison of the energy innovation system in Denmark with other countries' energy innovation systems both in general and on specific subareas/technology areas. Moreover, it will give further illumination of the mutual connections between the changes in the energy systems and the innovative strengths and competitiveness.

Quantitative indicators of energy innovation systems and their performance are important in order to measure developments in the systems in general and with respect to individual energy technologies. Existing energy statistics do usually not focus on innovation system aspects, though e.g. the R&D statistics (IEA) and pilot work on exports of energy technology are exceptions. Klitkou et al. (2010), Tanner et al. (2009) and Borup et al. (2008) collect and discuss data on a number of new indicators of the energy innovation systems e.g. on collaboration patterns, global market share, domestic market, product & process innovations, business creation, scientific publications and patents. Discussions of what new indicators are needed are also found in e.g. Andersen (2007) and Kemp & Pearson (2007). There is, however, need of further analyses and discussion of how quantitative indicators of innovation for sustainable energy systems shall be established. Moreover, there is need of longer time series of data to trace the developments over the years.

Methodologically, the research activities of the alliance will build on a combination of the general, national and sectoral approaches to innovation systems and the technology-specific approaches. This includes experiences about functions of innovation systems and multilevel perspectives (Hekkert et al. 2007, Markard & Truffer 2008). With its' basic foundation in evolutionary economics, innovation system studies focus on learning activities in a broad sense, ranging from market-based learning, learning-by-using and learning-by-doing over entrepreneurial experimentation and industrial product development, to formalised knowledge production and educations at universities etc. The systemic interplay between the different learning activities is what creates the competitiveness and relative strength or weakness of a specific innovation system. It is not only technology-push and science-push factors, and not only demand-pull and market-pull factors, that creates competitiveness and relative strengths, but the connections and synergies between them.

It is the overall hypothesis of the alliance's research agenda that the characteristics of the innovation systems differ with respect to individual energy technologies and that they are results of historic developments in combination with current activities.

Moreover, it is a hypothesis that innovation in the sense of business development often diverges from innovation in sense of improvement of the energy systems towards renewable and sustainable systems and increased efficiency. It is a challenge that demands active effort to keep them together. Whether energy innovation is part of a new paradigm of innovation ('eco-innovation', Rennings 2000), and differ from traditional innovation by having a more pronounced or advanced way of including environmental, climate and sustainability perspectives, is part of this hypothesis.

A number of more specific hypotheses will appear in the individual specific research work packages.

5. Innovative value, impact and relevance of the project

The innovative value of the research alliance, scientifically speaking, lies especially in:

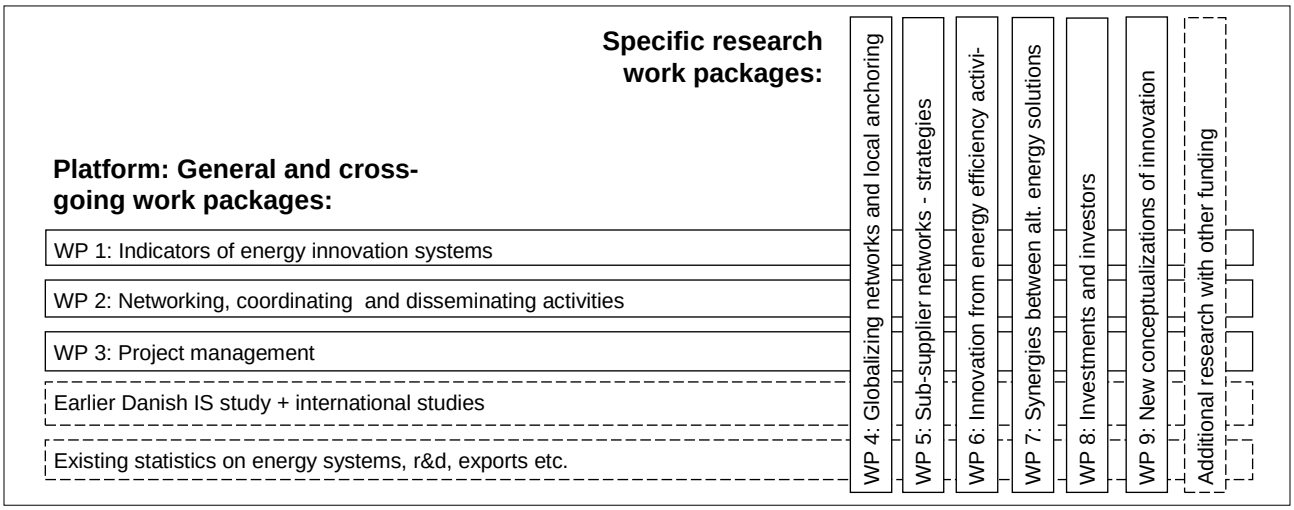
- the emphasis on situating the analysis of the Danish energy innovation system in an international context, including the role of globalizing value chains and innovation networks.
- the integration of insight from a broad set of quantitative indicators and statistics with more qualitatively based insight; the combination of a general overview and specific insights on a number of points is an important novelty.
- the investigation of systemic and integrative aspects in the sense of integration in the energy systems and in the market and use patterns.
- the emphasis on collaboration patterns and learning in networks
- the investigation of investment and investors not only in a quantitative sense, both also who the investors are and why they invest.

These points are also of important innovative value to societal actors and businesses working in the field. To these, the innovative value will moreover consist in the general perspective of innovation systems where industrial and business perspectives are seen together with market, planning, knowledge, and energy system perspectives. The analyses will result in opportunities for assessing the efficiency of the innovation system e.g. concerning interaction patterns, networks, competences and capabilities, and they will identify efforts needed in order to ensure a high innovative capacity and a continuously relevant energy technology development in Denmark. Hence, it will constitute a basis for strategic decision making by institutions, businesses, technology developers, and policy makers. The connection of the activities to a number of relevant user groupings (see below) ensures the impact of the alliance activities and contributes to its' continued relevance. This supports the wider dissemination of the results and contributes to capacity building in important energy and policy institutions.

6. Project's methodology and results

The methodological approach of the research alliance is structured in two main parts (see figure):

1) A platform constituted by general and cross-going analysis elements, by discussion and dissemination activities and by project coordination and management. (Work packages 1-3)
2) Specific analysis elements focused on selected aspects of the innovation dynamics of especial interest and relevance (Work packages 4-9)



Platform: General and cross-going work packages

The general and cross-going elements constitute a solid platform for the specific analysis elements. The results from these work packages have a high degree of novelty, but the processes towards the results are relatively predictable with few uncertainties. The platform draws on earlier Danish, Nordic and international projects (dashed boxes in the figure) and on existing statistics on energy systems, R&D, exports, etc. It is expected that the platform can be used for establishment of a number of other, specific research projects funded from other sources. The platform is open for other universities and research institutions than the partners involved in the research alliance.

WP 1: Indicators of energy innovation systems

This work package intends to provide a quantitative knowledge platform on innovation in the energy sector. The knowledge will be fuelled into the specific research activities of the project as well as be disseminated directly to the interest groupings. The work package has three tasks.

Task 1.1: Survey of innovation activities and interaction patterns. The aim of this task is to provide quantitative evidence on the innovation activities and patterns of interaction and collaboration in different areas of energy technology. The method is a biennial questionnaire survey building on the experience from two earlier analyses on energy innovation and on the CleanTech area (Tanner et al. 2009, and Brøndum et al. 2009). Each of the surveys will result in a report on the findings and a policy summary for the user groupings. The data will provide a basis for research in the specific research activities.

Task 1.2: Innovation indicators and Energy Technology Scoreboards. The aim of this task is to establish a statistical data platform and present relevant indicators for the Danish energy industry on parameters such as industrial RD&D investments, added value, employment, human R&D resources; of market shares, exports/sales, specialisation indexes; and of 'through-put' indicators like publishing, patenting, etc. The task builds on earlier projects in Nordic and European level. The task is based on existing statistical data that is collected on the level of each energy technology to the extent possible. The intent is to develop an annually updated time track of data and indicators. The opportunities for developing relevant composite indexes will be explored. The task will result in Danish scientific contributions to the current international research in and practical experiments with Energy Technology Scoreboards. Furthermore, the annually updated time track will be made publicly available and targeted the user groupings.

Task 1.3: New indicators of innovation for sustainable energy systems – what is needed and what is possible? The aim of this task is - based on Task 1.1 and 1.2 - in to examine the need and opportunities for establishing new indicators of energy innovation for future sustainable energy systems. The task takes an explorative approach and investigates reliability and validity for possible new indicators on individual energy technologies. This could comprise indicators on e.g. energy technology transfer, licensing activity, venture capital, composite indexes and indicators on standards; infrastructure; network indicators; market facilitating policy measures, etc. Through the project the results will be incorporated directly in task 1.1 and 1.2 and the final results will be published in international journals.

WP 2: Networking, coordinating and disseminating activities

This work package intends to serve as the main vehicle of the project's alliance function. The coordinating mechanism will be an annual event with an expert forum and a steering committee meeting. Moreover a doctoral summer school will take place. The work package has four tasks.

Task 2.1: Radar on energy innovation studies. The aim of this task is to develop a shared understanding of the international research agenda in the research area of the alliance and furthermore to disseminate information of the international state-of-the-art on the area among the participants of the alliance as well as wider to the relevant user groupings. The radar will serve as a tool to position the research of the alliance in relation to the international research in the area. The method will be an annual review and assessment paper on on-going energy innovation studies. A draft of

the annual review paper will be discussed and qualified at the annual steering committee meetings and presented to the user groupings (analysts, policy makers and strategy developers) at the annual expert forum meeting.

Task 2.2: Expert forum. The aim of this task is to bring together practitioners and researchers from public and private institutions in Denmark and abroad, and examine the implications of recent research results and other forces that will shape the energy innovation policy agenda in the years to come. The method is an annual 1-day expert workshop on energy innovation, energy innovation policies and framework conditions. The radar papers form an input to the discussions.

Task 2.3: Doctoral summer schools and PhD network. The aim is to provide an international setting where doctoral students with in the area can present their ongoing work and receive feedback on their PhD-projects from the senior participants of the alliance as well as invited international experts. Furthermore, it is the aim of the summer school to serve as a forum where doctoral students can establish their own international networks for the future.

Task 2.4 Steering committee, networking and dissemination. The overall aim of this task is its 'alliance function'. The aim is - through biannual meetings - to facilitate the consolidation of expertise included in the alliance. This in particular includes the international experts affiliated with the project. The scientific networking also includes the involved senior staffs' contribution into other tasks and work packages. The steering committee will deal with uncertainties and unforeseen events during the project. Internal and external dissemination activities are included in this task.

WP 3 Project management
The activities of the project management are elaborated in chapter 10 of this application.

Specific research activities
Work package 4 – 9 contains strategic research with a higher degree of uncertainty and unpredictability than work package 1 – 3. The themes of the following work packages stem from indentified needs among the user groups and researchers for new knowledge in the area. The exact results implementable by potential users are relatively unpredictable – apart from the production of five PhD-degrees and ca. 20 articles in international journals. Focus will be set on academic excellence and international novelty of the activities and on interaction with leading international researchers.

WP 4: Globalizing networks and local anchoring - learning activities in Denmark and abroad
Earlier analyses have identified a significant local, domestic anchoring of the innovation systems for energy technologies, even in highly international and globalizing areas like wind energy. This seeming paradox can be explained by a.o.t. the very complex and broad interaction networks, the tacit dimension of knowledge, and the 'history bound' character of industrial competences building and clustering. However, there is need of more knowledge about what is done, and what can be done, in order to integrate technology learning from abroad and from at home.

WP 5: Sub-supplier networks – knowledge strategies, consolidation and internationalization.
With the increasing maturity of areas like wind technology and bioenergy technology, we also see a significant development among sub-suppliers of components and services in the fields. A considerable consolidation and strategic networking is taking place. This work package analyses the strategies for knowledge development and learning in these growing sub-supplier constellations. As suppliers increasingly are involved in development of components to meet the demands of leading manufacturers, they also become the linchpins for knowledge sharing. The underlying research question is to investigate the role of suppliers' international customer relations to lead manufacturers to their ability to contribute to the enhancement of the national innovation system's performance.

WP 6: Innovation from energy efficiency activities. With the recent rapid rise globally of the climate agenda, energy savings and energy efficient technologies have gained unheard policy and

market interest. Earlier studies have shown that the area of energy efficient technologies in Denmark is a highly innovative field. New product introductions and new business activities occur more frequently than in many other areas. However, what the innovation dynamics more specifically consist in and how the competitiveness is actually created in this area have not yet been analysed. Departing from the renewed policy efforts on energy savings and efficiency this work package will analyse this. It is a hypothesis that despite common policy institutions, the energy efficiency innovations appear differently in different sectors.

WP7: Synergies between alternative energy solutions. The future will involve many alternative solutions for incorporating renewable energy sources and matching these with final needs. These solutions both have synergies among them, e.g. the development of smart electric grids and electricity consumption practices, or integration of wind power in the grids, and at the same time they have elements of competition between alternatives, such as demand-side management vs. energy storage. Taking a dynamical systems perspective, the work package will explore the significance of these interdependencies for the proper characterization of industry boundaries, systems of innovation, and learning processes.

WP 8: Investments and investors. Traditionally investment in new technologies and innovations is considered a matter of either R&D funding (public or internally in private companies) or investments by venture capital actors. In the energy area, however, there are signs of that the landscape of actors engaging in investment in Denmark is broader and more varied than this, ranging from large institutional investors, over public and private project developers, collective saving associations and engaged entrepreneurs to household investors. Moreover, due to institutional changes venture capital investments in the energy area have increased substantially above other venture investments. This can imply other innovation dynamics than traditionally considered. The work package investigates this and analyses the purposes and meanings of the investments to the involved actors.

WP 9: New conceptual frameworks of innovation - is energy innovation eco-innovation? In recent years a row of new conceptualizations of innovation in connection to the climate and sustainability challenges have appeared, unifying environmental and economic goals, e.g. 'green growth', 'sustainable innovation', 'eco-innovation', etc. The aim of this work package is to investigate whether and how energy innovation reflects these new conceptual frameworks. Evidence from Denmark and Germany indicates that there currently are fruitful synergies in combining a green and climate-friendly energy focus with innovation in a traditional sense (Rennings et al. 2009, Borup et al. 2009, Andersen et al. 2010). It is a further hypothesis that differences to traditional innovation appear both concerning the sets of actors involved, in the contents of the innovation activities, and in the political support and legitimating of the activities.

7. Project plan

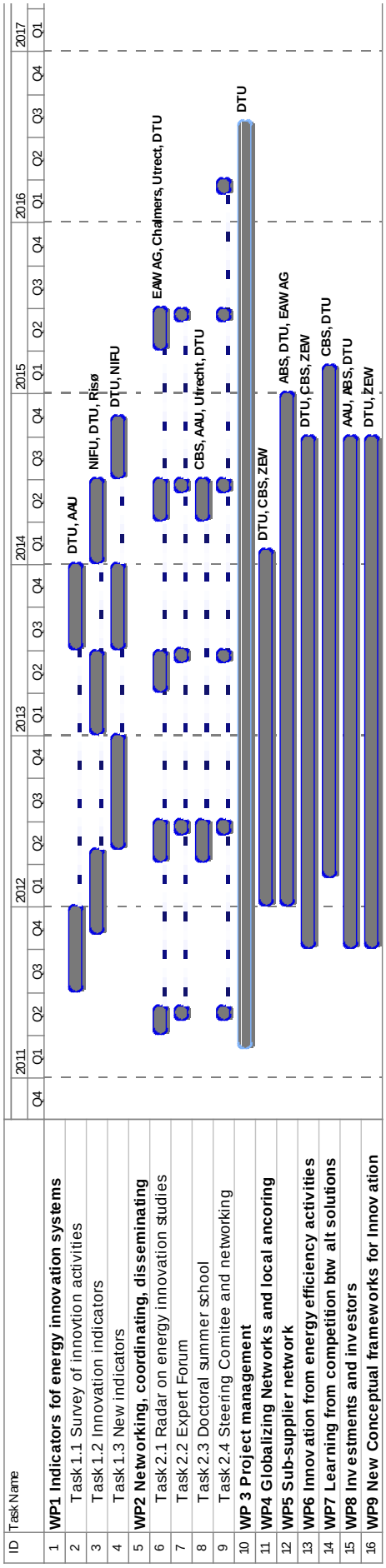
The research alliance will run from February 1st 2011 to November 30th 2016. The major milestones of the project plan and the time schedule can be seen from the Gantt chart on a following page.

Schedule for meetings

The PhD summer school is planned to run in 2012 and 2014. It will establish a tradition of a biennial, international PhD summer school on energy innovation systems and their dynamics. The theme of the PhD summer school in the individual year will be connected to workshop subjects of that year. Time is allocated to senior staff for preparation and participating in the summer schools in order to secure an internationally high standard. Steering group and network meetings of the research alliance will to the extent possible be held in connection to the workshops and summer school.

Overview of coordinated network meetings, expert forum issues and summer schools		**Responsible participant**	**Indicative venue**
2011	*Internal alliance meeting*: perspectives and results from existing studies	DTU	Lyngby (DTU)
2012	*Internal alliance meeting* Forum: Globalizing networks and local anchoring in energy innovation systems. PhD summer school	ASB, EAWAG, DTU, Risø, ZEW	Aarhus (ASB)
2013	*Internal alliance meeting* Forum: Indicators of energy innovation systems, support and policies for change	Risø, NIFU, ZEW, AAU, DTU	Copenhagen (CBS)
2014	*Internal alliance meeting* Forum: Complementary developments, competence clusters and the establishment of new energy technologies PhD summer school	Utrecht, CBS, DTU, Chalmers, Risø	Aalborg (AAU)
2015	*Internal alliance meeting* Forum: International institutions, market formations and policy	Risø, AAU, NIFU, DTU	Copenhagen
2016	*Internal alliance meeting*: finalisation and administrative end-meeting	DTU	Lyngby (DTU)

Gantt chart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Task Name
2011
2012
2013
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Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1
1 WP1 Indicators fof energy innovation systems
2 Task 1.1 Survey of innovtion activities
3 Task 1.2 Innovation indicators
4 Task 1.3 New indicators
5 WP2 Networking, coordinating, disseminating
6 Task 2.1 Radar on energy innovation studies
7 Task 2.2 Expert Forum
8 Task 2.3 Doctoral summer school
9 Task 2.4 Steering Comitee and networking
10 WP 3 Project management
11 WP4 Globalizing Networks and local ancoring
12 WP5 Sub-supplier network
13 WP6 Innovation from energy efficiency activities
14 WP7 Learning from competition btw alt solutions
15 WP8 Investments and investors
16 WP9 New Conceptual frameworks for Innovation
DTU, AAU
NIFU, DTU, Risø
DTU, NIFU
EAW AG, Chalmers, Utrect, DTU
CBS, AAU, Ufrecht, DTU
DTU
DTU, CBS, ZEW
ABS, DTU, EAW AG
DTU, CBS, ZEW
CBS, DTU
AAU, ABS, DTU
DTU, ZEW

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