Centre for Sustainable Energy Studies (CenSES)

Analysing transition strategies towards low-carbon economies

1. Research focus and relevance

Norway has ambitious goals in the energy sector. As described in the FME Society call, Norway has the potential to become Europe's leading energy and environment-conscious nation by becoming: a) a society with approximately zero greenhouse gas emissions; b) a large exporter of environmentally friendly power to Europe; c) a society that provides good conditions for world leading and export oriented energy and energy technology companies, particularly with respect to solar energy, offshore wind power and CO_2 capture and storage.

To contribute to obtain these aims, CenSES will develop fact based knowledge for strategic decisions by the government and industry. This includes knowledge for a national energy and national and international climate policy and for strategies of innovation and commercialisation. What is called for is the development of a knowledge base that may guide and support the articulation and implementation of strategies to achieve transitions towards sustainability with respect to energy and climate. CenSES combines the strength of leading Norwegian social science research institutions supported by international partners and important Norwegian stakeholders to meet these challenges.

CenSES' research objective is to conduct research that supports public and private decision makers in strategic decisions and policies that will promote environment-friendly energy technologies and lead to a sustainable energy system.

The realization of the vision stated in the Norwegian R&D strategy and the FME call requires a transition of a substantial part of the present energy system that will reach into many aspects of society. The focus on transition comprises national and local policies, energy production and infrastructure as well as industrial and technological development. The behaviour of firms and households – as consumers, asset owners, and engaged citizens with preferences and values – is at the heart of CenSES' research strategy. In addition, CenSES is committed to communicate new knowledge about transition strategies to potential users, including the general public.

The CenSES consortium includes research groups from Institute for Energy Technology, Institute for Research in Economics and Business Administration, Norwegian School of Economics and Business Administration, Norwegian University of Science and Technology, SINTEF, Sogn and Fjordane University College/Western Norway Research Institute and University of Oslo. This consortium integrates the following disciplines: energy system and market, industrial ecology, economics, political science, sociology, innovation studies, and science and technology studies. Such a broad multi-disciplinary consortium is absolutely needed in order to accommodate the challenges put forward by the FME Society call. CenSES is developing an advanced strategy to integrate these disciplines and their output, based on empirical studies as well as long practical experience. CenSES partners also have a unique track record of collaboration between social scientists and energy technology scientists, also with respect to the newly established Centres for Environment-friendly Energy Research (FME).

To accomplish its mission, CenSES investigates costs and other implications of transition strategies related to the production, distribution and consumption of energy. CenSES studies drivers and conditions along transition paths knowing that plans and reality may be rather different. In particular, not all transitions are sustainable. Transition is a conception of a whole-sector, multi-level process producing significant and lasting changes in production and consumption patterns and practices. It therefore requires complex multi-level governance; it is not just a matter of injecting single technological innovations and expecting them to take off. The emphasis is on socio technical institutions (at all levels) that need reforming and that may act as obstacles to transition (i.e by

providing entrenchment, lock-in, political resistance, economic obstacles, inadequate infrastructure).

Relevance to the call and the user partners

CenSES addresses the following thematic priorities in the call:

Model development and energy scenarios: Energy system models and economic models will be developed and applied in CenSES to answer questions like:

- How do transition strategies influence welfare, energy supply and security, energy prices and industrial development, greenhouse gas emissions and other environmental impacts at national as well as regional (sub-national) scales?
- How may models and theories of energy systems capture issues of political support and technological uncertainty?
- What are the important barriers and drivers, in terms of end use demand?
- In terms of leadership internationally, how important is technological change, carbon leakage and competitiveness issues in a small open economy in a European context?

Regulation and international coordination in energy markets:

- How does the design of energy markets and carbon quota markets influence transition strategies towards a sustainable energy system?
- How does the development and regulation of the European energy markets influence the Norwegian and Nordic market? Which opportunities does it give for exports of renewable energy and regulation resources, and how should transmission capacities from the Nordic countries to continental Europe be developed and used optimally?
- How should infrastructure regulation proceed to ease the introduction of renewable energy and future sustainable energy consumption?
- What are the most efficient measures for reaching political goals for emission reductions?

Quantitative and qualitative aspect of the development in energy use and features affecting future energy use

- How do drivers and barriers, policy instruments, technology development, energy efficiency, public engagement and the market for goods and services contribute to shape present and future end use in industry, households and the transport sector?
- What are the drivers for energy efficiency? What are the effects of the most frequently used policy instruments to influence end use energy demand such as support schemes, taxes, and information? What would be adequate policy measures?

Climate and energy policy

- How to identify robust public policies and regulation frameworks enabling innovation and transition towards a sustainable energy system?
- How effective are various cost effective instruments to achieve different political objectives?
- Which deviations from cost effective reductions are likely given modest global emission reduction goals and weak global renewable energy policy?
- How does public policy interact with industry and social interest in the formation of energy policy?
- How do companies' experiences and expectations with respect to regulations and policy affect their strategies and investment decisions?

Innovation and value creation

- What factors influence the commercialization of research? How can research result in spin-off and technology transfer? How does one identify commercial potential, and enable paths towards actual commercialization?
- How do local and regional barriers in private and public sector hinder transition strategies and what strategies are needed to overcome such barriers?

- If there is a tension between knowledge creation and spillover, how does this influence policy in a small open economy in Europe?
- What are the roles of citizens in transition strategies and what role do the public play for implementation of environment friendly technologies?

CenSES will provide the following deliverables:

Integrated research areas: CenSES will provide integrated interdisciplinary research based in social sciences with strong links to the natural sciences/engineering.

Cross cutting user cases: CenSES will perform a number of cross-cutting user cases which have time perspective of 1-2 years.

Master program: Norwegian Universities and Colleges lack a comprehensive educational program in Social Studies of Energy which is needed in order to meet the future challenges of the energy sector with regard to knowledge, competences and expertise. Thus, in order to meet this shortcoming, CenSES will develop courses on both master and PhD level.

National PhD school in Social studies of Energy: CenSES will organize a multidisciplinary PhD school to coordinate and strengthen the education of the Centre's PhD students but also to attract PhD students from outside and from abroad. The school will facilitate collaboration between NHH, NTNU and UiO and regional university colleges.

Dissemination strategy: CenSES will develop a comprehensive dissemination strategy of the research to the public, including: (i) yearly conferences, (ii) workshops and seminars, (iii) an Innovation Forum in cooperation with the technology-oriented FMEs, (iv) an Energy Strategy Board for the active user partners and a CenSES Network for network partners, and (v) a public website, bi-monthly newsletter, and high visibility in the news media to reach a wider audience.

Review articles and international conference presentations: During its lifetime, CenSES will contribute with 120 articles in Journals with peer review and 150 papers presented on international conferences.

Books and articles in books: During its lifetime, CenSES will contribute with 3 scientific books and 40 book chapters in edited books.

2. "State-of-the-art" and Research Areas

The focus of CenSES is on transition strategies towards a sustainable energy system or carbon lean economies. The analysis of such strategies is a multi-disciplinary task, with considerable challenges related to the understanding of how transitions may be triggered and developed, made credible and sustained (Coenen & Lopez 2010, Kemp & Rotmans 2009, Smith et al. 2005, Harstad and Eskeland 2010). This includes a focus on governance, new regulatory frameworks and improved technology policies (Mowery et al. 2010). State-of-the-art research in the area addresses the following four overarching but interrelated topics: (1) Policy making and transition strategies, (2) Energy system and markets, (3) Economic analysis, and (4) Innovation, commercialization and public engagement.

With respect to **Policy making and transition strategies** current research analyzes how policy instruments are made and combined for the multi-faceted objectives of security of energy supply, climate mitigation, sustainability and a green economy. Important weaknesses have been identified, e.g., by Shove (2010) who characterizes the dominant policy with respect to climate as too much oriented towards 'the ABC model' – attention, behaviour, choice, which put too much emphasis on behaviour. She calls for an approach better suited to conceptualise transformation in society on the scale and at the rate that is required in order to be successful.

One such approach is transition management. It departs from an idea that broadly shared visions of sustainable futures may be constructed, involving experimentation with hopeful future system configurations and stakeholders into participatory decision contexts able and willing to modulate and develop the required transition processes (Kemp et al. 2007, Smith and Kern 2009, Loorbach 2007). However, transition management has important deficiencies, like the problem of re-occurring non-sustainable transitions and the question whether impacts of socio-technical change may be predicted (Shove and Walker 2007, Scrase and Smith 2009).

Energy transition strategies may be analysed and assessed by highlighting a policy perspective where sociotechnical aspects are well integrated. The new economic sociology of markets (Callon et al. 2007) provides tools to study and assess the construction of energy markets and the relationship between markets and policymaking. The concept of co-production of knowledge and policy (Jasanoff 2004) illuminates governance and policymaking practices with a view to stabilization and destabilization, including comparative and international studies of policy and governance (IEA 2008) which are also fruitfully analysed through this perspective (Jasanoff 2010).

Studies concerned with **Energy system and markets** in CenSES employ numerical analyses of future energy systems, distinguishing between equilibrium models capable of modelling competition and market power, and optimization models assuming an either perfectly competitive market and/or maximization of a joint objective (like welfare, social surplus, CO_2-emissions) for the different players. In the first category, we find global climate models (Integrated Assessment Models) developed to study climate policy and climate change. They typically integrate knowledge across several disciplines. Examples are GCAM operated by our international partner JGCRI (JGCRI 2010) and the Emissions Prediction and Policy Analysis (EPPA) model at MIT, an integrated energy-economy model that can be coupled with climate, ecosystem and urban air pollution models.

Second, there are long-term energy system models that focus on the general energy system. These are more detailed with respect to technology development and the physical system properties and less detailed on the interaction with the climate system and economic systems. Examples include models developed under the IEA framework; MARKAL (Fishbone and Abilock 1981, Fidje et al. 2010, Martinsen 2010), TIMES (Loulou et al. 2005, Fidje & Rosenberg 2010), PRIMES (Antoniou et al. 1999) developed for European analysis and POLES (Criqui 1999) for global analysis. Some of these models, like the TIMES model, can be developed as a technology rich (multi)regional model, communicating with the economic models at different levels. More technology specific investment models with a higher time and spatial resolution facilitates operational flexibility as well as long term effects (Myklebust et al. 2008ab, Stiller et al. 2009, Klokk et al.2010, Schütz et al. 2009, Shütz & Tomasgard 2010). Third, we find short-term market and system operation model**s** addressing stochastic variations in supply, demand and prices (Wolfgang et al. 2009, Mo et al. 2005, Tomasgard et al. 2007, Midthun 2007). The CenSES consortium with its international partners has available models within all these classes. A main challenge is integration of different model classes in analysis, e.g. to understand better the links between the energy system and the rest of the economy and to understand climate and environmental effects of energy strategy. Another important motive for developing these models further is the need to have better decision support for future infrastructure investments .

Economic analysis incorporates how the energy sector with its energy carriers and technologies is a contributing factor – an input – into production and consumption activities in the overall economy. The current literature applies fairly aggregate macro models (as in Nordhaus' RICE model), general equilibrium models with sectoral detail (John Weyant and others in the EMF forum, including the EPPA model mentioned above), or partial equilibrium models with greater technology detail (Eskeland et al, 1994, 1997, 1998). Other ambitious efforts carried out to link energy and environmental issues to the national and international economy are combinations of energy system models and different macro models in a hybrid type of modelling. Different examples are found in Strachan and Kannan (2008), Shäfer and Jacoby (2005), Böhringer & Rutherford (2008). This approach opens for tracing impacts and simulations both ways between the energy sector and the economic models.

There are, however, few examples of such combinations of energy models and economic models at the regional level. A suggested approach linking MARKAL/TIMES models with the REMI model is given in R. Loulou et al 2005. Examples of Multiregional models which integrate the transport sector with the entire regional economy are found in Ivanova et. al.(2006) and Sundberg (2009).

A future curbing greenhouse gas emissions requires analysis of implications for income and welfare, emphasized by researchers such as Thomas Schelling, Nicholas Stern, William Nordhaus,

Ottmar Edenhofer, and the above. Such analysis concludes that rapid emission reductions can be achieved in the first half of this century at moderate costs (half to three percent of GDP) but faces formidable challenges regarding international cooperation (Hepburn and Stern, 2008). The studies differ widely on the urgency of emission reductions, highlighting the CenSES focus on transition paths.

Issues such as carbon leakage competitiveness and non-global policy goals (e.g. environmental protection and energy security) are important. These command analytical approaches reaching from general equilibrium models through, say, models of transport and emissions in the context of an urban area. These will be further developed and integrated with the research on energy systems, innovation and commercialization. Innovation and technological change, through research and development and learning by doing, is studied in light of policy (Alfsen et al, 2010) and acceptance by relevant user constituencies (Latour 2004), and evolutionary theories of the firm.

Research on **innovation, commercialization and public** engagement covers a wide range of topics. First, innovation research is dominated by system perspectives (Fagerberg & Srholec 2008, Geels 2008, Sørensen 2010) which have led to a number of innovation systems models at national, regional, sectorial and technological levels of analysis. Departing from the premise of innovation as a collaborative endeavor CenSES will use a broad theoretical perspective, including a resource based, dynamic capabilities approach, and evolutionary theories of the firm (Barney 1991, Teece 2007). Following Barney (1997) we focus on how firms get access to and how they use resources, including financial, physical, human and organizational resources. Public policy and regulations may influence both access to and use of resources (Autio 2005, Foxon et al. 2005, Bergek et al. 2008) and will be given particular emphasis in the analyses of firm and project level strategies and decisions.

The large scale investments needed to develop, innovate and implement new alternative energy technologies require fairly large coalitions of actors meeting a politically moderated demand (Barreto and Kemp 2008). This suggests a need to focus on infrastructural innovation, even if existing literature in this field is limited to studies of relatively small-scale experiments (Jacobsson and Bergek 2004, Geels 2005). An important feature of the energy sector is that market structure in part is shaped by the electricity grid. This invites incremental innovations related to system efficiency rather than radical innovation with respect to products (Taanman et al. 2006, Hekkert & Hoed 2006). Generally, the energy sector seems characterized by firms with low R&D intensity (Jamasb et al. 2008), which reflects a focus on incremental improvements.

A resource based perspective will be combined with attention to open innovation processes as described by Chesbrough and Teece (2002, see also Dahlander & Gann 2010). Companies typically focus on narrow sets of competencies but develop close relations to external partners for new product ideas as well as for developing technologies, systems and components. These external partners may be customers, suppliers, competitors, universities, research centres, or others (von Hippel 1988). Firms' abilities to interact, access and use external knowledge developed by other actors and organizations within innovation systems are highly important in this regard (Chesbrough 2003), as well as their ability to establish good industrial relations and union-management cooperations within the firm, enabling them to implement, adapt and develop this external knowledge (Ravn & Øyum, forthcoming).

Public engagement is critical to the outcome of innovation and commercialisation. The latest analytical and prescriptive work emphasizes technological citizenship and the relationship between citizenship and consumption. Recent research asks what is needed to achieve robust and mature public evaluations: early involvement, transparency, adequate information, opportunities for deliberation, and acknowledgement of contributions from a diversity of expertise (Bijker & d'Andrea 2009).

On this basis, CenSES will organize its research activities under the following Research Areas:

RA1. Policy making and transition strategies

RA2. Energy system and markets

RA3. Economic analysis

RA4. Innovation, commercialization and public engagement

A fifth Research Areas is needed to provide space for the integration of results from the other four areas. **RA 5. Scenario development** plays a crucial role in the orchestration of the multi-disciplinary research of CenSES and the facilitation of interaction between the different RAs, the research teams and users of the centre. RA5 is an arena of integration where policy and framework conditions, technology strategies, investment strategies and impacts are to be coupled in a consistent way. The results from the other RAs will be supplemented by Life Cycle Analysis and by scenario techniques.

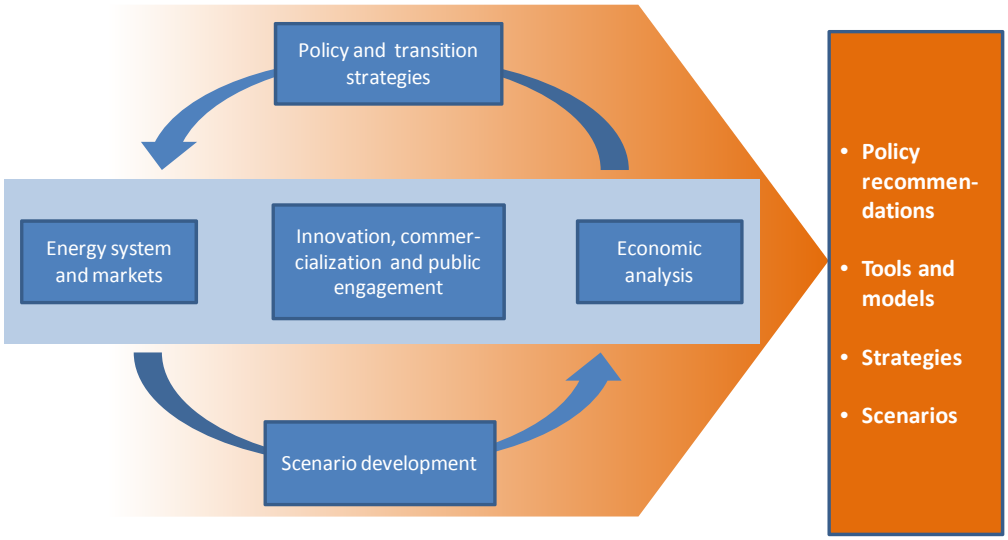


Figure 1. The overall organisation of the Research Areas in CenSES

3. Research challenges, methods and publications

The description of state of the art in social sciences for research on sustainable energy (section 2 above) provides the foundation for the definition of research areas (RAs) that are the scientific core of CenSES. In the following, we describe the research challenges to be addressed by each of the RAs and the linkages between them.

3.1. RA 1: Policy making and transition strategies

The objective of this research area is to strengthen the knowledge base for the formulation of policy for energy transitions at national, regional and local level, taking into account Norway's contribution to international energy and climate policy. This research shall improve the understanding of how ambitious governmental policies and regulations may provide competitive advantages as well as promoting sustainable energy systems. In turn, this aims to facilitate policy making in a long term perspective, for instance by providing a sector specific analysis of policy instruments supporting goals outlined in Energy 21. All together this research agenda aims at designing governance strategies that can initiate, organise and frame institutional and regulatory changes with the aim of initiating dynamic and systemic transitions of society's energy systems. With research on different configurations of actors, CenSES provides an improved platform for policy initiatives. Several key policy stakeholders have expressed interest in contributing. This research area will result in approx. 20 publications in international scientific journals (like *Energy Policy* and *Science, Technology and Human Values*), 10 book chapters and approx. 25 conference papers. The research will be organized with focus on four interrelated areas:

Comparative analysis of governance and public policy for energy systems: The possibility of policy innovations will be studied through comparative analysis of government interventions in the area, including the EU and supra-national bodies providing advice (like IEA). EU has committed itself to wide-ranging energy and climate improvements by 2020, but there is no comprehensive knowledge about the effectiveness of available policies, given varying contexts. We shall also study how public policy interacts with economic and social interests in influencing the production, distribution and consumption of energy. Public policy initiatives are often sector-based

and uncoordinated. A central concern will be to map and analyze the potential for better integrated governance (Jordan and Lenschow 2008). The research will involve several international regions and will be done in conjunction with a more nationally focused:

Assessment of national policy instruments for promoting sustainable energy: Here, we shall analyse the effectiveness of the current use of economic instruments like taxes, subsidies and mixtures of these (certificates, emission markets, cap and trade) with regard to promoting multifaceted objectives like curbing CO_2 emissions, increasing the share of renewables and achieving security of supply. What national framework conditions and policies are needed to meet international climate commitments? What are the effects in the energy sector, and what is the role of R&D as a policy instrument? In this research, demand driven innovation will be focused, identifying best practice cases from other nations. A goal is to identify policy mechanisms that facilitate the creation of markets for sustainable energy.

Transition pathways from an oil and gas economy to a low-emission economy – emergent technologies: We will analyze long term strategies for how Norway can remain a significant European energy provider on the basis of carbon lean technologies. We seek to provide a new approach for analyzing emerging technologies by approaching the innovation system in its formative phase, emphasizing how actors, technology, markets and institutions co-evolve. A important part will be to study the development of climate mitigation projects in real time, focusing on planning and building of physical objects like transmission power grids, wind mills, new renewable power production units (bio-energy, small scale hydro-power units etc). This includes policy issues but also address cultural, cognitive and behavioural aspects. In the research on formation of opinions and engagement, and the role of knowledge, we will use methods like surveys, focus groups and interviews. We will analyze the relationship between local and national stakeholders through several lenses, like area planning (physical buildings obviously mean using area for a new purpose), risk perception, knowledge, mediation and social justice discourses. Qualitative and quantitative data from earlier projects will be reanalyzed, and we shall study climate mitigation project implementation processes as they unfold and involve actors.

Innovations and learning in energy policy: How do energy policy-makers learn? What kind of knowledge input is used and what strategies are pursued to develop a capacity for policy innovation? To investigate such issues, we shall apply a practice-based approach to study policy-making fairly detailed, to provide a deeper understanding of the activities and strategies involved (de Vries 2007, Latour 2007) in the making of proposals of transition policies. We are particularly interested in the relationship between scientific knowledge and policy-making. Will scientific knowledge become easier to make use of if one achieves greater transparency in the interaction between scientists and experts on the one hand, and policy-making and the public on the other?

3.2. RA 2: Energy system and markets

In this RA, several energy system models will be employed and improved. Our international partners will provide access to global models of energy, market and climate. The models will be used for studies both for scenario development (Ch. 3.5), user cases (Ch 3.6) and in connection with analysis of policy making and economic analysis in RA1, RA3 and RA4. The models will be maintained, updated and made available to new projects and activites. Public authorities and companies may contribute with model input, data and assumptions, and use the model results in order to improve decision and investment strategies. Publications (30-40 peer reviewed papers) are planned in journals like Energy Journal, Energy economics, Energy policy, European journal of operations research, 10 book chapters and 40 conference papers. Main challenges to be addressed are:

Modelling technologies and technological learning: Through co-operation with the technology-oriented FMEs we shall make sure that our energy system models are using the best available estimates for technological development. We will create an updated database with cost data, efficiencies and expectations for CCS and renewable energy technologies. In particular, research in RA4 on innovation and commercialization will also provide important input regarding technology adoption.

Modelling government measures and regulation: Different policy measures and regulations studied in RA1 will be implemented in the models. This will be included both as endogenous variables where possible and exogenous variables. In particular the ability to study cost efficiency when meeting different targets on environmental effects, security of supply and economic growth will be of importance. In connection with RA3 we will study effects on the economy and the interaction between energy systems and market design.

End use demand: Through a combination of organizational, economic and social analysis as well as relevant technological knowledge, we will study how drivers and barriers, policy instruments, technology development, energy efficiency, public engagement and markets for goods and services contribute to shape present and future end use demand in industry, households and transport. The research effort shall include cooperation with the FME Zero Emission Buildings (ZEB) to improve the understanding of energy efficiency measures in buildings and with other research groups with respect to energy efficiency in industry. A qualitative market study on drivers for energy efficiency measures will be conducted through a series of case studies of relevant market actors, which includes suppliers of energy efficiency technologies and services as well as potential customers. This research has clear links to RA1, RA4 and RA5.

Modelling uncertainty and dynamics: The future energy system needs to cope with increasing shares of variable energy generation technologies like wind and solar power. Smart grid technology and technologies for dynamic demand response will also change the way the energy system operates, demanding substantial flexibility of all entities from consumers, via distribution and transmission, to power generation. Hence it is important to study and model how energy systems may cope with both long term uncertainty with respect to policy, technology and environmental effects as well as with short-term uncertainty of demand and generation capability. Failing to understand operational flexibility and short term variations may lead to faulty investments and mismatch between operational needs and actual investments.

Modelling new market design, market mechanisms, and integrated energy markets*:* Increased need for energy system flexibility should affect the design of energy and emission markets. It is expected that integration of energy markets will increase in years to come, across energy sources and carriers as well as national borders. Such integration may lead to higher efficiency, better resource utilization and less need for expensive energy storage. On the other hand, complexity increases both in planning models, regulation of the sector and management of the energy systems. This research has clear links to RA1.

Effects of global policy on regional energy systems: Here we use Integrated Assessment Models at the global level and integrate with regional energy system models to study local effects of and responses to global energy policy. Sustainable energy strategies in the regional energy systems are optimized based on a global perspective, utilizing regional advantages while considering risk and uncertainty. This work will have strong connections to RA1, RA3 and RA5

3.3. RA 3: Economic analysis

Transition strategies and policy implementation will be examined in light of policies pursued in other parts of the world with an emphasis on Europe. Present research on developments in Europe – both of the real economy and of politics – raises questions about whether there is sufficient far-reaching technological change to attain a transition towards a low-carbon society through 2020 to 2040 (Alfsen et al, 2010, Eskeland et al 2010). RA3 will therefore eclectically study the manoeuvrability available for players in Norway as well and Norwegian authorities. Dual goals of competitiveness in electricity generation and energy technology (e.g. off shore windmills) will be analysed. This will be done in conjunction with RA1, RA2 and RA4 as CenSES also traces impacts of policy and technological development down to the regional level, including strategies for an urban area with local transport and environmental challenges (Bergen as an example). This includes using economic analysis to combine results and methods in areas from human behaviour and the social sphere through natural sciences and technology. The research area will result in approx. 15 publications in international scientific journals, 6 book chapters and approx. 30 conference papers

Investigating national economic effects and local agendas: A major tool to study overall economic effects of policies implemented in the energy markets in Norway and abroad will be a

general equilibrium model developed at SNF/NHH. This contrasts and complements partial equilibrium models using a 'small open economy' paradigm (see Gaasland, 2008). The model will be further developed to study impacts and costs of climate, energy and technology policies. This analysis enables comparing the effectiveness among different policy tools (learning by doing and R&D). This is particularly important because of inter linkages through input markets and substitutability in consumption,(e.g. oil and electricity for heating), etc. CenSES will analyse the economic effects of different policy measures, for example aiming at increased electrification in transport. This analysis will in part support partial equilibrium models, enabling us to study various sectors in more detail as well as local issues. Endpoints of analysis in addition to Greenhouse Gas Emissions (GHG) and costs will be questions such as structural and technological change, as well as for instance air quality considerations.

Regional economic analysis: For some issues, analysis in a regional setting is warranted: a) choice of energy carriers in the transportation sector; b) development of local energy production in relation to energy efficiency, energy intensive industries, and transmission; c) near-term technological change versus policy framework for far-reaching technological development. These studies will include and develop regional models based on experience gained from models such as Panda (SINTEF Technology and society, A. Stokka et al. 2010), multiregional equilibrium models developed for the transportation sector, as well as the equilibrium models at SNF/NHH. This type of analysis can be combined with analysis and models from the energy systems of RA2 to capture the interaction between changes in the energy sector and the rest of the economy at different geographical levels. The effects of policies should be traced down to the regional level by links to macro economic models at Statistics Norway or CGE models at SNF.

Economic stimuli and the effects of R&D: An important question for a small nation that aims at becoming a technology leader in some areas is whether far-reaching technological change shall require greatly scaled up government funding of energy related technological R&D (illustrative examples being carbon capture and storage and ocean based turbines). The question is increasingly relevant with weakened prospects for high expected emission costs worldwide (Harstad and Eskeland, 2010). How and whether government can stimulate R&D is a research task that will draw on modern microeconomic theory and related experiences in fields such as medicine and defence technologies. Cooperation as well as targeted technology efforts are dimensions to be analysed. This activity will provide input to RA1 and RA4.

3.4. RA 4: Innovation, commercialization and public engagement

This research area analyses the complex interaction between public policies and firm level strategies and decisions, using the company as well as the project level as units of analysis. Public engagement is also included in this RA as the understanding and engagement of the public is an important factor influencing company decisions, implementation and policy development related to post-carbon transition strategies. The combination of the policy, framework conditions and regulative dimensions analysed in RA1 and the focus on the company/project level will represent an important basis for analysis and recommendations related to further policy development and better framework conditions for commercializing new technologies.

The research will be based on a variety of social science methods, including large surveys (new and existing), in-depth case studies from Norway and from other countries, interviewing, documents and publically available statistics. We will start our activity based on existing data sets, and then define the need for new data collection. We shall provide recommendations on policy measures that may strengthen the innovative capacity and value creation of Norway's (non-petroleum) energy sector. This research area will result in 40 publications in international scientific journals, 10 book chapters and 50 conference papers. The research will be organized with focus on four interrelated areas:

Firm level decisions and strategies: We shall study company level strategies and decisions processes influencing production, distribution and consumption of energy. In particular, we emphasize the influence of public policy and regulations on firm level processes and how innovative and responsible firms interact with government, other firms and the general public to find new solutions to the climate challenges. Examples of important issues are investigation of how

enterprises take practical action to safeguard CO_2 neutrality responsibility? How can such corporate level transition practices be sustained, enhanced and disseminated? How is corporate strategy interpreted and implemented at a local level? How may firms mobilize and utilize internal (unions, employers) and external resources (NGOs, governmental agencies, the general public) in these processes? The research will be based on case studies that shall be analysed in a detailed way to cover development processes as they unfold, also facilitating reflection on/in action (Schön 1983) .

Innovation processes and commercialization of research based technology: The factors that influence the commercialization of research are poorly understood and more multi-level and process studies of the university spin-off and technology transfer phenomenon have been called for (Mustar et al. 2006). Specific technology projects with commercial potential will be identified (partly from the existing FMEs), and their paths towards actual commercialization (spin-offs, transfer to existing firms etc) will be studied. We will focus knowledge transfer processes and possibilities of "open innovation" practices (Chesbrough et al, 2006) between R&D-institutions and companies. As part of this activity, we will study how "social media" related to information and communication technology tools may be used for knowledge sharing and interaction in innovation processes. The main contribution from this work package is increased understanding of technology transfer and value creation related to the energy sector from public research institutions.

Local and regional barriers and strategies: An important lesson from the Norwegian history of hydro power is that many of the most important barriers facing firms exist at a local and regional level. A first line of research will analyze how firms cooperate with regional and local authorities in developing relevant policies and policy instruments. A second line of research analyses the role of local energy planning. The analysis will be based on case studies of 10-15 energy companies in 3-5 municipalities in two counties.

Public perceptions and engagement – technological citizenship: Public acceptance is a critical issue in the implementation of environmentally sound energy technologies and regimes of sustainable energy use. However, one has to be careful not to assume that acceptance mainly is an issue of information and education. The growing integration and cross-dependencies resulting from modern production, consumption, and infrastructures, such as the energy and transport systems, are challenging the existing democratic institutions and their relationships to professional public bodies for policy making and policy enforcement. Thus, there is a need to develop new forms and new ways to structure democratic processes for society to facilitate citizens' engagement with science, technology and innovation. The point is that transition towards a green, low carbon economy cannot take place without the relevant technologies being socially embedded in society. Working from new theories of public engagement and technological citizenship, we shall approach controversies around sustainable energy projects to analyse not only how such controversies are played out, but also what options for democratic engagement that are created or could have been created, and the effects of the controversy upon the development of sustainable energy technology.

3.5. RA 5: Energy Scenario Development

The main objective of the Scenario Development activity is to provide research-driven knowledge and analyses to policy makers to aid in the development and evaluation of future energy scenarios and sustainable energy strategies. In the Energy Scenarios the time horizon of the analyses will typically be 2020 and beyond in order to incorporate effects of climate change. At the same time, RA5 will be a main area of integrating results from the other Research Areas. Policy issues and energy strategy questions to be analyzed in the scenario studies will be based upon research results and models from the RAs and input from the users through the Innovation Forum, Strategy Board (think tank), and the co-operating FMEs. The Energy Scenario Development activity shall also provide input to the other RAs regarding research questions and needs of improved models. The topics to be studied in RA5 may refer to the energy sector as a whole or more detailed sector scenario analyses may defined, .g., specific policy implications for electricity generation, household consumption (including effects of new building codes), and transport (including electrification of vehicles).

Specific Norwegian policy issues will be analyzed in relation to international policy choices, especially EU policy requirements. Examples include the effects of EU regulations and

deregulations on the Norwegian and Nordic energy markets, e.g. implications for the feasibility of proposed Nordic measures, and effects on markets, investments, technology change, and relevant climate and environmental indicators. This RA will result in 6 publications in international scientific journals, 4 book chapters and approx. 10 conference papers. RA5 will develop energy scenarios using the following set of approaches:

1. Scenario definition: Input to scenario definition will partly be information, data and results from the other centre activities and partly information and assumptions provided by the users.

2. Scenario analysis: Throughout the duration of CenSES, RA5 will have a dynamic interaction with the other RAs. Their results will be evaluated in scenarios with shifting assumptions and conditions. This will provide a quantitative foundation for assessing different energy policies, and will represent an important interface to the other RAs in CenSES.

3. Impact assessment: We will analyze results along the following dimensions: Environmental effects, GHG emissions, total system cost, economic growth, energy export, national industrial growth and export. The real objective is often a combination of these, and we will include activities focusing on impact assessment and trade-off analysis with strong participation from researchers and experts in environmental analyses and industrial ecology.

4. Robustness analysis and risk management: Because these scenarios are highly uncertain we will include methodology for analyzing robustness, sensitivities and risk as part of the scenario assessment.

RA5 will be based on state-of-the-art with respect to practising multi-/inter-disciplinarity, utilising the four different ways of organising such knowledge identified by Sørensen et al. (2008): a) Through an *additive strategy* knowledge elements are aligned into a totality. This is the most common way of organizing interdisciplinary work and will play a central role in CenSES, in particular in RA5, since in most cases this strategy is a sufficient and appropriate way of combining otherwise disparate knowledge. b) Through a *translation* strategy CenSES scientists will undertake the task of translating and explaining knowledge elements as a basis for dialogue with user from industry or public institutions, including relevant technologies for environmentally friendly energy. c) *Revision* is a strategy of inter-disciplinarity employed when research outcomes are to be assessed, for example with respect to profitability, risk or environmental effects of policies and strategies. For instance, life cycle assessments may provide knowledge relevant for choosing between policy strategies (i.e., the substitution of petrol cars with electric vehicles). d) The strategy of *hybridization*, which implies that knowledge objects are integrated into new and more stable knowledge hybrids. An example is the planned effort to use qualitative knowledge about energy end use as input to energy models and to employ policy analysis to enhance the understanding of the impact of different energy scenario models.

3.6 Cross cutting user cases

We will over the life-time of the centre perform a number of cross-cutting ‘User Cases’. While the research in RA1-RA5 has a time frame of 5-8 years, these cases will be limited to a period of 1-2 years and will be defined dynamically through the life time of the centre. Energy scenarios in RA5 focus on the development over the next 20-50 years, while these cases will generally use a shorter time perspective. The research in the user cases will be performed within the relevant RAs budget. User cases will satisfy several purposes:

- make sure research is integrated and coordinated across the RAs.
- address challenges requiring input from at least two RAs, thus promoting cross-disciplinary research.
- ensure user participation in the RAs, as specific user cases may be initiated by the user partners, and user partners will be actively involved in the development of user cases.
- be a good reality check for the relevance of research going on in the RAs .

The following are examples of user cases that have already been identified in cooperation with the users, of which 3-5 will be conducted during the first couple of years:

Energy efficiency improvements: Missing in action? Often, techno-economic models indicate that energy efficiency improvements are very profitable, while real world studies indicates low

implementation. This user case contrasts behaviourally based studies and historic transition/adoption rates with technology based models to inform policy formation.

Norway as green battery for Europe: How to share burdens and benefits? Connections between Norway and Europe are necessary to balance variations in as well as to export energy. The study examines efficiency as well as burden sharing.

The role of natural gas: Transition fuel or long-term solution? In a long-term transition towards a low carbon society, natural gas may play several roles. Depending on an uncertain commercial success of CCS technologies, natural gas may or may not remain in the generation mix for a long time. What are the policy and techno-economic consequences of these alternative paths?

Electricity and transport: Increased burden or joint benefits? When seen as a load, a significant increase in electric vehicles (EV/PIH) may increase the burden of both networks and generating system. Where do the EV's connect to charge, when and at what capacity? By careful design of "smart" technologies, EV's may be actively used as a moveable storage unit, charging and discharging according to the needs of the power system. We investigate the interaction between the transport sector and the electric system and the need for new business models.

Energy technology and technology transfer – a commercial opportunity and an instrument in climate policy? We will study how technology innovation and commercialization can be made faster as a driver of the transition towards a carbon-lean society. Technology transfer to development countries is a mechanism that can take many shapes and play catalyst roles in climate agreements. We study how innovation and dissemination should interplay in policy. Barriers and potential for small-scale applications of a series of - primarily Norwegian - emission reduction technologies will be examined through intensive case studies in emerging economies as well as developing countries.

3.7. Relation to existing projects

In addition to the FME funding we apply for here, CenSES builds on a significant portfolio of ongoing research projects financed by the Research Council of Norway, EU, industry and government. All user partners of these projects are already invited into the CenSES network. Their supervisors, PhD students and post docs are members of CenSES PhD School. When it comes to the research in these projects, it will form a solid base for the new activities we apply for in FME CenSES. Here we list the most relevant existing projects that we will benefit from and vice versa. CenSES will contribute to increased impact and visibility for the research in these projects. :

- Modelling and forecasting risk in the electricity market, carbon market and related energy markets (ElcarbonRisk),
- Investment in renewable electricity under climate policy uncertainty, PureLEC, Renergi
- Congestion Management and Block Bids in Deregulated Electricity Markets, Renergi
- Public acceptance of post carbon strategies, Research Council of Norway, Renergi
- Building markets, shaping policy? The role of economics in energy policy and energy use, Renergi
- RenewStrat, Implementing and commercialising new energy technologies, Renergi
- ECar, A strategy for electrification of road transport in Norway, Research Council of Norway, Renergi
- Guidelines for the implementation of "Electric Road Transport" policies in Europe, ERA-net/Renergi
- Socially Robust Solar Cells (SoRoSol), Research Council of Norway, NANOMAT
- Dissemination of Sientific Knowledge as a Policy Instrument in Climate Policy, NORKLIMA
- LinkS: Linking global and regional energy strategies, Renergi. This project will as the only one mentioned here be completely integrated with CenSES (in RA1, RA2 and RA5) and included in the CenSES budget.

Some of the projects are further described in the institutional CVs in Appendix 5 and their PhD theses under related projects in CenSES PhD list in Appendix 3. In addition we have applied to the Renergi program for funding of 6 new projects, all of which complements and strengthen the research in CenSES.

4. Researcher training and recruitment

4.1 Master program

We plan to develop a comprehensive master program in Social Studies of Energy at NTNU. The first step in this direction will be to develop a master specialization in technology management as part of the new master study program in renewable energy at NTNU starting in 2011 or 2012. The development of master programs in line with the needs of society and the recruitment needs of CenSES will of course be done in conjunction with existing master programs at the involved institutions like the ESST master program at UiO (Society, Science and Technology in Europe) and to the Master in Energy, Natural Resources and the Environment at NHH. We estimate that 20-30 master students will write their thesis for CenSES in these programs every year.

4.2 National PhD school in Social studies of Energy

CenSES will organize a multidisciplinary PhD school to coordinate and strengthen the education of the Centre's PhD students but also to attract PhD students outside CenSES and from abroad. In particular, the school will facilitate collaboration between NHH, NTNU and UiO and regional colleges with respect to the training of PhDs in the fields covered by CenSES. The school will be based on three sets of activities. First, 2-3 PhD courses on social studies of energy will be offered yearly. Here will we draw on our international partners to contribute. The courses will cover topics in energy economics, technology policy, optimisation, innovation, energy cultures, etc. In addition, the PhD students will follow ordinary courses offered by their home institution. Second, the school shall provide opportunities for PhD students to meet, to have professional exchanges and to develop a common professional identity. An annual workshop or summer school and dissertation workshops will be important instruments to achieve this goal. These events will be forums where the PhD students may present their work. Third, the school will take initiatives to improve the quality of supervision, for example by organizing seminars where supervisors may exchange experiences and discuss strategies of supervision. CenSES partners will offer opportunities for PhD students from other partners to visit for shorter or longer periods. In addition, the PhD school will help strengthen the international dimension of students' training. The PhD school will benefit from and be coordinated with the existing PhD programs.

4.3 CenSES PhD students

FME CenSES will have 34 PhD students and 6 post docs (see Appendix 3 CenSES PhD list for details on people and thesis titles.) Approximately half of the FME CenSES PhD students are already in place financed by the internal funding provided by the universities (most of them started in the fall 2010). This will ensure a quick start-up of FME CenSES. They are distributed across research areas in the following way:

Partner	RA1	RA2	RA3	RA4	RA5	SUM
PhD students in FME CenSES	7	9	5	12	1	34
Post Docs in FME CenSES			1	2	3	6
PhD students in related projects	1	6	5	2	4	18
Post Docs in related projects		1		1		2
Sum	8	16	11	17	8	60

Naturally this overview is approximate as overlap between areas exist and some PhD students will be active in several RAs. For example most of the PhD students will contribute to RA5, even if their main activity is in another RA. We also include the overview from related projects.

5. Significance of the research centre

The main added value of organizing a research centre with the CenSES partners is a) strengthening of multi-disciplinary research through creating broader network arenas than possible in ordinary

research projects. By promoting collaboration between researchers from different fields, we b) enable a comprehensive approach to analysis of the framework conditions and policies necessary for transition strategies, energy systems, markets, the economic system, the role of new technology and innovation, and the assessment of economic and environmental impact of policies. In addition, c) new issues and methods may be focused in the interface between the different research traditions included in the CenSES environment. d) increased visibility and dissemination to the public and other scientists, both when it comes to research in CenSES and related projects.

The knowledge developed within CenSES will be disseminated through several activities like:

Yearly conference: CenSES will arrange a yearly conference addressing research results and new ideas for industry, government and international researchers. We will invite the other FME centres established on social sciences and international policy to cooperate on this as a joint activity.

Workshop and seminars: Various activities with national and international participation both focusing on research and dissemination.

Innovation forum: CenSES runs the Innovation forum for environmentally friendly energy in co-operation with technology oriented FME's. The first meeting was in September 2010 and 7 out of 8 FME's where represented. The objective of the Innovation forum is to create a meeting place to promote innovation and commercialization in the interface between technological research, social science and industry. Central activities in the Innovation forum are:

- Connecting research and industry across different technologies
- Competence development: connecting industry and education
- Joint PhD seminars for FMEs and CenSES focusing on innovation and technology transfer
- Addressing shared challenges for FMEs and industry along the axis of idea- research-innovation-commercialization

Energy strategy board: Strategic think tank, including leaders from academia, government and industry and a yearly national conference organised in cooperation with the centre's partners. This will be developed in co-operation with Technoport initiative. In order to succeed transition strategies must engage several dialogues simultaneously between several actor groups in the society: Politicians and other decision makers, end users/ consumers, business community, trade unions, environmental organizations. The strategy board will facilitate this.

Relevance for users and society will be ensured at 3 levels. Firstly, most user partners will participate actively in research areas. Scenario studies and user cases are in particular designed with this in mind. Secondly, we have the *CenSES network.* Many companies and organizations that are not actively co-operating in CenSES research will still have interest in our activities. These will be CenSES network partners and participate in the CenSES open arenas listed above. Thirdly, we will also disseminate knowledge to a wider audience through a *public website* (www.censes.no), *bi-monthly newsletter*, and high *visibility in the news media*.

CenSES already have a strong collaboration with the technology research areas in projects. As a centre we will in particular co-operate on mapping the technology frontier into energy system models.CenSES researchers already collaborate with six of the eight Centers for Environment-friendly Energy Research (FME) that was established in 2009: CEDREN, BIGCCS, ZEB, NOWITECH, CenBio and 'Solar United'. CenSES sets out to strengthen the cooperation with these and welcome a stronger cooperation with the remaining two centers. Co-operation with the FMEs is currently on the topics of innovation, commercialization, framework conditions and energy system modeling. Seven of the FMEs participate in 'FME Innovation Forum', an initiative started by CenSES in September 2010 (all were invited). We will also strengthen co-operation with technology energy research through agreements with the Norwegian Smartgrid Centre where CenSES is represented in the board and the core team and Centre for Renewable Energy (SFFE) where CenSES is part of the management team. We will also co-operate with NCE Halden on issues regarding emission trading and energy markets (one PhD is planned to start in 2011). We plan to increase co-operation with national research groups on international climate policy.

6. Organisation

CenSES consists of the 7 research partners (IFE, HSF/VF, NHH, NTNU, SINTEF, SNF, UiO) with a total of 30-40 professors/research scientists and 40 PhD-students/post doctoral fellows funded by the centre. In addition, CenSES has 20 user partners and 9 international partners. Thus, efficient centre management is a crucial task, and CenSES has devoted considerable thought on how to set up an effective management structure that also is able to facilitate the multi-disciplinary collaboration critical to the success of the centre. The main focus and competence areas of the research partners are listed in the institutional CVs and summarized below.

Table 1. Collaboration in the Research Areas. (RA leader emphasized)

Partner	RA1	RA2	RA3	RA4	RA5
NTNU Department of Interdisciplinary Studies of Culture (HF)	**X**	x		x	x
NTNU Industrial Economics and technology management (IØT)		x	x	**X**	x
NTNU Industrial Ecology (IndEcol)			x		x
SINTEF Energy	x	x		x	**X**
SINTEF Technology and society (T&S)	x	x	x	x	x
Institute for Energy Technology (IFE)		**X**			x
Sogn and Fjordane University College (HSF) & Western Norway Research Institute	x		x	x	x
University of Oslo, Centre for studies of technology, innovation and culture (TIK)	x	x		x	x
Institute for Research in Economics and Business Administration(SNF)	x	x	x		x
Norwegian School of Economics and Business Administration (NHH)	x	x	**X**		x

CenSES was established April 2, 2009, in response to a felt need to strengthen social science research with respect to environmentally friendly energy and to support the comprehensive ongoing technological activities. The research partners came together in this consortium because they represented partly overlapping, partly complementary competences. NTNU HF has a long-standing and comprehensive experience with sustainable energy through qualitative science, technology and policy studies as well as policy studies. Similar competence is found at TIK, where they also have a strong group doing innovation economics, and at SINTEF T&S, but with a different methodological tradition. The latter group contributes competence in energy economics, which is supplemented by research partners NHH and SNF. Energy systems research and energy modelling is a stronghold of IFE, SINTEF Energy and NTNU IØT. IFE and SINTEF Energy also contributes with international competence in scenario analysis. NTNU Ind Ecol represents a strong research group on assessing environmental impacts (LCA). HSF have a strong research program on renewable energy and local barriers, regional innovation and environmental impact, which is complemented by competence in innovation, entrepreneurship and organization theory at NTNU IØT. Overlapping competence facilitates communication and stimulates high quality research; complementary competence makes CenSES able to address the wide and partly multi-disciplinary challenges articulated by the FME-Society call. By promoting collaboration between researchers from different fields, we enable a comprehensive approach to analysis of the framework conditions and policies necessary for transition strategies, energy systems, markets, the economic system, the role of new technology and innovation, and the assessment of economic and environmental impact of policies. In addition, new issues and methods may emerge in the interface between the different research traditions included in the CenSES environment. A particular strength of the research consortium is possibility to combine quantitative energy system models and analysis with analysis of policy frameworks, acceptance and innovation/commercialization processes to secure innovative and high quality results. All partners will focus on issues were they have a strong competence as well as contributing to multi-disciplinary activities. CenSES has chosen to apply quantitative as well as qualitative methodology in all RAs to spur innovative research.

We categorize users of CenSES in two groups:

Working Partners. These are industrial and government partners who actively will participate in the research work or Innovation forum and influence how research projects are specified. The external members of the executive board will be picked from this group. All will be represented in the general assembly and be partners in the consortium agreement

CenSES Network Partner. These are partners who will be part of CenSES dissemination network and offered possibilities to participate in discussion and seminar activities and the open arenas. There is no requirement that they support CenSES with finances or report their in-kind, but then they will not be represented in the general assembly or be partners in the consortium agreement.

Currently some of the partners have indicated willingness to spend time on CenSES, but not quantified it. They are currently not included in budgets, and they will at the time of writing the consortium agreement choose which of these groups they will join. We will invite government institutions that are not presently in these categories to participate in one of the categories (KLIF, relevant ministries, Gassnova).

Management structure

General Assembly: All research and user partners contributing with time or finances are members of the General Assembly (GA), which gives guidance to the Executive Board (EB) in their decisions regarding major changes in scientific strategy and approves annual implementation plans.

Executive Board (EB): The EB consists of eight representatives, four from user partners and four from research partners (including board leader). EB oversees the strategic management of CenSES and gives recommendations to CenSES management group.

Centre Management: Centre Management consists of Director, Prof. Asgeir Tomasgard and Deputy Director, Prof. Marianne Ryghaug, supported by a full time centre co-ordinator dr. Ola Edvin Vie. In addition, the management group consists of one representative from all research partners. The management group is collectively responsible for the research activities of the centre, while the individual partner representatives have a responsibility for managing local activities according to the common goals.

Scientific committee: An international scientific committee will have representatives from our international partners. The main activity for the committee will be a yearly workshop with the Board and Management Group with focus on: a) evaluation and discussion of the research in the centre. b) visions and new impulses from he international members. The committee will be an instrument for the Board as well as centre management in their strategic work and revisions of research plans.

Research plan: A detailed research plan for the centre will be made. It will show detail for objectives, deliverables and progress for a two year period and long term objectives and deliverables according to this proposal and the consortium agreement. The centre management will revise plans yearly by advice from the board. When approved by the board the general assembly will formally approve the plans.

Collaboration in CenSES:

Collaboration between participating researchers and the combination of the kinds of knowledge produced will be facilitated through the scenario development activities, user cases and the management of the RAs. The management team will take a collective responsibility for the research plan. The team will facilitate further co-operation between the CenSES partner and co-ordinate activities at a much higher level than today's co-operation on single projects. The management team will have bi-weekly video conferences and as often as possible meet physically. Our experience from previous large, cross-disciplinary projects has shown the importance of quite frequent meeting to facilitate team-building and scientific exchanges. CenSES is a virtual research centre. Thus, the facilitation of regular face-to-face meetings and innovative co-ordination measures are given high priority. We shall achieve this by:

- Establishing at least three joint working spaces in Trondheim (main location), Oslo, and Bergen at partner institutions. These joint working spaces will be connected with open video conference lines and collaboration equipment as well as regular work desks.
- CenSES shall establish supervisor teams for PhD-students by engaging professors across participating institutions and disciplines. PhD students will be motivated to spend time with the user partners and the other research partners.
- A project webspace**:** The management of knowledge, information and services will be supported by the project website. Cross-disciplinary work will be promoted by the scenario development, user cases and the mix of qualitative and quantitative methods in the RAs.
- A multi-disciplinary PhD school.
- The Innovation forum will promote co-operation both within the centre and with technology research groups.

7. International cooperation

The international partners described in the proposal will contribute in the following ways (see also the international CVs in the appendix):

- Collaboration with respect to PhD training. This is included in budgets.
- Participation in workshops and conferences, including collaborative activities (included in budgets).
- Exchange of researchers. A part of CenSES' budget will be allocated to support such mobility, including the invitation of eminent scientists.
- Research collaboration on the CenSES research activities. This is mainly financed by the international partners own research activity and budgets (outside CenSES). This activity is substantial.

University of Maryland, has strong competence on equilibrium models for energy markets and regional policy studies where effects of energy strategies on environment and the economy is in focus. They will be included in RA, RA2 and RA5 both with models, comparative policy studies and analysis.

Tsinghua University, Institute for Energy, Environment, and Economy have strong modelling groups on Energy system analysis and sustainable energy strategy as well as climate change policy and strategy. They have developed models for the Chinese economy and energy system which will be useful for CenSES when we want to understand the effect international climate policy will have on emissions, technology transfer, international emission quota prices and international resource prices.

Linköpings universitet, Program energisystem is a cross-disciplinary co-operation carrying out research on technical, economical and social prerequisites for achieving sustainable development of energy systems. They will contribute on RA1, RA2, RA5.

Joint Global Change research Institute, is responsible for developing the Integrated Assessment Model GCAM. They will participate in policy and scenario studies in RA1 and RA5 using this model.

Lancaster University, Department of Management Science will contribute on uncertainty management in economic analysis, energy system design and scenarios (RA2,3,5). They will dedicate a PhD student to this work.

University of Edinburgh, Institute for the Study of Science, Technology and Innovation (ISSTI), conducts research, teaching and consultancy on social and policy aspects of science, technology and innovation, governance in energy and sustainability, risk and regulation; and on emerging technoscience fields, thus contributing in RA1, 2 and 4. The institute is interdisciplinary in the social sciences and has multidisciplinary cooperation with technical specialists.

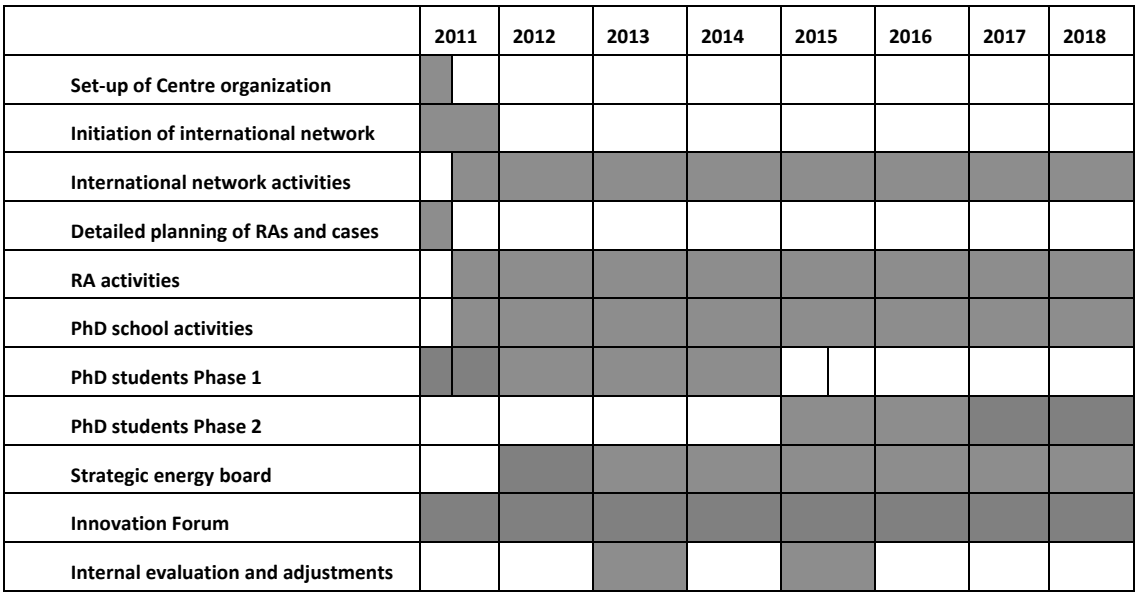
Fraunhofer Institute for system and innovation research will contribute on energy system, modelling, comparative policy studies and innovation (RA1 and RA2).

TNO Innovation and environment will participate in RA3 on economic analysis and comparative studies of policies (RA1 and RA3).

Energy Technology Systems Analysis Programme (ETSAP): Participation in ETSAP an co-operation with ETSAP members is a fundament for RA2 as the ETSAP activities involve development of and analysis through the use of our energy system models (MARKAL and TIMES) and contribution to technology fact sheets on production, transmission and end use technologies.

For more information about the relevant research activity of our international partners, see the institutional CV's in appendix 6.

8. Progress plan and milestones



Milestones and deliverables:

Date	Milestones	Deliverables
July 2011	CenSES up and running. Research groups, international network and research users in place 1st stage of research initiated, 1st international workshop, 1st stage of PhDs admitted	CenSES website Report about organisational status, including recruitment of PhDs Report from 1st international workshop
Dec 2011	Strategic energy board initiated, 1st national conference, 1st round of user interaction with FME centres and core group policy-makers completed: adjustments to research plans . PhD school started.	Report from first meeting of Strategic energy board Report from 1st national conference Report from 1st round of user interaction Report summarising adjusted research plans
Dec 2012	1st stage of research, user cases and scenarios completed.	At least 10 international papers submitted for publication. Report summarising 1st stage of research Report summarising user cases Report summarising scenarios
Dec 2013	1st round of internal evaluation and adjustments completed	Internal evaluation report.
Dec 2014	At least 10 spin-off proposals submitted to RCN/EU programs, 2nd stage of PhD students admitted	Report about spin-off proposals Report summarising dissertations produced by 1st stage PhD students Report about recruitment of PhD students in the 2nd stage
Dec 2015	1st period of Centre completed. 2nd stage of research completed. 2nd round of internal evaluation, adjustments suggested. 2nd international conference, 2nd round of user feedback completed	Report summarising 2nd stage of research Report from 2nd round of internal evaluation Report from 2nd international conference 45 international papers submitted for publication Report from 2nd round of user feedback
Dec 2016	3rd stage of research initiated, research plans adjusted according to feedback from evaluation	Report summarising adjusted research plans

Dec 2018	3rd and final stage of research completed. 3rd round of user feedback, 30 spin-off project proposals submitted to RCN and/or EU programs	At least 120 international papers submitted for publication Report summarising 3rd stage of research, including submitted dissertations Report summarising spin-off project proposals

9. Budget

Costs per year per partner

Partner	Costs in NOK 1000								Total	- of total
	2011	2012	2013	2014	2015	2016	2017	2018		
NTNU IØT	6 533	7 214	5 144	4 899	4 279	4 406	4 538	4 385	**41 399**	**17 %**
- management	410	428	446	465	485	506	528	551		
- research	6 123	6 786	4 698	4 434	3 794	3 900	4 010	3 834		
NTNU HF	4 595	4 716	4 842	4 974	5 205	5 348	5 497	5 653	**40 832**	**17 %**
- management	1 251	1 304	1 361	1 419	1 480	1 544	1 610	1 679		
- center activiy	797	797	797	797	797	797	797	797		
- research	2 548	2 615	2 685	2 758	2 929	3 008	3 091	3 177		
NTNU IndEcol	1 178	1 201	1 226	1 251	1 352	1 379	1 408	1 438	**10 432**	**4 %**
UiO	2 838	2 838	2 838	2 838	2 913	2 913	2 913	2 913	**23 003**	**9 %**
HSF/VF	3 439	4 290	2 915	2 064	1 213	1 213	1 213	1 213	**17 562**	**7 %**
NHH	2 588	2 638	2 688	2 738	2 788	2 838	2 888	2 938	**22 106**	**9 %**
SINTEF EF	3 704	3 995	3 631	3 249	3 238	3 227	3 215	3 202	**27 459**	**11 %**
SINTEF TS	2 207	2 198	2 184	2 302	2 172	2 161	2 149	2 136	**17 507**	**7 %**
IFE	2 107	2 098	2 084	2 202	2 092	2 081	2 069	2 056	**16 787**	**7 %**
SNF	1 407	1 398	1 399	1 502	1 372	1 361	1 349	1 336	**11 122**	**5 %**
Total research partners	**30 598**	**32 585**	**28 951**	**28 019**	**26 624**	**26 925**	**27 237**	**27 270**	**228 210**	**94 %**
User partners	1 393	1 393	1 393	1 393	1 393	1 393	1 393	1 393	**11 144**	**5 %**
Abroad	500	500	500	500	500	500	500	500	**4 000**	**2 %**
Total	**32 491**	**34 478**	**30 844**	**29 912**	**28 517**	**28 818**	**29 130**	**29 163**	**243 354**	**100 %**

The research council project LinkS is integrated in CenSES with the following costs distributed on the 3 first years: SINTEF (2550, 2950, 1428) and NTNU (1980, 2200, 300).

Costs per research area, centre activities and management

RA1	RA2	RA3	RA4	RA5	Center	Management	Total
35 951	61 735	37 585	51 018	31 226	10 372	15 466	**243 354**

Centre activities are PhD school, workshops, conferences, dissemination, exchange, etc. This budget is placed on NTNU HF, but will be used by all partners. Management of Research Areas is categorized as research.

10. Costs distributed among the individual partners

Partner	Costs in NOK 1000				
	Personell & indirect	Purchase of R&D	Equipment	Other direct costs	Total
NTNU IØT	37 399	600	0	3 400	**41 399**
NTNU HF	32 460	0	0	8 372	**40 832**
NTNU IndEcol	10 432	0	0	0	**10 432**
UiO	21 403	0	0	1 600	**23 003**
HSF/VF	15 962	0	0	1 600	**17 562**
NHH	20 506	0	0	1 600	**22 106**
SINTEF EF	25 891	0	0	1 568	**27 459**
SINTEF TS	16 707	0	0	800	**17 507**
IFE	15 187	0	0	1 600	**16 787**
SNF	10 482	0	0	640	**11 122**
Total research partners	206 430	600	0	21 180	**228 210**
User partners	11 144	0	0	0	**11 144**
Abroad	1 600	0	0	2 400	**4 000**
Total	**219 174**	**600**	**0**	**23 580**	**243 354**

11. Financial contributions from the individual partners

	Funding in NOK 1000						
	Average per year			All years			
Partner	Financial	In-kind	**Total**	Financial	In-kind	**Total**	**- of total**
NTNU IØT	0	3 890	**3 890**	0	31 116	**31 116**	13 %
NTNU HF	500	2 226	**2 726**	4 000	17 808	**21 808**	9 %
NTNU IndEcol	0	629	**629**	0	5 029	**5 029**	2 %
UiO	0	2 000	**2 000**	0	16 000	**16 000**	7 %
HSF/VF	0	1 013	**1 013**	0	8 106	**8 106**	3 %
NHH	0	1 825	**1 825**	0	14 600	**14 600**	6 %
SINTEF EF	0	2 050	**2 050**	0	16 400	**16 400**	7 %
SINTEF TS	0	1 200	**1 200**	0	9 600	**9 600**	4 %
IFE	0	700	**700**	0	5 600	**5 600**	2 %
SNF	300	200	**500**	2 400	1 600	**4 000**	2 %
Total research partners	**800**	**15 732**	**16 532**	**6 400**	**125 860**	**132 260**	**54 %**
Others	350	0	**350**	2 800	0	**2 800**	1 %
Hydro	500	0	**500**	4 000	0	**4 000**	2 %
Statoil	500	0	**500**	4 000	0	**4 000**	2 %
NTE	200	300	**500**	1 600	2 400	**4 000**	2 %
Statkraft	181	150	**331**	1 450	1 200	**2 650**	1 %
Bergen Kommune	150	150	**300**	1 200	1 200	**2 400**	1 %
Transnova	100	200	**300**	800	1 600	**2 400**	1 %
SFE	144	150	**294**	1 150	1 200	**2 350**	1 %
Troms Kraft	250	0	**250**	2 000	0	**2 000**	1 %
SSF	19	150	**169**	150	1 200	**1 350**	1 %
BKK	100	50	**150**	800	400	**1 200**	0 %
Sognekraft	0	150	**150**	0	1 200	**1 200**	0 %
450 Consulting	0	50	**50**	0	400	**400**	0 %
Norwea	0	43	**43**	0	344	**344**	0 %
Enova	0	0	**0**	0	0	**0**	0 %
Innovasjon Norge	0	0	**0**	0	0	**0**	0 %
NVE	0	0	**0**	0	0	**0**	0 %
Statnett	0	0	**0**	0	0	**0**	0 %
GE	0	0	**0**	0	0	**0**	0 %
Runde Miljøsenter	0	0	**0**	0	0	**0**	0 %
IntPow	0	0	**0**	0	0	**0**	0 %
User partners	**2 494**	**1 393**	**3 887**	**19 950**	**11 144**	**31 094**	**13 %**
Research Council	**10 000**	**0**	**10 000**	**80 000**	**0**	**80 000**	**33 %**
Total	**13 294**	**17 125**	**30 419**	**106 350**	**137 004**	**243 354**	**100 %**

The NTNU's and SINTEF's share of the research council project LinkS is included for the first 3 years, represented as in-kind funding from SINTEF (2050, 2350, 928), NTNU (1980, 2200, 300) and financial funding Hydro (500, 500, 500). Hydro has confirmed participation in CenSES through Links until 2013. If they decide not to continue after 2013 they will be replaced by another industrial company. 'Others' represent estimated contributions from the user partners that did not specify contribution, but confirmed that they will contribute financially.

12. Gender equality

In the management and coordination of the Centre, we are committed to realize equal opportunities as well as possible. Several of the senior researchers and a substantial part of the Management Group are women. Also, CenSES aims to build an inclusive and open community of researchers and a growing involvement of women researchers in the field of social studies of energy will be encouraged. As well as exploring opportunities to recruit women junior researchers, we shall involve women researchers wherever possible in the networks where CenSES is engaged.

The consortium will commit to making meeting and communication procedures open, accessible and participatory for all members, and to counteracting practices that discriminate between genders. All research partners are aware of, and committed to redressing, gender imbalance in academic employment.

We shall achieve a proper gender balance (at least 40 % of the minority gender) in the recruitment of PhD students, post. docs and research scientists. CenSES will also seek to support women qualifying for senior positions. Current activities such as the national entrepreneurship network forum (k-plass.no), Kvinnovasjon Norway and GRO-nett will be used actively to support energy related innovation and entrepreneurship involvement by women in particular.