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# CREE – Oslo Center for Research on Environmentally friendly Energy

**Revised proposal**

## 1. Research Focus and Relevance

To a large extent, energy and climate policy is focused on how to develop and utilize new technology and more environmentally friendly energy sources. This does not occur by itself, but instead is dependent on institutional and economic frameworks. In this regard, CREE will contribute to the collection and establishment of knowledge on how framework conditions affect both the energy market and technological development, including innovation and the diffusion of technology for renewable energy, energy efficiency and carbon capture and storage. The center will work on developing better framework conditions and policy instruments designed to reach the goals established in national and international energy and climate policy. The work of CREE will thus be highly relevant for our user partners, which consist of Norwegian policy makers, regulators and important agents in the energy market.

CREE will work with all of the issues mentioned in the announcement. We will further develop our methodological framework and use it to analyze problems in relation to the design of policy instruments, markets and regulation, international energy and climate policy, as well as innovation and diffusion. Our research will primarily be grounded in economics – for which our research partners will be the Department of Economics (University of Oslo), the Research Department (Statistics Norway), the Frisch Centre and the Tilburg Sustainability Center - but will also draw on other disciplinary perspectives. Using economics to study the problems mentioned is one approach. Economics is useful and important, although coupling knowledge from economics with knowledge from other fields is essential for establishing a solid basis for energy and climate policies. This is the reason why we will have a close cooperation with other disciplines within the social sciences, law and technology (IFE, SINTEF Energy and the MILEN network at the University of Oslo).

## 2. Thematic Priority Areas and State-of-the-Art

CREE will organize its research into five different working packages:

***Working Package 1: The International Politics of Climate and Energy***
***(Research Directors: Michael Hoel, Department of Economics, University of Oslo, and Ole Jørgen Røgeberg, Frisch Centre)***

The belief that we are on the brink of an international climate treaty that will successfully cut global greenhouse gas (GHG) emissions to avoid dramatic increases in global mean temperatures from pre-industrial levels is dwindling every day, with a number of factors having contributed to this (Rogeberg et al., 2010). Public and political priorities have shifted after the financial crisis, the developing and developed worlds are unable to make progress on the question of burden sharing and their respective emission trajectories, and there is a lack of treaty mechanisms robust and powerful enough to lock in national policy priorities, given the lack of a supranational judicial system able to enforce it. The Kyoto Protocol exemplifies this last point through its lack of good enforcement mechanisms. Missing a target adds a shortfall with a 30% penalty to the next period's abatement targets, though future targets are subject to negotiation with future shortfalls penalized in the same way. Based on this, we plan to address a broad set of topics that are of interest both from a research and political perspective:

- *Improving the current climate regime* - Building on the UNFCCC and the Kyoto Treaty, can new institutions and mechanisms be added in order to increase incentives for abatement, joining and complying?
- *Alternative treaty forms* - What issues are raised by alternative treaty forms such as sector-based treaties or R&D collaborations?
- *Dealing with non-signatories* - How can abating countries best prevent carbon leakage from eroding abatement achievements?
- *Equity issues* - How can economic mechanisms, such as tradable emission permit markets, be used to deal with equity issues?
- *Implications for energy markets policies* - How are energy markets and policies affected under various global climate policy scenarios?

Each of these research topics covers important research questions. Below, we discuss some ideas within each that we currently find promising and that illustrate the type of research that could result. The specific issues that eventually result in actual research may, obviously, turn out to differ from these, but will still draw from the same topics. In addressing these topics, we will cooperate with the Natural Resource group at the Faculty of Law, and with other social scientists through MILEN (including CICEP)

## Improving the Current Climate Regime

Current research concentrates on improving treaty mechanism design with a view to increasing national incentives for both joining treaties and accepting substantial abatement targets (see e.g. Barrett, 1994; Carraro and Siniscalco,1998; Buchner and Carraro, 2005; Asheim et al., 2007). In an ongoing project, we are considering how the incentives to join an international environmental agreement and comply with the agreement depend on different aspects of treaty design, e.g. the extent of quota trading, trade policy and the use of fines.

One current discussion concerns the possibility (and international legality) of using trade policy to both attract members and punish abatement shortfalls. In the language of trade, there is a distinction between a trade sanction and a trade control (in particular, a trade-related environmental measure - TREM). The latter are instruments used in a predictable way to regulate trade in products addressed by some type of international treaty. An example of a multilateral TREM is the Montreal Protocol, which bans trade in products containing ozone depleting substances with non-parties to the protocol. Unlike the current Kyoto compliance system, trade controls do not rely on "self-punishment." In contrast, trade controls should be compatible with current trade rules and practices as expressed by GATT and WTO law. Moreover, trade sanctions and control must be credible threats, i.e. countries putting them into place must in some way or another gain from doing this. Potential research questions are: How can trade controls such as import bans, border adjustment measures or taxes be included in future climate agreements in order to enhance participation and enforce compliance? Is it possible to make such measures WTO compatible, and are there ways to avoid or resolve any legal conflicts?

The inclusion of emissions from deforestation and forest degradation in developing countries (REDD+) in the current international climate regime is under negotiation. While negotiations continue, policy measures are already underway in a number of developing forest countries. Whereas reducing emissions from forests has been lauded as the fastest and most cost-effective mitigation tool available, recent developments show that in order for REDD+ to be an effective mechanism, time consuming significant systemic changes in forest countries need to be undertaken. Moreover, opportunity costs to be compensated by REDD payments could differ significantly from country to country. One interesting question concerns the economic implications of different opportunity costs, as well as attempts to assess the overall costs of systemic changes. The implementation of REDD+ initiatives also raises a number of legal challenges such as the right to income from carbon storage in forests and the pricing principle used for this type of carbon storage. A number of different legal and economic aspects will need to be considered in light of this to efficiently, effectively and equitably implement REDD+.

Alternative Climate Treaty Designs

The literature on treaty mechanisms usually focuses on abatement agreements (Barrett, 2003), as this is sufficient for isolating and examining the free rider problems involved. Future climate agreements may, however, focus on targets other than "top-down national emission/abatement targets," such as, e.g. sector-based approaches. The literature here distinguishes between three types: government driven, industry driven and R&D driven (Meckling and Chung, 2009). While the latter two approaches are based on voluntary participation by private actors, the first approach has as its point of departure that emission reductions are enforced by national laws. This normally requires negotiation between nations in order to agree on the type and stringency of regulation. Thus, this is similar to the Kyoto process, with the primary difference being that the focus is on separate industries and not the entire economy.

Sector-based approaches would guarantee some leveling of the playing field by ensuring that firms in developing countries also have to meet emission standards. Nevertheless, there are several ways of designing a sector-based treaty. For instance, it is not obvious whether or not emissions from the sector in question should be included in the overall GHG emission targets of Annex 1 countries. Further, should the sector-based target be a nation-specific emission *level* target, a nation-specific emission *intensity* target or simply a technology standard? Is it possible to classify sectors to avoid outsourcing of the emission intensive parts of the production process in order to reach the target? Additionally, the benefits of sector-based emission trading need to be analyzed.

Another set of questions concerns the emerging international architecture of climate agreements under the UNFCCC. What are further feasible alternatives for agreements, how should they be analyzed and evaluated, and what are their legal implications? For instance, what are the consequences of a possible gap between the first and second commitment period of the Kyoto Protocol, as well as the structure and content of a new comprehensive climate agreement that includes both developed and developing countries? This also relates to the aforementioned alternative of sectoral treaties, which becomes relevant as an integral part of or an alternative to a comprehensive climate agreement.

Additional issues are raised by a R&D collaboration as far as funding, coordination of domestic policies and mechanisms (involving price, technology standards, etc.) for technological diffusion (Golombek and Hoel, 2009). The international cooperation on Carbon Capture and Storage R&D (within the G20 and EU) is an important example where such research could prove relevant. This topic is also related to the design of optimal climate treaties. De Zeeuw and Hoel (2010) show that if mitigation costs can be brought down sufficiently through R&D, non-cooperative behavior may lead to large declines in carbon emissions. This does not mean that international treaties are not needed anymore: A treaty can still improve the situation, either by promoting more investment in R&D to reduce the cost of adoption, or by preventing overinvestment in R&D. An important conclusion that can be drawn from this work is that the stability of international environmental agreements is much better than in a setting in which treaties only focus on the reduction of emissions. This work could be extended by considering more realistic cases in which countries differ in the priority they give to emission reductions, together with other economic dimensions. With such heterogeneity, more countries can be expected to implement strong mitigation efforts to assist in lowering mitigation costs, which in turn may depend on the R&D efforts undertaken by the countries that give emission reductions the highest priority. If total R&D efforts are increasing in terms of the size of a coalition undertaking a major effort to help bring down mitigation costs, there may be some tipping point: With a sufficiently large coalition, the R&D effort may be so high that mitigation costs drop to a level that makes (almost) all countries willing to implement a strong mitigation effort.

Dealing with Non-Signatories

While robust and well-designed treaty mechanisms could cause treaty members to abate, the continuing existence of nations and/or emission sources outside the treaty leads to the problem of carbon leakage (see e.g. Felder and Rutherford, 1993). Carbon leakage occurs through two main mechanisms: Competitiveness effects (i.e. a market share shift in favor of foreign emission-intensive firms) and energy price effects (i.e. reduced prices of carbon-intensive energy as demand falls in regulated areas, thus raising consumption and emissions elsewhere). The research partners already have ongoing activities within this area, but there are further, important questions relating to the topic that remain: How can the leakage triggered by major single abatement projects such as CDM projects or forestation measures be taken into account when evaluating the "net abatement" effects these projects would entail, and to what extent can such leakage be counteracted? To what extent can firms in a carbon-light nation use technological innovation or investment in "green tech" to counteract the competitiveness effect?

Equity Issues

Researchers or policy makers may not agree on optimal emission reductions even if they agree on the natural science background and costs to abate greenhouse gas emissions. The reason for this is that optimal emission reductions depend on equity issues to a large degree, with how we discount future climate impacts of special importance, see Dasgupta (2008). However, ethical issues have not been fully explored in economic models, as greenhouse gas abatement not only affects the welfare distribution between present and future generations (impacts will be felt in the future, but the costs have to be taken today), but also the distribution within a generation such as that which exists between rich and poor countries (see Kverndokk and Rose, 2008, for a survey). These two equity aspects are very important in finding optimal emissions reductions.

Consider the intergenerational equity issue as one example. The empirical evaluation of policies to mitigate climate change has been largely confined to the application of discounted utilitarianism. Recent research (for a survey, see Asheim, 2010) points to alternative evaluation criteria that assign more weight to future generations (Asheim and Mitra, 2010; Zuber and Asheim, 2010). The use of integrated assessment models can indicate whether the application of such alternative criteria influences our choice of climate and energy policies.

Implications for Energy Markets and Policies

Energy production is a major source of GHG emissions, and international climate policy will have a major effect on energy markets and vice versa. To better understand and quantify these linkages, it will prove necessary to study international climate policies within global and national integrated (economy-energy-emission) general equilibrium models (see WP5). If Western countries reduced their use of coal this would lower the global price of coal, stimulating demand in other countries, though this would partially undo the global abatement. Analyses of policies within such empirically oriented models can provide important policy-relevant insights regarding the likely future effects of various international climate policy regimes on say, e.g. the value of Norwegian petroleum reserves.

In this working package we will collaborate with researchers in CICEP, especially from their working package 2 (Exploring effective and feasible international climate change regimes). This includes discussing the work in joint workshops, and possibly collaboration on papers.

***Working Package 2: Innovation and Diffusion policy***
***(Research Director: Rolf Golombek, Frisch Centre)***

Atmospheric greenhouse gas stabilization targets as low as 450 ppm $CO_2$ equivalents could be needed in order to avoid dangerous anthropogenic interferences with the earth's climate system. Such targets may require more than twice as much carbon-free power by the middle of this century than we now derive from fossil fuels (Hoffert et al., 2002). Clearly, this is the technological challenge of the century. Many different policy tools are being implemented in order to spur the introduction of carbon-free energy technologies. However, according to many observers, the current effort is far too weak.

Arrow (1962) was one of the very first contributors to make the innovation process in economic models endogenous. The literature later culminated in a seminal paper by Romer (1990). Ever since, the learning by doing model (Arrow, 1962) and the capital variety model (Romer, 1990) have been frequently applied to environmental economics. Learning-by-doing models have been used in, e.g. van der Zwaan et al. (2002), Manne and Richels (2004) and Rosendahl (2004), while applications of Romer type models are by Gerlagh et al. (2008), Bye et al. (2008) and Greaker and Pade (2009).

During the 1980's, industrial organization literature also made great leaps forward in innovation economics, see Tirole (1997) for a review, and has also been picked up by environmental economics. In particular, incentives for environmental R&D have been studied that compare both different environmental policy instruments and different assumptions about the ability of the government to commit to future policies. Examples of this early literature are Downing and White (1986) and Laffont and Tirole (1996), whereas examples of later contributions are by Requate (2003), Montgomery and Smith (2007) and Golombek et al. (2010).

Environmental R&D is a tale of several market failures. First, there are environmental externalities which need to be internalized through appropriate environmental policy measures. This is essential since it is the internalizing of the environmental externalities that create the demand for the new environmental technology. Second, there may be market failures in the innovation and diffusion processes. Research creates new knowledge which benefits other firms, and thus entails a positive externality. On the other hand, competing research firms may duplicate each other and/or exhaust the pool of good ideas, thereby negatively affecting other research firms.

More recently, economists have also come to understand additional market failures that may operate in the adoption and diffusion of new technologies. For a number of reasons, the value to a user of a new technology may depend on how many other users have adopted the technology. This type of "increasing returns" may be created by learning-by-using, learning-by-doing or network externalities, see Greaker and Heggedahl (2010). When the qualities of a product are hard to assess, consumers may assess it by observing the number of other people who are purchasing the product, inducing informational cascades which creates a scope for advertising (Brekke and Rege, 2007). Similarly, the responsibility to act in an environmentally friendly manner are shaped by observing others, (Brekke et al., 2010), although this may cause market failures with multiple equilibria (Nyborg et al., 2007). The adoption of new technologies may also be hindered by principal-agent problems and cognitive costs. For instance, if the purchaser of a new house has incomplete information about how much energy it may use, the builder may not be able to recover his/her investment in energy saving solutions. Cognitive costs may likewise lead home owners to not invest in profitable energy saving appliances.

In this work package we plan to address a broad set of topics which are of interest from both a research and political perspective:

- *The optimal policy mix* - R&D in environmentally friendly technologies can be spurred by a variety of instruments such as high permit prices, subsidies to private R&D, innovation prizes, etc.; how should governments design and combine the instruments optimally?
- *CCS and R&D* - CCS may be a key technology for achieving the atmospheric stabilization of GHG concentration – what does the optimal R&D policy for a small, open economy with a limited home market for CCS look like?
- *Behavioral economics* - Is it possible to identify types of cognitive costs that prevent environmentally friendly technologies from succeeding in the market?

<u>Optimal Policy Mix</u>

There is a comprehensive body of literature on the use of efficient instruments to obtain the optimal social amount of R&D, see e.g., Gerlagh et al. (2010). This literature indicates that the optimal policy mix typically depends on key modeling assumptions and thereby on certain types of market imperfections. We plan to contribute to this literature, in part by examining instruments that have so far received limited attention and in part by producing a guide to policy makers for design of R&D instruments.

In the literature, the primary focus has been on emission taxes and quotas, which spur demand for environmentally friendly technologies. Alternatively, the government may offer support and incentives that increase the supply of R&D; the government may also finance basic research, cover specific R&D costs, offer general R&D subsidies, award prizes for new blueprints or subsidize support systems for new products such as charging stations for electric cars. We want to examine when the government should undertake this type of research, and when the research should be undertaken by the private sector and what kind of government supply support may be offered to private investors. In particular, we want to study how an award for a new product/process should be designed.

In economics, government interventions are rationalized through correcting for market failures. For example, the development of new blueprints increases the knowledge base on which future developments are based. This is a positive externality, and hence there is a case that can be made for government subsidies in order to make the innovators internalize the effect. Further, the patent system is often imperfect, and does not provide sufficient incentives for innovations. The main part of the literature analyzes how the government should design its instruments when R&D is a one-shot decision. A firm typically develops a (first-generation) product such as an energy efficient or environmentally friendly technology. Then, based on feedback from its clients, the firm improves the product so that its sales are increased, and so on. However, a firm may not start on this process because it knows that once it has developed the first-generation product, other firms may copy its blueprint because of limited patent protection. In addition, the development of the first-generation product may be costly, whereas demand for the product may be small, thus the profit for the first stage of the process may be negative. We want to explore under what conditions sufficient R&D is undertaken to develop the (final-generation) new product, and how the government should design its instruments in order to reach the first-best social outcome when there are dynamic interrelations between R&D and learning.

<u>CCS and R&D</u>

Carbon capture and storage (CCS) may become a bridge between the present greenhouse gas (GHG) intensive society and a future GHG-free society. The development of CCS requires R&D, with only a few firms thus far having developed such technologies. Using a numerical model for the European energy markets (LIBEMOD, see WP5), combined with game theory, we want to examine whether the government should support R&D that makes CCS less energy intensive, and how their support may depend on market characteristics.

We will use LIBEMOD to derive demand for CCS, and then use this in a game between CCS producers and governments to explore how R&D support to cut costs of CCS has an impact on the energy market. The game may be set up as follows: (i) governments set R&D support, (ii) firms choose to invest in R&D given the R&D support and (iii) firms determine their production of electricity. The model is a good starting point for giving guidelines for when it is optimal to support R&D in CCS, and how the amount of support may depend on factors such as the number of CCS producers, technology spillovers and $CO_2$ policy.

<u>Behavioral Economics</u>

Recent studies have demonstrated that individuals may fail to respond to economic incentives in the expected way (Thaler and Sunstein, 2008), and that these failures seem to display regularities that make them likely to appear in the context of consumers’ investments in energy-saving equipment (NOU2009:16). The energy required to heat a house is only one aspect to consider when buying a house, and for many consumers this will be subordinate to other characteristics such as location, size and appearance. Moreover, most households buy houses infrequently and are inexperienced with the decision; consequently the bidding is often a stressful situation in which decisions have to be made with a short period of time. Similar arguments apply to many energy saving technologies. Governmental policies such as public purchases and provision of free public consulting services may be designed to overcome such market failures. We will study these problems by developing theoretical economic models to derive qualitative predictions and policy recommendations, and empirically exploring model predictions and/or model assumptions using laboratory experiments.

***Working Package 3: Regulation and Market***
***(Research Director: Nils-Henrik M. von der Fehr, Department of Economics, University of Oslo)***

The extensive regulatory reforms that have been introduced in the energy sector in recent years have mainly aimed at increasing the efficiency in the utilization of existing energy resources, as opposed to promoting environmentally friendly or green energy. Reforms have opened up markets to more competition, particularly in energy production and retailing, in an attempt to reduce market power and costs. They have also tightened the regulation of natural monopoly activities, especially networks and other infrastructure, in an attempt to increase efficiency and cut costs. Finally, reforms have been introduced to integrate markets by strengthening interconnector capacity and harmonizing national regulation to enhance competition and provide more equal access to energy.

Although not aimed at green energy *per se*, these reforms have tended to extend the use of green energy in some areas, such as through the integration of hydro power in Scandinavia and wind and thermal power in Continental Europe. In other areas, the development of green energy has been hampered by unfortunate or missing reforms, e.g. where wind power has been restricted by a weak infrastructure and bottlenecks in international interconnectors. One could also argue that regulatory reforms have undermined green energy in some areas where a more efficient utilization of existing energy resources has reduced the need for investment in new (green) generation capacity.

In parallel with the more general energy market reforms, various measures to promote green energy have been introduced. Some of these may be considered more or less unrelated to the functioning of energy markets such as emission control for generation facilities, disposal of waste from energy production or building standards to reduce the need for heating. Other measures have had a more direct impact on the performance of energy markets such as the system for tradable carbon emission permits and feed-in tariffs for electricity produced from wind and other renewable energy sources. In some cases, there has been considerable tension – if not outright conflict – between the measures used to promote green energy and regulations which aim at more efficient energy markets; one example is the introduction of large amounts of new intermittent energy into systems in which the regulation of networks has not allowed for sufficient increases in transmission capacity.

While there has been quite a bit of effort expended in trying to understand the functioning of energy markets in general and the introduction of green energy in particular, we still do not have a very good understanding of how best to regulate these markets. This is due in part to the political economy of energy, in which a number of different and often conflicting goals are pursued; the EU 20-20-20 strategy is a good example, as it not only aims at reducing the use of overall energy, but also at increasing energy efficiency and promoting green energy, while at the same time preserving the competitiveness of European industry by not raising the cost of energy. We are a long way from understanding how these goals interact and how an overall consistent policy can be achieved.

Our lack of understanding concerns the more fundamental character of energy markets. For example:

- What is a reasonable level of energy security and how do we ensure that it is achieved?
- What are the requirements of a network infrastructure when large amounts of wind and other intermittent energy sources are introduced into the system?
- How do we best ensure integration of national energy markets, both with respect to the physical infrastructure and to the system's operation and regulatory oversight?
- How should measures to promote green energy be harmonized with the overall regulation of energy markets?
- When should we use market-based measures and when should we use other regulatory measures to increase the sustainability of our energy use?

In this working package, the main question will be how the regulation of energy markets affects the development of green energy and how measures to promote green energy affect the functioning of energy markets. It is of particular interest to study regulation across national borders, with a specific respect to infrastructure, since an international regulatory framework is essential for the exploitation of Norwegian energy and environmental resources, both in traditional areas and in new areas such as the capture, transport and storage of $CO_2$. The work will mostly be in the form of theoretical and empirical studies of specific issues, but will also utilize the numerical models which are either already available or will be developed as part of the overall work program. As such, this working package will interact particularly closely with WP4 and WP 5.

Below, we give examples of more specific research projects in this work package:

Integration of Wind Power in the Nord Pool Area and Beyond

Offshore wind energy has been identified by the EU as a key renewable energy technology, in which Europe should lead the world technologically, with countries such as Denmark, Germany, Sweden and the UK having either already invested in substantial windmill capacity or having plans to do so, both on and offshore. The intermittency of wind power makes it difficult to integrate on a large scale in ordinary electricity systems; however, with access to sufficient amounts of storable hydro power, the potential of wind is much greater. Hence, the idea of Scandinavian hydro power acting as a battery for Europe has attracted scientific, technical and media attention (Førsund *et al.*, 2008; Førsund and Hjalmarsson, 2010). In this project, we ask how hydro capacity can cope with a large-scale expansion of wind power both in and around the North Sea, taking into account the possibility of pumped storage and the cost of building international grid interconnections that provide backup and regulate capacity to the countries in the Nord Pool area and beyond.

Green Certificates and Competition in Electricity Markets

A number of studies have analyzed how green certificates may affect the functioning of electricity markets, both with respect to short-term price setting and long-term investment. One finding reveals that green certificates may affect the performance of electricity markets negatively by increasing price volatility (see e.g. Nielsen and Jeppesen, 2003; Amundsen *et al.*, 2006, and Nilsson and Sundqvist, 2007). In addition, green certificates may allow players with market power to engage in so-called "margin-squeezing", by reducing the premium on green energy which then undermines the incentive of competitors to make an investment in such energy (von der Fehr and Ropenus, 2009). In this project, we explore the impact of green certificates on the performance of electricity markets, and analyze how potentially negative effects may be overcome by suitable regulation.

Quantifying Impact on Markets

While theoretical analyses are essential for isolating and understanding the qualitative nature of phenomena, quantification requires numerical modeling. This is particularly important where different markets interact (such as different markets for electricity or different types of energy) or where regulation has effects across different markets. In this project, we aim to use numerical simulation models to produce long-term scenarios for power market developments (including demand, transmission and supply) under various assumptions regarding technological development and government regulations in Norway and the rest of Europe, and for other factors that are exogenous to electricity market models. Attention will be concentrated on the need for investment in the transmission and generation of different types, utilization of hydro-power reservoirs, prices for electric power and interaction with related markets such as the market for green certificates. A wide range of contemporary issues can be studied quantitatively, including: How much and where should transmission capacity be increased? To what extent will European price fluctuations be imported if additional cables are built? How does an incentive for renewable generation and/or increased energy efficiency affect prices and the need for investments in alternative generation or transmission?

***Working Package 4: Evaluation of Environmental and Energy Policy Measures (Research Director: Bente Halvorsen, Statistics Norway)***

Stimulating energy saving efforts and the increased use of renewable energy sources have been on the political agenda for several decades. Consumers and firms have faced multiple environmental regulations aimed at changing their behavior. The policy instruments used may either be monetary (taxes and subsidies), direct regulations (standards, emission quotas) or softer policy tools such as information campaigns, energy labeling and voluntary agreements. To secure an efficient use of resources in future environmental efforts, it is vital to evaluate the past performance and effectiveness of these policies in terms of whether they achieved their goal. This Working Package aims to increase our understanding of how households and firms respond to various types of policy instruments, and how these policies affect the economy through interactions between markets. A variety of analytical approaches will be applied that draw on economic theory and other social sciences. We plan to address a broad set of topics which are of interest from both a research and political perspective:

- *Rebound and adverse effects* - How much of the initial energy efficiency gains are eaten up by increased consumption? Can the regulation of one good have unwanted effects on the consumption of close substitutes? How does the use of multiple policy tools affect behavior?

- *Soft policy measures* - How can we measure the effect of soft policies on preferences and behavior? How do these soft policies affect habits and attitudes, and do they affect the demand response to harder policy tools such as taxes and regulations?

- *Environmentally friendly transportation* - Have $CO_2$ taxes on car fuel induced the purchase of more energy efficient cars? Does the increased use of biofuel and electric cars reduce emissions from road traffic?

Rebound and Adverse Effects

In order to increase the use of more energy efficient and environmentally friendly technologies, investment subsidies are frequently applied. The behavioral response to these grants, however, may not always work as expected. This is due to an increased energy efficiency, since cheaper energy gives consumers the opportunity to increase consumption of all goods (budget effects), and an incentive to increase the consumption of the energy source becoming more efficient, as it becomes cheaper to use relative to other energy sources (substitution effects). Both effects may increase energy consumption, thereby offsetting some or all of the initial reduction in consumption (the rebound effect). Additionally, both budget and substitution effects may result in changes in the demand for other goods, with subsequent undesirable effects (adverse effects). These cross good effects may also be desired and change the consumption of a good by regulating close substitutes (Halvorsen et al., 2010). These changes in energy demand will also affect prices in the energy markets, resulting in a change in energy consumption and production throughout the entire economy. Several empirical analyses have found the rebound and adverse effects to be considerable (Frondell et al., 2008; Turner, 2009; Brannlund et al., 2007). Even so, few empirical micro econometric analyses have studied the rebound and adverse effects of increased energy efficiency in household energy consumption.

Preliminary results suggest that households which possess heat pumps use more electricity than other households. This may be due to rebound effects, but this may also be because these households have a larger initial electricity consumption, which makes the investment in heat pumps more profitable. To separate the sample selection problem from the rebound effects, a comparative analysis of the partial effect of owning a heat pump is needed, taking into consideration that the households who own this equipment may systematically vary from other households. We will conduct an econometrical analysis on energy demand function, including information about the ownership of heat pumps, complemented by qualitative anthropological analyses.

When household production is regulated, which makes it more expensive and time consuming to produce the desired services at home, it will increase the demand for these services from other sectors. E.g., when electricity becomes more expensive due to increased taxation, and waste disposal becomes more costly and time consuming, the households' demand for public transport and dining out will increase. As a consequence, household energy consumption may be reduced, although the total energy consumption is not necessarily reduced, as production in other sectors increases. To quantify the transfer of energy consumption from households to other sectors due to the regulation of household production, we will apply both a micro econometric analysis and an integrated CGE-model MSG (Bye, 2008) in order to assess how these leakages affect emissions in other sectors.

Soft Policy Measures

Soft policy measures aim to change the behavior of consumers and firms by changing perceptions, habits and preferences with respect to energy consumption. Hard policies change behavior through changes in economic incentives and external factors which affect a decision. This implies that hard and soft policy measures change behavior through different mechanisms: one through changing exogenous factors that affect the decision and the other by changing preferences. In a traditional economic analysis, preferences are assumed not to change over time, thus ignoring the main aim of most soft policy measures. From the literature on behavioral economics and social psychology, we know that the assumption of fully informed individuals with stable and rational preferences over time may not hold (Sutherland, 2007). Most empirical economic policy analyses focus on the effects of hard policy tools such as taxes (e.g. Berkhout et al., 2004; Halvorsen, 2009; Bruvoll and Larsen, 2006; Kasahara et al., 2007). Still, empirical evidence on the effects of soft policy tools suggests that information campaigns can be very effective in changing behavior (Henry, 2003; Janmaat, 2007). It is therefore highly important to model how various policy instruments affect preferences in order to assess the effectiveness of soft instruments in changing behavior through changes in preferences. It is also of interest to know if and how they affect the effectiveness of hard policy measures. There exists some literature on how *hard* policy tools may crowd out morally motivated (intrinsic) behavior (Frey, 1997; Tögersen, 1994; Halvorsen, 2008). However, we know little about how the use of *soft* policy tools affect decisions, prices and income response in established markets, such as the energy market.

Information is viewed as being important in increasing awareness. The literature shows that some forms for information are more effective than others. Vague or generic information about the importance of a clean environment and the need for changing behavior has had only modest success (Boardman and Palmer, 2007; Dulleck and Kaufmann, 2004). Many of the routines around energy use are hard to change, due to, e.g., the lack of transparency about how much energy is actually used in a given practice. Information that increases the visibility of energy consumption and costs can have a routine shaking effect and stimulate people to choose less energy-intensive practices (Wilhite and Ling, 1995; Fisher, 2007). The potential of consumption feedback information in conjunction with other measures will be explored through field studies in Stavanger and Oslo. For this analysis, we will apply practice theory, which has its origins in sociology and anthropology, and encompasses the contribution of routines, social relationships and social norms in addition to economic and technological factors (e.g., Warde, 2005; Wilhite, 2008; Westskog et al., 2010; Wilhite et al., 2001).

Environmentally Friendly Transportation

A substantial share of $CO_2$ emissions occurs in the transportation sector. The $CO_2$ emission in g/km varies considerably across cars. To induce individuals to use cars that emit less $CO_2$, emission taxes on purchases and gasoline have been employed in Norway. We will econometrically investigate as to what extent these taxes have given individuals the incentive to buy and use cars that emits less $CO_2$ and how these taxes can be designed so that emissions become less than 120 g/km on average. We will use an unbalanced panel data set that covers all sales of cars in Norway over a 10-year-period.

For many policymakers, biofuels have seemed like a dream come true. $CO_2$ emissions could be cut because biofuels crops absorb $CO_2$ when they grow, and cars require only minor modifications to become green “flex-fuel” models. In Norway as well as in the EU, the political ambition is to enforce a policy that implies 10% biofuel coverage by 2020. Recently, the environmental impact of increased biofuels use has been put into question (Searchinger, 2009), as the impact on indirect land use has previously been ignored. We will investigate the total environmental impact of biofuel use and study to what degree it is possible to find types of biofuels that actually cut emissions.

Various policy measures have been conducted to increase the share of electric and hybrid cars, both on a local and national level. The effect of these policies on emissions from household car use depends heavily on several factors. Are households that buy electric cars primarily motivated by the money and convenience incentives embedded in these policy measures or by a wish to contribute to a better environment? How has the policy influenced the share of electric cars owned by households? Are electric and hybrid cars viewed as luxury goods which are primarily bought by wealthier households? Finally, and perhaps most importantly, are these cars bought as the main car, which reduces the emissions from household car use, or as an additional car, which is used as a substitute for public transportation, walking or bicycling shorter distances? Here, we may apply both a micro econometric and practice theory approach. Applying the practice theoretical perspective, everyday habits in the ways people commute, shop, take their children to school, exercise and socialize are studied and the acceptance of hard and soft policies to encourage shifts from private car use to public transportation are explored.

***Working Package 5: The Next Generation of Numerical Models***
***(Research Director: Brita Bye, Statistics Norway)***

To analyze policies that stimulate innovation and diffusion of new environmentally friendly technologies, integrated economy-energy-environment models are a necessary tool. We will use the unique competence available in our research team to further develop our energy market models and our integrated macroeconomic Computable General Equilibrium (CGE) models (see Bye, 2008) to make them well suited for our analyses. The cooperation with our technology sub contractors (IFE and SINTEF Energy) will be particularly valuable in the modeling work. WP1 to WP4 will provide new knowledge that will be vital for further development of our various numerical models. The research questions raised imply an extensive use of numerical models in order to evaluate consequences for small, open, energy-reliant economies such as Norway, and give adequate policy advice to the Norwegian government. In this working package, we will put a special focus on the following issues:

- *National and international integrated models* - Unilateral and international policies interact and demand development of economy-energy-environment models to improve the analyses of how different policies affect efficiency and emissions.

- *Technological innovation and diffusion processes* - We will model and empirically pin down the dynamic characteristics of the innovation and diffusion processes in a general economic model framework.

- *Identification and quantification of policy effects* - Identification of behavioral, technological and market characteristics will improve the empirical basis of our integrated models and policy analyses.

- *Electricity market models* - We will improve the modeling of the electricity market by integrating detailed technology-based bottom-up electricity market models with top-down energy market and macroeconomic models.

- *Model Forum and Scenarios* - We will establish a model forum for the development of energy and environmental economic models, and present energy and climate policies scenarios for the Norwegian economy.

<u>National and International Integrated Models</u>

WP1: *International policies of climate and energy* require analyses based on both national and international integrated models. From the small open economy perspective of Norway, international policies place restrictions on domestic policies which may be explored by our model for the European energy market, LIBEMOD (Aune et al., 2008, 2010; Golombek et al., 2009). LIBEMOD describes several energy technologies, including a number of power technologies, and is well suited for analyses of the effects of international energy and climate policies on the implementation of new technologies, and will also be used in WP2. We will extend the model to include all Eastern European EU countries in order to improve the analytical tool for studies of EU policies and the interplay between EU and Norwegian measures, and the model will be updated with the latest cost estimates for power technologies. We will also include energy transport costs, which are vital for a large energy producer such as Norway, in order to take part in the integrated European energy market.

Curbing global carbon emissions raises the need for linking Norway to global integrated models. While domestic emission targets are best met by uniform taxes, accounting for global contributions to GHG abatement needs to take into consideration the future terms of trade, the risk of replacing carbon intensive production (leakages) and global demand (Bruvoll and Fæhn, 2006). We will update the modeling of leakages in our integrated CGE models for the Norwegian economy, as well as further developing our cooperation with Christoph Böhringer in modeling Norway as a separate country in a global CGE model based on the GTAP database to study international policies and how such policies interact with Norwegian policies regarding welfare and leakage effects. In addition, we will consider adding to our model portfolio a global integrated assessment model of the interaction between the economy and the climate called MERGE (Manne and Richels, 1992; Blanford et al., 2009) to improve our analyses of international energy and climate policies.

Technological Innovation and Diffusion Processes

WP2: *Innovation and diffusion policy* raises the need to model technological innovation and diffusion processes in the energy field. Innovation processes are spurred by both accumulated knowledge and learning by doing. It is pivotal to model and empirically pin down the dynamic characteristics and reciprocal dependency of the innovation and diffusion processes. Our contact with technological expertise will be important for further development of models that integrate technological research, development and penetration processes into economic frameworks.

At present, we have two different CGE models (MSG-TECH model and two versions of the ITC-model) of Norway at Statistics Norway that capture various aspects of the technological diffusion and development processes. A central strategy for further model development is to integrate the relevant aspects of these two models into one framework specifically built for energy and climate policy analyses, which will require extensive modeling work. It will also require additional empirical contributions since the current literature offers insufficient or ambiguous evidence.

The integrated assessment model MSG-TECH (Fæhn et al., 2010) used in Climate Cure 2020 (2010) is a detailed CGE model that reflects the main empirical features of the small, open Norwegian economy. The empirical model is dynamic and thus well suited for analyzing energy and environmental policies that have a long-run perspective. The model includes the possibilities for implementing new environmentally friendly technologies that reduce emissions. We can then study important interactions in connection to how new technologies affect total and relative demand for fossil fuels, biofuels and electric power. We will improve our modeling of environmentally friendly technologies that develop and use bottom-up energy technology models in cooperation with IFE (see e.g. Fishbone and Abilock, 1981; Loulou et. al., 2005; Fidje and Rosenberg, 2009).

A large part of technological development takes place outside Norway and the productivity growth of Norwegian firms depends on various types of cross-border diffusion. Nevertheless, part of it also relies on innovations spurred by R&D within our borders. In the ITC-2 model (Bye et al., 2008; Heggedal and Jacobsen, 2008; Bye and Jacobsen, 2009), two types of R&D processes are modelled: general and climate technologies (specified as CCS), which are inspired by Romer (1990) and Diao et al. (1999).

Evidence over recent years indicates that the absorption of productivity growth from abroad can be affected to some extent by our own dispositions (Coe and Helpman, 1995; Griffith et al., 2004). These could be investments in well-educated personnel, R&D activities; contact networks through trading, joint ventures/direct investments or participation in fairs and congresses. The ITC-1 model (Bye et al., 2009) includes absorption effects, though these processes are not yet modeled for GHG emission efficiency growth.

Our ambitions regarding model developments of the energy market model LIBEMOD and our CGE models MSG-TECH and ITC are demanding and will require a substantial amount of resources. In order to secure the fulfillment of our plans in WP5, we have applied for additional funding to upgrade the LIBEMOD model from the FME infrastructure program.

Identification and Quantification of Policy Effects

WP4: *Evaluation of environmental and energy policy measures* raises important issues for the development of our numerical models. Econometric analyses on the effects of energy and environmental taxes, direct regulations, investment support, etc. will provide valuable input to the integrated models with concern to the quantification of different economic and technological mechanisms, modeling of policy instruments and identification of behavioral and market characteristics. Integrated CGE models such as MSG-TECH can also supplement ex-post evaluations of policies in WP4 by accounting for interaction effects throughout the economy (Bruvoll and Larsen, 2006; Bruvoll and Bye, 2009).

Electricity Market Models

WP3: *Regulation and market* puts a specific focus on the market for electricity, including production, transmission and distribution. The electricity market's special characteristics, with large fluctuations in demand during a 24-hour period, strong seasonal effects in both demand and supply, and decreasing marginal costs, make analyses of these markets a challenge. Norway is part of the European energy market, and we will extend the LIBEMOD model by including more of the special characteristics of Norway as a major energy supplier placed at a geographical outpost that demands more transfer capacities, etc. We will collaborate with our partner SINTEF Energy, which developed and runs the The Power Market Simulator (see e.g. Wolfgang et al., 2009), which is a detailed model of the supply and demand for electricity in Norway for both a 24-hour period and a year, in order to improve our more aggregated models for Norway and the international energy markets.

Model Forum and Scenarios

To develop the numerical models, we are dependent on input from our technology subcontractors and user partners. Thus, we will introduce a Model Forum with regular meetings to discuss ways to develop the models. Integrated economy-energy-environmental models yield a consistent framework for performing various policy scenarios. Based on forecasts from relevant sources such as Statistics Norway, the Ministry of Finance and International Energy Agency (IEA), in conjunction with technological expertise from IFE and Sintef Energy, we plan to present relevant scenarios for the Norwegian economy pertaining to energy and environment issues, given different assumptions about domestic and international policies.

## 3. Research Methodology

As CREE is relatively broad in topics analyzed and we want to be successful in contributing new knowledge as well as in disseminating relevant results to users, our research will be based on a broad set of methodologies. We will conduct theoretical analyses and empirical studies. The partners have specialized expertise which will be merged within the various parts of the research. Both the theoretical and empirical studies will be anchored in microeconomics, but will also draw on perspectives from other social sciences. On the empirical side, the research will be based on numerical economic models, econometric studies in which we make use of our large datasets, qualitative analyses of different cases and laboratory experiments. We will bring together researchers from various fields, who will be engaged in multidisciplinary activities such as conferences and workshops in addition to working on projects.

The output from CREE will be directed at both the research community and potential users. CREE will introduce a new working paper series in which our research partners will publish their works. Yet, this series is not the final destination for our research. All of our research partners have a long tradition in presenting research at international conferences and publishing papers in peer-reviewed journals, and we will continue this tradition. Nonetheless, as communication with users is important for scientifically based policy making, we will also stress publications such as newspaper articles, policy notes and Norwegian and popular science journals.

## 4. Researcher Training and Recruitment

Our plan is to recruit two PhD students and one post-doc researcher when we establish CREE and to recruit a new PhD student and a post-doc in 2015. Hence, if we get funding for eight years, we will have funded at least three PhD students and two post-docs over the lifetime of CREE. While one PhD student and the post-doc are expected to be employed at the Department of Economics, University of Oslo, the other PhD student will be employed at Statistics Norway. Statistics Norway will also recruit a young researcher in addition to the PhD candidate. The Norwegian research partners may also recruit more researchers depending on external funding.

The funding for social research on environmental and energy in Norway has experienced large cycles over the past years, yielding a small recruitment to the field over some years, particularly for energy and environmental economics. Thus, CREE will have a significant impact on recruitment to the field.

The Department of Economics at the University of Oslo has a PhD program in economics that will draw on resources in CREE, including our researchers and international network, for supervision and to hold PhD courses. We also plan to have an exchange program for PhD candidates between Oslo and Tilburg, as well as with some of our other international contacts such as the University of Calgary.

## 5. Significance of the Research Center

A major contribution of CREE will be to facilitate cooperation between the research partners, as well as with researchers in other countries and in other disciplines. Such cooperation is essential for reaping economies of scale and scope and for realizing the research ambitions set out above. In our experience, however, establishing and maintaining cooperation between researchers across different institutions, different countries and, especially, different disciplines, is very demanding. It requires an institutional framework, a well-functioning administrative apparatus and sufficient funding for bringing researchers together. Below we detail how CREE will contribute to overcoming hurdles to successful cooperation, as well as bringing other benefits, such as more systematic contact with users and recruitment of researchers to the field.

The three national partners of CREE constitute a large share of the researchers working in the field of environmental and energy economics in Norway. At the same time, each of the institutions has its own unique competence. The Department of Economics has its main strength in theoretical research and the Frisch Centre in modeling international energy markets, whereas the Research Department at Statistics Norway has long experience in developing large macroeconomic and energy market models. All the partners have considerable experience with empirical research, and both the Frisch Centre and the Research Department at Statistics Norway have built a strong competence in the analysis of Norwegian register and survey data. Also, the Frisch Centre and the Department of Economics run a laboratory for experimental economics.

While there is already cooperation among the Norwegian partners, CREE will facilitate a deepening of this by providing resources and an organizational structure for collaboration both within the community of economists and with the wider research community. The field of energy and climate is naturally multidisciplinary, making it important for CREE to be closely integrated with researchers in other social sciences, law and technology. As multidisciplinary research is more resource demanding than research within a given discipline, CREE will be an important factor for success in this respect.

CREE will be part of MILEN, the University of Oslo’s interfaculty research network on environmental change and sustainable energy. To facilitating interfaculty and interdisciplinary research, MILEN aims to improve the competence of university researchers in working across disciplines, and will organize cooperation at workshops, seminars and conferences, as well as through the development of multidisciplinary courses at the PhD and master’s level. We will work together with MILEN to organize seminars and workshops, and present our PhD students and researchers to the multidisciplinary environment and methods that MILEN represents.

Researchers from MILEN will also actively participate within CREE. From the network, we will draw on researchers from social anthropology, law and political science. From the discipline of social anthropology, Harold Wilhite (the academic director of MILEN) and his colleagues from SUM – the

Centre for Development and the Environment, will participate. They all have long experience on topics related to sustainable consumption, which is relevant for understanding behavior when evaluating policy instruments (see WP4). In addition, we will work closely with the research group in Natural Resources Law at the Faculty of Law, which is directed by Professor Hans Christian Bugge. The group's activities are multidisciplinary and comprise research on natural resources, energy, environment and property. Law expertise is crucial in gaining an understanding on topics studied at CREE such as international energy and climate policies, innovation and policy instruments (see WPs 1, 2 and 4). Further, to achieve a better understanding of politics, political science is important. Since the political scientists in the MILEN network are involved in CICEP (Strategic Challenges in International Climate and Energy Policy) directed by Professor Arild Underdal, Department of Political Science, we have agreed with CICEP to establish a formal cooperation between the two centers, which means arranging joint workshops, seminars and graduate courses. Possibly this will also lead to joint research papers. From our side, the cooperation will primarily be on WP1 (International politics of climate and energy). Lastly, we are also in close contact with the Department of Psychology, as we share a common interest in behavior economics, and they will be a discussion partner on our future research in that field.

Collaboration with experts on technology is also important if we want to perform relevant energy research. Therefore, we will engage SINTEF Energy Research and IFE (Institute for Energy Technology) as subcontractors. SINTEF Energy has a long experience in modeling electricity markets and their researchers will be included in WP3 (regulation and market) and WP5 (the next generation of numerical models). IFE possesses a deep knowledge about different technologies, e.g. through their development and use of the energy system models MARKAL and TIMES, which have been developed in a cooperative multinational project over a period of almost two decades by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA). This knowledge will be an important part of the work in WP5, particularly in the Model Forum. Also note that SINTEF Energy, IFE and the University of Oslo are already involved in existing technology FME centers. Based on these channels, we will keep in contact with these centers to be informed about the latest international trends within technological development and the energy markets.

Tilburg Sustainability Center (TSC), a new multidisciplinary center hosted by Tilburg University, working on topics such as environmentally friendly energy, innovation and international environmental agreements, is engaged as our international partner. While the national partners have collaboration with researchers at TSC, the new center will strengthen and extend this contact, as well as give Norwegian researchers access to the multidisciplinary sustainability network in Tilburg and give Dutch researchers access to the Norwegian network. The ambition of TSC is to become a leading international center for scientific expertise in the field of sustainability, in addition to providing support to companies, governments and other organizations. The cooperation with the Norwegian partners may help both centers to become internationally leading in their respective fields.

The resources and the organization of CREE will also make it easier to maintain better contact with the users of energy and environmental research. This requires resources in the form of regular meetings, conferences, and other interaction, all of which will be provided by CREE. The organizational structure of CREE (see below) will also establish a formal meeting point with our users. An additional value added to the center is that funding over an eight-year period allows for the possibility of long-term planning. This is especially true when it comes to recruitment of the field.

The aim of CREE is to be an internationally leading center for scientific expertise in social science-related energy research and to produce relevant research for Norwegian users. To help disseminate our research to users, we will organize Annual User Conferences in which we will present possible scenarios and relevant research topics on energy markets and climate policies. In addition, we will establish a Model Forum and regular User Partner Activities. Users will also be involved in the center’s board, as well as in research activities of relevance.

In addition to meetings and seminars, findings from our research will be disseminated through our web page, a new working paper series, papers in scientific journals, and articles in popular science journals. The connection to University of Oslo means our research will be spread to students at different levels.

## 6. Organization

The host institution of CREE will be the Frisch Centre, an independent research institution founded by the University of Oslo, which has environmental and energy economics as its largest field. The researchers will be located at their home institutions, but will have the possibility of spending time at either another research partner's or user partner's institution. As the three national research partners are located close to each other, collaboration, meetings and seminars are easy. Both the Department of Economics and the Frisch Centre are involved as partners in the virtual center HERO – the Health Economics Research Programme at the University of Oslo, which is funded by RCN. The organization of CREE will be based on our experience with HERO, and we do not plan undertake any specific investments to establish CREE.

Senior Research Fellow Snorre Kverndokk (Frisch Centre), who has been working on energy and climate change issues for more than 20 years, will be the director of CREE. He has long experience as a project leader, including being the Acting Research Director of HERO. He also has international experience from research projects such as the Intergovernmental Panel on Climate Change (IPCC), several shorter and longer-term visits abroad and teaching appointments in Europe and the US. The director will be supported by a secretary who will assist on organizing CREE activities, including PR, the web page and the working paper series, and a *management group* that will consist of the research directors for the different working packages.

CREE will have a *board* comprised of one representative from each of the three Norwegian research partners in addition to two from its user partners representing industry and government. The board will meet two to four times per year, with the main tasks being to follow up and evaluate research, budget and accounts.

The user partners of CREE at the moment are (the main focus in parenthesis):

Gassnova (CCS)
Norwegian Climate and Pollution Agency (climate issues)
Norwegian Ministry of Petroleum and Energy (energy issues)
Norwegian Water Resources and Energy Directorate (electricity markets)
Statkraft Energy (electricity markets)
Statnett (electricity markets)
Statoil (oil, gas and energy markets)

In addition to being involved in the board of CREE, the user partners will also be invited to be part of the *Model Forum* (see WP5) and to participate in the *Annual User Conference*. Further, we will establish annual *User Partner Activities* such as meetings to discuss ongoing research. Some of the user partners may also be directly involved in the research, and the planned arenas for the mutual exchange of thoughts will hopefully spur a closer collaboration and co-funding.

The research directors for the working packages are Deputy Director Rolf Golombek and Research Fellow Ole Røgeberg (Frisch Centre), Professors Michael Hoel and Nils-Henrik von der Fehr (Departments of Economics, UiO), Senior Researchers Brita Bye and Bente Halvorsen (Research Department, Statistics Norway). Other key personnel are:

<u>Frisch Centre:</u> Senior Research Fellows Sverre Kittelsen and Eric Nævdal, Professor Steinar Strøm
<u>Department of Economics, UiO</u>: Professors Geir Asheim, Kjell Arne Brekke, Finn Førsund, Diderik Lund, Karine Nyborg and Jon Vislie
<u>Research Department, SSB:</u> Head of Research Mads Greaker, Senior Researchers Taran Fæhn, Cathrine Hagem, Bjart Holtsmark and Knut Einar Rosendahl
<u>Tilburg Sustainability Center:</u> Professors Reyer Gerlagh and Aart de Zeeuw

We have attached CVs from the directors of CREE and the working packages, representatives of our international partner and main subcontractors, as well as our international researchers (see below).

## 7. International cooperation

To become a leading international research center requires an international network and collaboration. CREE includes a number of experienced researchers in the climate and energy field, with each of them having a substantial international network. Researchers from CREE have also participated in several international projects such as IPCC, the Centre for Advanced Study, Oslo, and the interdisciplinary European research cooperations: the European Energy Institute (EEI) and THINK (the latter being funded by the European Commission). Due to extensive international experience, we think that we will be an attractive research partner in the future as well.

In addition to our international research partner the Tilburg Sustainability Center, we will involve researchers from a number of countries in adjunct positions, as guests at CREE and as collaborators on various projects. The following have agreed to take an active part in CREE:

Professor Fridrik Baldursson, University of Iceland
Professor Christoph Böhringer, University of Oldenburg
Associate Professor Jared Carbone, University of Calgary
Assistant Professor Johan Eyckmans, European University College Brussels and Katholieke Universiteit Leuven (KULeuven)
Professor Matti Liski, Aalto University School of Economics

Our researchers currently have a collaboration with a number of institutions such as the EEI European Energy Institute (Leuven), EPRG (Electricity Policy Research Group (Cambridge)), the IEFE Centre for Research Energy and Environmental Economics and Policy (Milan), The Institute for Energy Research and Policy (Birmingham), the MIT Center for Energy and Environmental Policy Research (Cambridge, MA), Resources For the Future (Washington, DC), THINK DG Energy Think Tank (Florence/Leuven), the Environmental Directorate (OECD), Johns Hopkins University and University of Gothenburg.

We will arrange at least one annual workshop to gather the participants in our research network.

## 8. Progress Plan with Milestones

CREE plans to start its activities in the summer of 2011 and run for eight years until the summer of 2019. Some important milestones will be the Kick-Off workshop in September 2011, the Annual User Conference, Research Workshops and Model Forum meetings. In January 2012, we also hope to arrange a session during the ASSA Meeting in Chicago called “Interactions between energy markets, quota markets and new technologies”. In addition, we plan to have User Partner Activities at least twice a year, including meetings in which we will discuss certain topics, as well as visits (seminars) to the user partners. Some of these may be arranged together with CICEP. All working packages will start in 2011 and run simultaneously for the next eight years until the summer of 2019. Research milestones will be presentations at our workshops and conferences, other conferences and publications in good peer-reviewed journals and our web page will report the progress of our research. Below, we summarize some of these milestones:

<u>Year 1 (2011):</u>
Kick-Off Workshop
User Partner Activity
Model Forum Meeting

<u>Years 2-8 (2012-2018):</u>
User Partner Activities
Model Forum Meetings
Annual User Conference

Annual Research Workshop

Year 9 (2019)
User Partner Activity
Model Forum Meeting
Final User Conference
Final Research Workshop

**9. Budget**

The activities at CREE will be funded by the Research Council of Norway (RCN), our own funding, University of Oslo and by user partners. The financial contributions from the individual partners and user partners are specified in Section 11 below. The total budget will be:

**Table 1: Total budget for CREE (in thousands NOK)**

| 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|
| 14,975 | 23,050 | 20,550 | 20,050 | 20,050 | 20,050 | 20,050 | 20,050 | 10,075 |

**10. Costs Distributed among the Individual Partners**

The funding from the individual research partners is already distributed within the institutions and is not mentioned in the tables below. The tables allocate the funding from RCN, external funding from UiO (500,000 per year, see below) and user partner funding (see below). Below we have not distributed the money between the three Norwegian research partners as the distribution will be determined annually depending on the requirements for the different working packages.

**Table 2: Distribution of the funding from the RCN, UiO and user partners (in thousands NOK)**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|
| Administration | 1,114 | 1,175 | 1,175 | 1,175 | 1,175 | 1,175 | 1,175 | 1,175 | 575 |
| Conferences | 170 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| PhDs/post-docs, UiO | 288 | 1,460 | 1,460 | 1,460 | 1,460 | 1,460 | 1,460 | 1,460 | 1,172 |
| UiO Econ-Frisch-SSB | 2,328 | 4,715 | 4,715 | 4,715 | 4,715 | 4,715 | 4,715 | 4,715 | 1,828 |
| TSC | 125 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 125 |
| Subcontractors | 475 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 600 |
| TOTAL | 4,500 | 9,100 | 9,100 | 9,100 | 9,100 | 9,100 | 9,100 | 9,100 | 4,600 |

**Table 3: Annual costs (in thousands NOK)**

| | |
|---|---|
| Research in man-years | 7,025 |
| Administration | 1,175 |
| Equipment | 200 |
| Travel | 400 |
| Conferences and seminars | 300 |
| TOTAL | 9,100 |

**11. Financial Contributions from the Individual Partners**

While the University of Oslo (UiO) is funded by governmental budgets and the Research Department at Statistics Norway (SSB) also has some governmental funding, the research at the Frisch Centre and a large part of the environmental and energy research at SSB are externally funded, primarily from RCN. This makes it difficult to contribute our own funding to CREE, as the external funding is already distributed to research activities. However, as some of the programs at RCN are related to the activities at CREE, we include RCN funding of energy and environmental activities to SSB and the Frisch Centre as our own funding. From 2013, we will make an estimate of this. In addition, we also include governmentally funded research time for our researchers at the University of Oslo and University of Tilburg. Finally, UiO has decided to contribute NOK 500,000 per year to CREE.

We will also receive contributions from our user partners, in the form of sponsoring of specific projects and active research participation. Statoil and Statnett have committed to financial support of maximum NOK 250,000 per year, while Statkraft will contribute with 100,000 per year. Thus, the total user partner contribution will be NOK 600,000 per year.

**Table 4: Funding for CREE (in thousands NOK)**

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|
| UiO | 250 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 250 |
| UiO – Econ | 350 | 700 | 700 | 700 | 700 | 700 | 700 | 700 | 350 |
| SSB | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 2,500 |
| Frisch | 5,000 | 8,000 | 5,500 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 2,500 |
| TSC | 125 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 125 |
| User partners | 250 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 350 |
| RCN | 4000 | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 | 8,000 | 4,000 |
| TOTAL | 14,975 | 23,050 | 20,550 | 20,050 | 20,050 | 20,050 | 20,050 | 20,050 | 10,075 |

## 12. Gender Equality

Even though a significant share of the research within environmental and energy economics is currently being performed by women, which is a tendency also reflected in the CREE staff, recruiting women and obtaining a more even gender composition is a central goal. We will emphasize this concern in the hiring of PhD students and post-docs, and we have already hired a woman as the center’s first PhD student, starting in August 2011. We hope and believe that supervision, project and working package leadership by female experts within CREE (two out of five) will ensure that CREE becomes an attractive working place and collaborator for both women and men.

## References


Amundsen, E. S., F. M. Baldursson and J. B. Mortensen (2006): Price Volatility and Banking in Green Certificate Markets. *Environmental and Resource Economics*, Vol. 35, Issue , pp. 259-287.

Arrow K. (1962): The economic implications of learning by doing, *Review of Economic Studies* 29, p. 155-173.

Asheim, G., C.B. Froyn, J. Hovi and F.C. Menz (2006): Regional versus Global Cooperation on Climate Control, *Journal of Environmental Economics and Management* 51(1):93-109.

Asheim, G. (2010): Intergenerational Equity, *Annu. Rev. Econ.*, 2:197–222.

Asheim, G.B. and T. Mitra (2010): Sustainability and discounted utilitarianism in models of economic growth, *Mathematical Social Sciences* 59, pp. 148–169.

Aune, F.R., R. Golombek, S.A.C. Kittelsen and K.E. Rosendahl (2008): *Liberalizing European Energy Markets. An Economic Analysis*, Cheltenham, UK: Edward Elgar Publishing. http://www.e-elgar-economics.com/Bookentry_Main.lasso?id=3071

Aune, F.R., H. M. Dalen and C. Hagem (2010): Implementing the EU renewable target through green certificate markets, Discussion Papers 630, Statistics Norway.

Barrett, S. (1994): Self-enforcing International Environmental Agreements, *Oxford Economic Papers* 46: 878-94.

Barrett, S. (2003): *Environment and Statecraft*, Oxford: Oxford University Press.

Berkhout, P. H. G., A. Ferrer-i-Carbonell and J. C. Muskens (2004): The Ex Post Impact of an Energy Tax on Household Energy Demand, *Energy Economics*, 26(3), pp. 297-317.

Blanford,G. J., R. G. Richels and T. F. Rutherford (2009): Feasible climate targets: The roles of economic growth, coalition development and expectations *Energy Economics* 31, 82–93.

Boardman, B. and J. Palmer (2007): Electricity disclosure: The troubled birth of a new policy. *Energy Policy* 35(10), pp 4947-4958.

Brannlund, R., T. Ghalwash, J. Nordstrom (2007): Increased Energy Efficiency and the Rebound Effect: Effects on Consumption and Emissions, *Energy Economics*, 29(1), pp. 1-17.

Brekke , K. A. and M. Rege (2007): Advertising as a Distortion of Social Learning, *The B.E. Journal of Theoretical Economics*: Vol. 7: Issue 1 (Topics), Article 38

Bruvoll, A. and T. Fæhn (2006): Transboundary effects of environmental policy: Markets and emission leakages, *Ecological Economics* 59/4, 499-510

Bruvoll, A. and B. M. Larsen (2006): Greenhouse gas emissions in Norway: Do carbon taxes work?, in T. Sterner and A. Muller: Environmental taxation in practice, Ashgate Publishing Limited. Also published in *Energy Policy* 32 (4), pp. 493-505.

Bruvoll, A. and B. Bye (2009): Evaluering av effekter av virkemidler i klimapolitikken, Rapporter 2009/48, Statistisk sentralbyrå.

Buchner B. and C. Carraro (2005): Economic and Environmental Effectiveness of a Technology-Based Climate Protocol, *Climate Policy* 4, 229-248.

Bye, B. (2008): Macroeconomic modelling for energy and environmental analyses: Integrated economy-energy-environment models as efficient tools, *Documents 2008/14*, Statistics Norway.

Bye, B., T. Fæhn, T. R. Heggedal, K. Jacobsen and B. Strøm (2008): An innovation and climate policy model with factor-biased technological change: A small, open economy approach, *Reports 2008/22*, Statistics Norway. http://www.ssb.no/emner/10/03/rapp_200822/rapp_200822.pdf

Bye, B., T. Fæhn and T. R. Heggedal (2009): Welfare and growth impacts of innovation policies in a small, open economy: An applied general equilibrium analysis, *Economic Modelling* 26, 1075-1088.

Bye, B, T. Fæhn and L. A. Grünfeld (2009): Growth and innovation policy in a small, open economy: Should you stimulate domestic R&D or exports?, Discussion paper 574, Statistics Norway. Under resubmit to Berkley Electronic Journal of Economic Analysis & Policy.

Bye, B. and K. Jacobsen (2009): Restricted carbon emissions and directed R&D support; an applied general equilibrium analysis, Discussion Paper 584, Statistics Norway. Under resubmit to Energy Economics.

Carraro, C. and D. Siniscalco (1998): International environmental agreements: Incentives and political economy, *European Economic Review* 42:561-572.

Climate Cure 2020 (2010): Measures and instruments for achieving Norwegian climate goals by 2020, TA2590+2678/2010, Climate and Pollution Agency, Norwegian Water resources and Energy Directorate, Norwegian Petroleum Directorate, Norwegian Public Roads Administration, Statistics Norway.

Coe, D. T. And E. Helpman (1995): International R&D spillovers, *European Economic Review*, 39, 859–887.

Dasgupta, P. (2008): Discounting Climate change, *Journal of Risk and Uncertainty*, 37: 141-169.

De Zeeuw, A. and M. Hoel (2010): Can a focus on breakthrough technologies improve the performance of international environmental agreements?, *Environmental and Resource Economics* 47, 395-406.

Diao, X., T. Roe and E. Yeldan (1999): Strategic policies and growth: An applied model of R&D-driven endogenous growth, *Journal of Development Economics* **60**, 343-380.

Downing, P. B. and L. J. White (1986): Innovation in Pollution Control, *Journal of Environmental Economics and Management* 13, p. 18-29.

Dulleck, U. and S. Kaufmann (2004): Do customer information programs reduce households' electricity demand? *Energy Policy* 32(8), pp 1025 – 1032.

Eurostat (2008): Energy, transport and environment indicators, Eurostat pocketbooks, 2008-edition.

von der Fehr, N-H. and S. Ropenus (2009): Green Certificates, Market Power and Vertical Structure, mimeo.

Felder, S., and T. F. Rutherford (1993): Unilateral $CO_2$ Reductions and Carbon Leakage: The Consequences of International Trade in Oil and Basic Materials. *Journal of Environmental Economics and Management* 25(2): 162–76.

Fidje, A., and E. Rosenberg (2009): Flerregional TIMES-modell for Norge, IFE/KR/F-2009/060

Fishbone and Abilock (1981): MARKAL: A Linear-Programming Model for Energy Systems Analysis: Technical Description of the BNL Version, International Journal of Energy Research, Vol. 5, No. 4, pp 353-375

Fischer, C. (2007): Influencing electricity consumption via consumer feedback: a review of experience. Proceedings of the 2007 ECEEE Summer Study. Stockholm: European Council for an Energy Efficient Economy.

Frey, B. S. (1997): *Not just for the money. An economic theory of personal motivation.* Edward Elgar, Cheltenham UK.

Frondell, M., J. Peters and C. Vance (2008): Identifying the Rebound: Evidence from a German Household Panel, *The Energy Journal*, 29(4), pp. 145–163.

Førsund, F R, B. Singh, T. Jensen and C. Larsen (2008): Phasing in wind-power in Norway: network congestion and crowding-out of hydropower, *Energy Policy* , 36(9), 3514-3520.

Førsund F. R. and L. Hjalmarsson (2010): Renewable Energy Expansion and the Value of Balance Regulation Power, Working Papers in Economics No 441, University of Gothenburg, School of Business, Economics and Law.

Fæhn, T., K. Jacobsen and B. Strøm (2010): MSG-TECH: Analyses and documentation of a general equilibrium model with endogenous technology adaptations, forthcoming in the series Reports, Statistics Norway.

Gerlagh R., S. Kverndokk and K. E. Rosendahl (2009): Optimal Timing of Climate Change Policy: Interaction between Carbon Taxes and Innovation Externalities, *Environmental and Resource Economics* 43, p. 369-390.

Gerlagh R., S. Kverndokk and K. E. Rosendahl (2010): Timing of Environmental R&D policy, submitted to Journal of the European Economic Association.

Golombek, R., M. Greaker, S. A. C. Kittelsen, O. Røgeberg and F. R. Aune (2009): Carbon capture and storage technologies in the European power market, Discussion Papers 603, Statistics Norway.

Golombek R. and M. Hoel (2009): International Cooperation on Climate Friendly Technologies, CESIfo Working Paper No. 2677.

Golombek, M. Greaker and M. Hoel (2010): Carbon Taxes and Innovation without Commitment, *The B.E. Journal of Economic Analysis and Policy* 10-1 (Topics), Article 32.

Greaker M. and L. Pade (2009): Optimal CO2 abatement and technological change: Should emission taxes start high in order to spur R&D? *Climatic Change* 96.

Greaker M. and T. R. Heggedal (2010): Lock-in and the transition to hydrogen cars: Should governments intervene?, *The B.E. Journal of Economic Analysis and Policy* 10-1 (Contributions), Article 40.

Griffith R., S. Redding and J. van Reenen (2004): Mapping the two faces of R&D: productivity growth in a panel of OECD industries, *The Review of Economics and Statistics* **86**, 883-895.

Halvorsen B. (2008): Effects of norms and opportunity cost of time on household recycling, *Land Economics* 84(3), pp. 500 - 516.

Halvorsen B. (2009): Conflicting Interests in Environmental Policy-making? A Micro-econometric Approach, *Environmental and Resource Economics*, 44(2), pp. 287.

Halvorsen, B., B. M. Larsen and R. Nesbakken (2010): Is there a win-win situation in residential energy policy?. *Environmental and resource economics*, 45(4), pp 445-457.

Heggedal, T. R. and K. Jacobsen (2008): Timing of innovation policies when carbon emissions are restricted: an applied general equilibrium analysis, Discussion Papers 536, Statistics Norway. Under resubmit to Resource and Energy Economics.

Henry, G.T. (2003): Driving Less for Better Air: Impacts of a Public Information Campaign, *Journal of Policy Analysis & Management*, 22(1), pp. 45-63.

Hoffert et al. (2002): Advanced Technology Paths to Global Climate Stability: Energy for the Greenhouse Planet, *Science* 298.

Janmaat, J. (2007): A Little Knowledge: Household Water Quality Investment in the Annapolis Valley, *Canadian Journal of Agricultural Economics*, 55(2), pp. 233-53.

Kasahara, S., S. Paltsev, J. Reilly, H. Jacoby and A.D. Ellerman (2007): Climate Change Taxes and Energy Efficiency in Japan, *Environmental and Resource Economics*, 37(2), pp. 377-410.

Kverndokk, S. and A. Rose (2008): Equity and justice in global warming policy, *International Review of Environmental and Resource Economics*, vol. 2, no 2, pp 135-176.

Laffont, J.-J. and J. Tirole (1996): Pollution permits and compliance strategies. *Journal of Public Economics* 62, 85-125.

Loulou, R et. al (2005): *Documentation for the TIMES Model, April 2005*, Available from www.etsap.org

Manne, A. and R. Richels (1992): *Buying Greenhouse Insurance – the Economic Costs of Carbon Dioxide Emission Limits*, MIT Press, Cambridge, MA.

Manne A. and R. Richels (2004): The impact of learning by doing on the timing and costs of $CO_2$ abatement, *Energy Economics* 26, p. 603-619.

Meckling, J. O. and G. Y. Chung (2009): Sectoral Approaches to International Climate Policy. A Typology and Political Analysis, Discussion Paper 2009-02, Cambridge, Mass.: Belfer Center for Science and International Affairs.

Montgomery, W. and A. E. Smith (2007): Price, Quantity, and Technology Strategies for Climate Change Policy, in *Human-induced Climate Change - An Inter-disciplinary Assessment*, Cambridge University Press.

Nielsen, L. and T. Jeppesen (2003): Tradable Green Certificates in selected European countries – overview and assessment. *Energy Policy*, Vol. 31, Issue 1, pp. 3-14.

Nilsson, M. and T. Sundqvist (2007): Using the market at a cost: How the introduction of green certificates in Sweden led to market inefficiencies. *Utilities Policy*, Vol. 15, Issue 1, pp. 49-59.

NOU 2009:16 Utvalget for vurdering av bærekraftshensyn i offentlige beslutningsprosesser (Commission for integrating sustainability concerns in public decision-making): *Globale Miljøutfordringer – norsk politikk: Hvordan bærekraftig utvikling og klima bedre kan ivaretas i offentlige beslutningsprosesser (Global Environmental Challenges and Norwegian Policy: How to Better Incorporate Sustainability and Climate Concerns in Public Decision-Making)*, Oslo: Ministry of Finance.

Romer, P. (1990): Endogenous Technological Change, *Journal of Political Economy* **94**, 1002-1037.

Rosendahl, K. E. (2004): Cost-effective environmental policy: implications of induced technological change. *Journal of Environmental Economics and Management*, 48, p. 1099-1121

Requate T. and W. Unhold (2003): Environmental policy incentives to adopt advanced abatement technology: Will the true ranking please stand up?, *European Economic Review*, 47 p. 125-146.

Røpke, I. (2009): Theories of practice — New inspiration for ecological economic studies on consumption. *Ecological Economics* 68 (10): 2490 – 2497.

Searchinger, T. (2010): Accurately accounting for the greenhouse gas emissions of bioenergy, forthcoming in *Science*

Sutherland, N. S. (2007): *Irrationality*, Pinter &Martin Ltd., London.

Thaler R. H. and C. R. Sunstein (2008): *Nudge - Improving Decisions About Health, Wealth, and Happiness*, New Haven and London: Yale University Press.

Tirole, J. (1997): *The Theory of Industrial Organization*. The MIT Press.

Turner, K. (2009): Negative Rebound and Disinvestment Effects in Response to an Improvement in Energy Efficiency in the UK Economy, *Energy Economics*, 31(5), pp. 648-66.

Tögersen, J. (1994): Monetary incentives and environmental concern. Effects of a differentiated garbage fee, *Journal of Consumer Policy* 19, pp. 125-143.

Warde, A. (2005): Consumption and theories of practice. Journal of Consumer Culture 5:131-153.

Wilhite, H. (2008): *Consumption and the Transformation of Everyday Life: A View from South India*. Basingstroke and New York: Palgrave Macmillan, 2008.

Wilhite, H. and R. Ling. (1995): Measured energy savings from a more informative energy bill. *Energy and Buildings* 22(2): 145-155.

Westskog, H, T. Winther and E. Strumse (2010): Addressing fields of rationality – a policy for reducing household energy consumption?, forthcoming in: Markandya, A. et al. *Handbook of Sustainable Use of Energy.* Edward Elgar Publishing Ltd.

Wolfgang, O., A. Haugstad, B. Mo, A. Gjelsvik, I. Wangensteen and G. Doorman (2009): Hydro reservoir handling in Norway before and after deregulation, Energy, 34: 1642-1651.

Zuber, S. and G. B. Asheim (2010): Justifying social discounting: the rank-discounted utilitarian approach, CESifo Working Paper 3192.

Zwaan B. C. C. van der, R. Gerlagh, G. Klaassen and L. Schrattenholzer (2002): Endogenous technological change in climate change modelling, *Energy Economics*, 24, p. 1-19.