CREE WORKPLAN 2014

CREE's activities are divided into five work packages as described in the project plan. The leaders of the work packages are listed in parentheses:

WP1: The International Politics of Climate and Energy (Michael Hoel/Ole Jørgen Røgeberg)

WP2: Innovation and Diffusion Policy (Rolf Golombek)

WP3: Regulation and Market (Nils-Henrik von der Fehr)

WP4: Evaluation of Environmental and Energy Policy Measures (Bente Halvorsen)

WP5: The Next Generation of Numerical Models (Brita Bye)

The research will take place by the four research partners - Frisch Centre (Frisch), Department of Economics, University of Oslo (ØI), Research department, Statistics Norway (SSB) and Tilburg Sustainability Center (Tilburg) - our subcontractors – Institute for Energy Technology (IFE), SINTEF Energy (SINTEF) and Natural Resources Law at the Faculty of Law, University of Oslo (Law). In addition to this, several international researchers connected to the center will also contribute.

Below the planned 2014 activities are described in detail. These activities are funded by CREE or have funding from one the four research partners. Activities related to applications to be determined in 2014 are not included.

WP 1: The International Politics of Climate and Energy

The main question in this work package is how international climate treaties best can achieve GHG abatement. This raises questions regarding how treaties should be structured to raise participation rates, abatement targets and policy implementation, and also how abatement efforts will influence other important goals – such as global equity issues.

Abatement treaties are the type of international climate treaties mostly studied in the literature. However, other designs like sectorial treaties, regional treaties or "topical" treaties focusing, for example, on R&D efforts are also possible. The increasing pessimism regarding prospects for a single, UN-led, ambitious "top-down" abatement treaty with global coverage has raised the question of whether such smaller, partial treaties could be coordinated and gradually integrated with each other, thereby addressing the climate problem "bottom-up".

The research activities in this work package spans from theoretical studies to numerical models and experimental studies using laboratory participants. In 2013 we have also

organized a workshop with CICEP on international climate cooperation, see http://www.frisch.uio.no/cree/Workshop_Sem_Conf.

The plans for new projects are unclear as a result of funding uncertainty. As highlighted in last year's work plan, "applying for funds to supplement the annual center endowment" has been a priority – and several of the 10 applications from CREE partners in the recent KLIMAFORSK round contained subprojects relevant to WP1.

On-going projects

I.1 Pareto-improving climate policies

Future generations will be richer than us, but may have a more inferior environment. While mitigation today will increase the quality of the future environment, it implies costs to the current generation. However, by transferring resources from the future to the present generation there may be possibilities for improving the welfare of all generations. This can be done by compensating mitigation today by less investments so that the present generation does not have to reduce consumption.

This is a numerical project where we do simulations with the RICE model. The work has so far resulted in two working papers. In 2014 these will be revised and submitted to journals and another working paper will be finalized.

I.2 Border Tax Adjustment

A standard result in the literature on international climate agreements is that few countries will sign an abatement agreement due to the free rider problem: all countries benefit from abatement activities of other countries whereas cost of abatement is born entirely by the country itself. In several studies, the equilibrium number of coalition members is two or three, and even if it is possible to construct bigger coalitions the effect on aggregate abatement is typically modest.

This subproject examines whether the introduction of a border tax on the carbon content of goods may make participation in an international climate agreement more attractive and thereby increase the equilibrium number of signatories. The basic idea is that a border tax imposed on imports of carbon-intensive goods to the group of signatories may increase the revenues to this group and/or change the relative prices of goods in favor of the signatories.

In 2014 a working paper will be finalized.

I.3 Climate treaties with reciprocal preferences

Research in behavioural and experimental economics indicate that reciprocity, that is, a preference to repay mean intentions by mean actions and similarly to repay kind intentions by kind actions, is widespread. If voters or individuals in power have reciprocal preferences, states may conceivably act as if they have such preferences too. This would make climate

negotiators less (more) willing to contribute to a binding global emission reduction agreement if other parties are perceived as irresponsible and unfriendly (responsible and friendly).

The importance of reciprocity is studied within a standard model for international environmental agreements with identical countries and a definition of "kindness" from behavioural economics. It is shown that with reciprocity, no cooperation and full cooperation may both be equilibria in the global climate game.

A draft paper has been written, which combines the literatures of international environmental agreements and the theory of reciprocity as indicated above. In the spring of 2014, the following activities are planned: 1) Revision and quality check of the simple model analysis sketched in the draft; 2) exploration of alternative definitions of "kindness" that may be more relevant to international relations than the one used in the existing draft; 3) consider, and if feasible, analyse explicitly the implications on the formal analysis of such alternative versions of reciprocity, and 4) discuss more broadly whether one can reasonably expect reciprocity to be a factor of importance in international climate negotiations.

The paper has been accepted for presentation in a Thematic Session at the World Congress of Environmental and Resource Economists in Istanbul, June 2014.

I.4 Participation and duration of climate agreements

Theoretical contributions to the formation of international environmental agreements often analyze either participation in abatement agreements or participation in an R&D partnership that aims to develop environmentally friendly technologies that will lower costs of abatement. However, abatement and R&D efforts are interrelated. If a country manages to lower its costs of abatement through successful R&D in environmentally friendly technologies, its future bargaining position may be weaken as other countries may claim that this country should abate more because its costs have been reduced (the hold-up problem). In the present project we therefore analyze participation in international environmental agreements in a dynamic game where countries pollute and also invest in green technologies.

We show that if complete contracts are feasible, participants eliminate the hold-up problem associated with their investments; however, most countries prefer to free-ride rather than participate. If investments are non-contractible, countries face a hold-up problem every time they negotiate; but the free-rider problem can be mitigated and significant participation is feasible. Participation becomes attractive because only large coalitions commit to long-term agreements that circumvent the hold-up problem. Under well-specified conditions even the first-best outcome is possible when the contract is incomplete. Since real-world IEAs fit in the incomplete contracting environment, our theory may help explaining the rising importance of IEAs and how they should be designed.

In 2014 a working paper will revised and submitted to an international journal

I.5 Reducing carbon leakage

A key challenge for unilateral policy initiatives, even for a big coalition like the EU, is carbon leakage and competitiveness concerns. In 2013 we have analyzed economic and emission effects of introducing carbon taxes combined with output-based rebating and also how second-best optimal rebate rates interact with carbon policies in other regions. We are especially concerned about the development of second-best optimal rebating rates for large versus small regions/countries in a world where a considerable share of global carbon emissions is still not regulated. We use both theoretical and numerical methods, the last one exemplified by the global CGE model SNoW.

One paper will be finished in 2014 and sent to an international journal. In 2014 the carbon leakage project will analyze other kinds of policies like endogenous carbon tariff rates. Financing will be by CREE and the EU/ENTRACTE project, but new activities will be limited unless relevant KLIMAFORSK applications are funded.

I.6 – Inequality aversion and trade

Widespread skepticism towards tradeable emission quotas is apparent in surveys and political debates. One potential explanation is that opponents see markets as rigged and favoring "rich countries." In a laboratory experiment we allow resource owners and buyers to trade at *given* prices, and examine the effect on trading volumes of high prices (that distribute most of the gains from trade to sellers), low prices (that distribute most of the gains to buyers) and "fair" prices that give both parties the same payoffs. Preliminary results are promising, and the experiment will be developed further and run on a larger sample of respondents during PhD-student Alice Ciccone's visit to Columbia University, spring 2014.

I.7 Is it wrong to buy a right to do a wrong?

An alternative hypothesis to the one explored in I.4 is that opposition to tradable emission quotas stems from a view that sees emissions as moral bads. Philosopher Michael Sandel from Harvard has made several arguments in this vein over the years. The project has run a laboratory experiment to see if a market in "bads" (taking from a common resource pool to benefit oneself despite hurting others even more) would trigger negative attitudes towards market trade. Results showed no effects on neither attitudes towards markets, trading volumes in markets, nor prices in markets relative to a control treatment with trade in a non-harmful good.

In 2014, the experiment will be expanded with a larger sample to address sample size concerns from referees. The paper is currently under revision.

I.8 Earned pies and outside options in structured bargaining.

Theoretical analyses of bargaining typically employ game theory, but the predictions of such models need to be tested empirically in order to identify the most descriptively accurate theory. In a seminal paper, Binmore et al.(1989) show that non-binding outside options have

no impact on the bargaining outcome, which is consistent with Rubinstein classic bargaining model. However, the axiomatic Nash bargaining solution predicts that players will take their outside option and then share the remaining surplus, that is, "split the difference".

Recent experimental studies on Nash demand game and unstructured bargaining games have found that the outside option has an effect on the bargaining outcome and this effect is stronger if the outside option is earned. We provide experimental evidences by testing change in behavior when the outside option is exogenously allocated by the researcher or earned through an effort task. In addition, we extend this study by including loss aversion in the model. In a second treatment, subjects can earn their individual contribution to the pie or they can get a random allocation of it. This allows us to test predictions of standard theory against the alternative theory of loss aversion.

We have completed the first treatment. Our experimental results for the control treatment successfully replicate Binmore et al. (1989). The second treatment will be conducted early in 2014.

I.9 Natural resources and the climate

We will write a chapter on climatic change in a Norwegian book on natural resource economics; the book is aimed for undergraduate students. In our contribution, we first go through the history of research and policy on climatic change, and then explain institutional factors. Then we go through the facts we have about climate change today and what we expect will happen in the future. In the analysis we first introduce a dynamic model that shows how we can determine the optimal emission reductions. We then turn to a simpler model and show how to implement the optimal emission reductions by means of direct regulation and economic instruments such as tradable permits and taxes. Game theory is then used to explain why it is difficult to reach a binding and comprehensive climate agreement. The chapter concludes with what a small country like Norway can do, as well as some thoughts about the future.

Table 1: Planned work months, WP1

Activity	Primary institution	Planned work months	Cree funded work months
I.1 Pareto-improving climate policies	Frisch Centre	1.8	1.8
I.2 Border tax adjustment	Frisch Centre	0.5	0.5
I.3 Climate treaties with reciprocal preferences	Dep. of economics	2	0
I.4 Participation and duration of climate treaties	Frisch Centre	2.4	1.2
I.5 Reducing climate leakage	Statistics Norway	5.3	2.7
I.6 Inequality aversion and trade	Dep. of economics	3.0	2.5
I.7 Is it wrong to buy a right to do a wrong?	Dep. of economics	4.0	3.0
I.8 Earned pies and outside options	Dep. of economics	4.0	3.0
I.9 Natural resources and the climate	Frisch Centre	1.0	1.0

WP2: INNOVATION AND DUFFUSION POLICY

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 - this is the technological challenge of the century.

Environmentally friendly 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.

Economists have realized that there are market failures also 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. 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. Similarly, the responsibility to act in an environmentally friendly manner is shaped by observing others, although this may cause

market failures with multiple equilibria. The adoption of new technologies may also be hindered by principal-agent problems and cognitive costs. In this work package we address a broad set of topics which are of interest from both a research and political perspective.

Ongoing activities in 2013

II.1 Strategic technology policy as supplement to renewable energy standards

Renewable energy standards have been introduced in several countries as a supplement to climate policy. Some countries have also subsidized the use of renewable energy or the producers of renewable energy capital. In this subproject we examine the rational for such policies.

Our point of departure is that a renewable energy standard creates new profit opportunities for firms that supply renewable energy capital. With imperfect competition among technology suppliers, technology policy could be used strategically. We consider both downstream subsidies to renewable energy suppliers and upstream subsidies to renewable energy capital producers. To the extent that there is imperfect competition upstream, subsidies may improve welfare both globally and nationally. Moreover, upstream subsidies are preferred over downstream subsidies from a national perspective. Finally, we show that strategically chosen subsidies by individual countries could in fact be optimal from a global perspective, given that the shadow price of emissions is correct from a global perspective.

A draft paper has been written, and in the first part of 2014 a paper suitable for submission to a journal will be available.

II.2 Carbon leakage: Pay or not pay the polluter?

Asymmetric regulation of a global pollutant between countries can alter the competitiveness of industries and cause emissions leakage. For most types of pollution, abatement technologies are available, but the markets for these technologies are not competitive, particularly when emissions regulations and advanced technologies are new. In this context of twin market failures, we consider the relative effects and desirability of subsidies for abatement technology.

We find that downstream subsidies tend to increase global abatement technology prices, reduce pollution abatement abroad and increase emissions leakage. In contrast, upstream subsidies reduce abatement technology prices, and hence also emissions leakage. Whereas downstream subsidies may weaken the position of domestic abatement technology firms, upstream subsidies may provide domestic abatement technology firms with a competitive advantage.

A draft paper has been written, and in the first part of 2014 a paper suitable for submission to a journal will be available.

II.3 How should CCS technologies be supported?

Carbon capture and storage (CCS) technologies have the potential to bridge the gap between the current carbon-based society and a future low-carbon society. Using CCS electricity technologies, either with coal or natural gas as the fuel, may reduce emissions by as much as 90 percent relative to standard fossil-fuel based technologies.

One main disadvantage of CCS is high cost. These may, however, be lower through continued R&D. An important question is then whether CCS should be prompted through subsidizing the producers of CCS technology (upstream subsidy) or through subsidizing the use of CCS technology (downstream subsidy). In a combined theoretical-empirical subproject we first study optimal design of CCS subsidizes within a simple model of imperfect competition where CCS technology producers are divided into two groups according to whether they are owned by EU citizens/member countries. We show that upstream subsidizes to EU producers outperform downstream subsidizes.

We then use the numerical equilibrium model of the European energy market LIBEMOD, combined with a new model block with non-competitive supply of CCS technologies, to study how the CCS subsidy should be designed. Although LIBEMOD encompasses many effects not captured in the simple theoretical model used in the first part of the subproject, for example, terms-of-trade effects, we obtain the same type of result as in the theoretical part of the subproject; upstream subsidizes to EU producers are preferable, though in some cases these should be combined with downstream subsidies.

A draft paper has been written, and in the first part of 2014 a paper suitable for submission to a journal will be available.

II.4 Environmental R&D instruments

There are several reasons to support environmental R&D: knowledge spillovers that make future R&D more efficient, commitment problems with respect to future environmental policy and globally insufficient environmental policies due to lack of international environmental agreements on global pollutants. We will study the optimal use of three technology push policies 1) Patent systems, 2) Innovation prizes and 3) Subsidies to R&D projects under various circumstances: i) Global environmental policies are too weak in the near and intermediate future, and ii) Governments cannot commit to future environmental policy goals. In particular, we are interested in to what degree there are systematic differences between market goods R&D and environmental R&D that suggest that different support programs should be offered.

This topic has also funding from EU's seventh framework program (ENTRACTE), which will last until 2015. In addition, we have applied ENERGIX for means to extend the study. The project was started in 2013, but on a very low activity level. In 2014 a draft paper will be written that covers some of the topics described above.

II.5 Optimal timing of clean energy policies

Should technology subsidies be used a as climate policy instrument in addition to imposing a price on GHG emissions, or is pricing of GHG emissions sufficient in order to obtain a social desirable outcome? If also technology subsidies should be offered, how should the path of subsidies be designed? This subproject examines these questions within a theoretical model where abatement requires use of environmentally friendly technologies and R&D makes these technologies more productive. We find that whereas the price of GHG emissions should always reflect the marginal environmental damage, the optimal level of the R&D subsidy, as well as the duration of a patent, should be time dependent. Often, the technology should be high but decrease over time. If, alternatively, the technology subsidy is kept constant over time, the optimal duration of a patent should be long, but decrease over time. Hence, the main result is that an optimal climate policy requires innovation subsidies to complement carbon pricing.

The paper was accepted for publication in JEEM in 2013.

II.6 Innovation in clean energy as a commitment device

The starting point of this project is how the present generation can make future generations reduce their GHG emissions. The basic idea is that by developing and installing environmentally friendly capital and technologies, for example, cheap solar power or insolation of buildings, costs of obtaining low GHG emissions will be reduced for future generations, thereby fulfilling the aim of the present generation to lower future GHG emissions.

In the first part of the project, Thomas Michielsen and Reyer Gerlagh at the Tilburg Sustainability Centre, set up and studied a model where concerns for future climate change introduce a time-inconsistency in policy-making. The study shows a regular pattern where a regulator prefers a tight climate target, but also prefers to delay costly tasks. Over time, targets are weakened as a natural outcome of the preferred delay.

In the model by Michielsen and Gerlagh, the government is naïve as is mistakenly assumes that it can control future governments. In a refinement, Reyer Gerlagh and Samuel Okullo sets up a recursive Integrated Assessment Model that can be used to study innovations as commitment device for climate policy by deriving the Markov equilibrium, that is, the current government correctly anticipates the response of the future governments. In 2013, the main task has been to write and test the model code for a simplified model version, as this is a new type of model.

In 2014 the model will be extended, in collaboration with Mads Greaker from Statistics Norway, to include innovations. The expected result is an assessment of the usefulness of policies that stimulate cost-reducing innovations in clean energy technologies as a mechanism that induces deep emission reductions in the future. Hence, current innovations are stimulated to entice future regulators into more stringent policies. In 2014, a draft paper will be written.

This research obtains CREE funding, which has enabled Tilburg Sustainability Center (in combination with another project with Statistics Norway) to offer a postdoc candidate a two year contract for 2013-2014. CREE will pay most of the postdoc wage costs in 2014. Part of the funding is used to cover wage costs of a professor.

II.7 Can non-market regulations spur innovations in environmental technologies?

Market-based regulations such as taxes or tradable quotas are recommended to encourage innovation in environmental technologies rather than non-market-based instruments, such as technology standards and non-tradable emission quotas. However, the latter types of regulation are common when a regulator faces complexities, such as multiple emission types and targets, heterogeneous recipients, and uncertainty with regard to marginal damages. Firms emit a number of different pollutants that cause damages, such as cancer, acidification, and global warming. Capturing all these aspects in relevant prices is difficult. Non-market-based regulations are therefore still necessary.

We have analysed whether these regulations spur innovation in environmental technologies. Using a unique Norwegian panel data set that includes information about the type and number of patent applications, technology standards, non-tradable emission quotas, and a large number of control variables for almost all large and medium-sized Norwegian incorporated firms in the years 1993-2010, we are able to conduct a comprehensive study of the effect of non-market-based regulations on environmental patenting. Unlike previous studies that are typically conducted at the industry level, we are able to take firm heterogeneity into account, and thereby reduce the common problem of omitted variable bias. We empirically identify strong and significant effects on innovations from implicit regulatory costs associated with the threat that a firm will be sanctioned for violating an emission permit. This suggests that non-market regulations have an effect through warnings of sanctions (fines, permit withdrawal, prosecution, and bad publicity). The results contrast most existing empirical studies on the effects of non-market regulations. The policy implication of our results is that technology standards and non-tradable emission permits can be a useful complement to market-based instruments in spurring innovation in environmentally friendly technologies.

A paper was written in 2013 and submitted to an international journal.

II.8 Technology agreements

Most of the literature on international climate agreements focuses on treaties that directly regulate emissions. In contrast to these papers, the present project analyzes an agreement between a group of countries that implement a joint R&D effort to reduce abatement costs. Even without an explicit agreement on emission reductions, a technology agreement leading to lower abatement costs as a consequence of the agreed upon R&D expenses might result in a broad reduction of emissions. There may exist an equilibrium with a group of countries participating in a coalition that undertakes R&D in order to reduce abatement costs, and

another group of countries (generally differing but overlapping with the first group) that uses the new technology to reduce their emissions. The paper gives an extensive analysis of the special case in which there are only two types of countries; some with "high" willingness to pay to avoid emissions, others with "low" willingness to pay. It is demonstrated how total emissions depend on the number of countries with high willingness to pay: It may be the case that as the number of such countries increases, emissions may first decline, then rise, and then again increase.

The paper, Hoel, M. and A. de Zeeuw, Technology Agreements with Heterogeneous Countries, will be published in T.L. Cherry, J. Hovi and D. McEvoy (eds), *Toward a New Climate Agreement: Conflict, Resolution and Governance* , Routledge, in 2014.

In 2014, a more general analysis of these types of technology agreements will be undertaken. Some research questions are: i) How do the equilibrium amount of emissions depend on the distribution of willingness to pay across countries? ii) What is the effect of introducing a subsidy to users of the new technology?, and iii) Under what circumstances will an agreement of this type outperform an agreement focusing only on emission reductions? The level of activity will, however, depend on whether an application to the program KLIMAFORSK obtains funding.

II.9 Obstacles to dissipation of environmentally friendly technology

In 2013 the literature survey, within the fields of behavioral and experimental economics, on energy efficiency investment was finalized and submitted to Samfunnsøkonomen. The review was presented at a CREE ENOVA meeting in Trondheim, and also at a meeting with psychologists from the University of Oslo. Below is summary of the literature review.

Several studies claim that it is possible to save between 10 and 25% of our total energy consumption through profitable investment. For an economist it is a paradox that apparently profitable investments are disregarded; this is the so-called energy paradox. While standard economic theory assumes that agents are rational, the field of behavioral economics can be classified into three main branches where each branch relaxes one of the following assumptions: bounded rationality, bounded will-power and bounded self-interest. The survey goes through the empirical literature on energy efficient behavior and policies relevant for such behavior, and interprets the findings in light of these three theoretical branches of behavioral economics.

If people have bounded self-interested preferences, investing in energy efficient technology could be motivated by the desire to contribute to the wellbeing of others, or the wellbeing of nature. Providing information on the positive effects for the environment or climate of energy efficiency and energy saving thus should increase investments in energy efficiency. However, studies do not find any significant effect on investment in energy efficiency from informational campaigns. If behavior is motivated by following social norms, then providing information about the behavior of others should matter. Several large US studies have

documented that providing comparative information about how a household's energy consumption compares to other's consumption has positive effects when this information is combined with faces that indicates whether the behavior is good (smile) or bad (sour).

If people are characterized by bounded rationality, providing different types of information should improve investment in energy efficiency. If the lack of investments is caused by ignorance about the investment opportunities, general information about energy saving or energy efficiency should help. Research shows that general information through information campaigns does not work, but tailored information through home audits, where an advisor comes home to people and informs them about exactly which investments would be profitable for their home, does help. Also, providing customers with information on product lifetime energy costs together with the sales price, as well as labeling energy efficient products, shifts sales towards more energy efficient products. Finally, providing households with feedback on their energy consumption has proven to give significant reductions in energy consumption.

If people have bounded will-power, for instance by having time-inconsistent preferences, they might fail to invest in energy efficiency because they give higher weight to the investment cost paid in present, compared to the future reductions in energy costs due to lower energy consumption. There has been limited research within this field. In general, goal-setting, either personal goals, goals combined with feedback, or publishing goals in public, could be relevant strategies for people with bounded will-power. However, research has not found any effects of personal goal-setting, and only very small effects of goals combined with feedback and publishing goals in public.

The paper received a revise and resubmit to Samfunnsøkonomen in December 2013.

Research applications - Experimental and behavioral economics

An important task in 2013 has been to work on applications for new projects. Four applications fall within the field of behavioral and experimental economics: Two applications for funding preprojects through NORKLIMA (deadline February), and two applications for ordinary research projects through KLIMAFORSK (deadline October). The two preproject applications both included field experiments. A major challenge is to find "real world" partners interested and willing to conduct the experiments. The first project proposal titled "Diffusion of climate friendly technology in households" focused on improving the understanding of why apparently beneficial investment opportunities often are left unexploited, while the second, "Mobility in a transition towards a low carbon society" focused among other issues on how policies promoting electrical cars affect the use of cars in general and electrical cars specifically. None of the preproject applications were granted, and without the preproject financing we did not manage to find the necessary partners for conducting the suggested field experiments.

New activities in 2014

Experimental and behavioral economics

The research activity in 2014 within behavioral and experimental economics depends heavily on the outcome of the applications. In addition to two submitted proposals to the program KLIMAFORSK, we are also currently in dialogue with ENOVA on a research cooperation. One possible idea is to study whether transforming the investment cost to an annuity can increase investments in energy efficiency. By suitably transforming the investment cost to an annuity so that costs and energy savings accrue in the same time period, one may avoid the bias of the present, which is assumed to be the problem for people with time-inconsistent preferences.

II.10 Knowledge spillovers from clean and dirty technologies - A firm level study on patent citations

The aim of this paper is to compare knowledge spillovers effects from clean and dirty technologies, and also to compare these across industries. Spillovers are measured using patent citations. We will use the unique Norwegian firm level panel data set spanning over the years 1993 to 2010, which has firm-specific information about type of technology as well as forward and backward citations. In contrast to other studies, we have access to important control variables for all Norwegian incorporated firms. We are thus able to conduct a comprehensive study of knowledge spillovers from clean and dirty technologies and from different industries. Knowledge about the size of clean technology spillovers relative to those from dirty technologies matters since such externalities determine the appropriate public R&D support.

A draft paper will be written in 2014.

Table 2: Planned work months, WP2

Activity	Primary institution	Planned work months	Cree funded work months
II.1 Strategic technology policy	Statistics Norway	0.5	0
II.2 Carbon leakage: Pay or not pay the polluter?	Statistics Norway	0.5	0
II.3 How should CCS technologies be supported?	Frisch Centre	1.5	0.5
II.4 Environmental R&D instruments	Frisch Centre	3.0	1.0
II.6 Innovation in clean energy as a commitment device	Tilburg	5.0	2.5
II.7 Can non-market regulations spur innovations?	Statistics Norway	1.0	0.5
II.8 Technology agreements	Frisch Centre	2.0	0.6
II.9 Obstacles to dissipation of env. friendly technology	Frisch Centre	2.5	2.5
II.10 Knowledge spillovers from clean and dirty technol.	Statistics Norway	6.5	1.5

WP3: Regulation and Market

Work Plan 2014

In this work package, the main question is how regulation of energy markets affects the development of green energy, and how measures to promote green energy impact the functioning of energy markets. It is of particular interest to study the implication of regulation across national borders, especially with respect to infrastructure, since an international regulatory framework is crucial for the exploitation of Norwegian energy and environmental resources, both in traditional areas and in new areas like capture and storage of CO_2. The work is planned mainly as theoretical and empirical studies, but numerical models, either already existing or developed in other work packages, will be utilized also. As such, part of the work within this package will be conducted in cooperation with or as part of Working Packages 4 and 5.

Work in 2014 will consist partly of continuation and finishing of on-going projects and partly of starting up of new projects. Some of these projects are of direct policy relevance and are either based on ideas and earlier work with user partners or will be undertaken in relation with these. Below we describe plans for core projects.

On-going projects

III.1 Information and transparency in electricity markets

The performance of electricity markets depends crucially on information collected from and made available to market participants. The EU Commission is currently working on new legislation to regulate the amount, type and format of such information. This raises fundamental question about the relationship between transparency, market power and competition, as well as the cost of collecting and publishing information. A fundamental insight from economic theory is that more information is not always better and the challenge is therefore to balance the positive and negative effects by collecting and publishing the right information.

In 2013, this subproject was both started and concluded, with a publication in Economics of Energy & Environmental Policy.

III.2 Interaction between Electricity and Quota Markets

Prices in the European market for CO_2 permits have varied considerably. These price variations have not only created uncertainty for market participants with respect to the profitability of investments to reduce CO_2 emissions, but have an impact on the cost of producing electricity, and hence electricity prices, which again have affected incentives to invest in generation. In this project, we study how price variations on the permit market affect the electricity market, and how the interaction between these markets impact incentives to invest in generation and measures to reduce emissions.

In 2013, this project was concluded with a publication in Environmental and Resource Economics.

III.3 Integration of Intermittent Power in Northern-European Power Markets

Wind power, on-shore as well as off-shore, and solar power has been identified as a key technologies for renewable energy, where the EU has an ambition that Europe should become a global leader and where countries like Denmark, the United Kingdom, Sweden and Germany already invest heavily, or have concrete plans to do so. Short-term variation in the availability of wind and solar power makes it difficult to integrate these technologies on a large scale in conventional energy systems, but with access to sufficient amounts of storable hydropower, the potential for wind is substantially larger. The idea that Scandinavia may become an electric battery - a "blue battery" - for Europe has therefore attracted considerable interest, both academically and politically. In this project, we ask to what extent the existing hydro capacity can accommodate a large-scale expansion of intermittent power in and around the North Sea, taking account of the possibility of building pumped storage and the cost of constructing large international interconnectors that will provide back up and balancing capacity for the countries both inside and outside of the Nord Pool area.

Work on this project is documented in CREE Working Papers no 6/2012 and 14/2012. These papers will be prepared for journal publication. In addition, the book Hydropower Economics

is being revised, where, in addition to extensions and improvements of existing chapters, two new chapters will be included, based on the above-mentioned working papers.

III.4 Green Certificates and Competition in Electricity Markets

A number of studies have analysed how green certificates affect the functioning of electricity markets, both with respect to short-term price formation and long-term investment. One result is that green certificates may undermine the efficiency of energy markets by increasing price volatility. In addition, green certificates may provide market participants with the possibility of exploiting market power by imposing so-called "margin squeezes". In this project we study the importance of green certificates for electricity markets, and analyse how potentially negative effects may be counteracted by suitable regulation.

Work on this project is documented in Nils-Henrik M. von der Fehr and Stephanie Ropenus, Green Certificates, Vertical Relations and Market Power. The paper is currently being revised for publication in a scientific journal.

III.5 Effects of Reduced Nuclear Capacity in Europe

The aim of this project is to study numerically possible impacts of reduced nuclear capacity in Europe. The nuclear crisis at Fukushima, Japan, in 2010 has affected nuclear policy in several countries. For Europe the most important policy change is the announcement of the German government to phase out all nuclear power plants by 2022. Nuclear power in Germany accounted for 23% of national electric consumption before the shutdown of 8 nuclear power plants in March 2011. The shutdown of the remaining plants will have a significant impact on the energy markets in Europe. Will the shortage of supply be met be increased fossil fuels or other renewable energy? How will this affect CO_2 emissions in Europe and from different European countries? How will the trade in energy goods between countries be affected from the shutdown? To study these questions, we will use a large-scale partial equilibrium model for the European energy market (LIBEMOD). The model will be updated when it comes to base year (2009) and when it comes to plans for nuclear (and other energy) investment decisions taken after the Fukushima crisis.

The project is partly financed through the EU project ENTRACTE. In 2013, work concentrated updating and extending LIBEMOD and preliminary analyses. In 2014, full-scale analyses of reduced nuclear capacities will be undertaken.

III.6 Natural Resources and Sovereign Expropriation

An important question for governments of countries endowed with large natural resources is how to govern these resources, including choice of ownership structure and rights to exploitation. An example is the Norwegian hydro resources, which, since the introduction of the "panic laws" in the early 20th century, have been governed by a regime in which "national" ownership is combined with leasing of exploitation rights to third parties. Questions of ownership and governance are inherently political and policies may change

abruptly, following changes in government, changes in the value of the resources or other events. At the same time, the type and quality of governance is crucial for the efficient exploitation of natural resources. In this project we study such issues, including how the regime governing natural resources depend on political and economic factors, as well as how such factors, through their influence on the regime, affect the efficiency of resource exploitation.

During 2013, we have continued work on building a suitable theoretical model to study some of the relevant questions. This is a challenging process, given the inherent dynamic feature of the problem, which requires use of sophisticated mathematical techniques, and has taken more work and a longer time than originally envisioned. Nevertheless, we are now approaching a suitable model and aim to finalise a first draft of a paper documenting this work early in 2014. Preliminary versions have been presented at a number of seminars and workshops.

Another part of this subproject is undertaken by Daniel Spiro. He studies how resource owners will behave with a risk of losing their resource due to nationalisation, how this in turn affects the incentives for governments to nationalise such resources and how world prices for resources may be affected by such interaction. The central result in this work is that nationalisation in one country will be closely linked to nationalisation in other countries. The analysis shows that if one country nationalises its resource then resource prices will rise making it worthwhile for others to nationalise too, thus raising the price further. This way the model predicts waves of nationalisation in correlation with price surges. The novelty of this paper is that it would be one of the first to analyse the interaction between political processes and world prices. While the main mechanism is in place, the remaining work relate to analysing alternative equilibria and some extensions of the model.

III.7 Should Foresters Forecast?

Growth dynamics of forests will likely be altered by climate change. As these shifts are hard to predict, this paper asks whether forecasting them is necessary for profitable management. While unpredictability of climate change makes it hard to calculate expected profit losses of not forecasting, by using Monte Carlo simulations we can obtain an upper bound of these losses. We show that an owner following a rule of thumb, which completely ignores future changes and only observes changes as they come, will closely approximate optimal management. If changes are observed without too much delay, profit losses and errors in harvesting are negligible. This has implications for the effort foresters should devote to long-run forecasting. It also implies the argument that boundedly rational agents may behave as if being fully rational has traction in forestry.

A first draft of a paper documents the initial results of the project. The paper will be further developed, with the aim of publication in a scientific journal.

New Projects in 2014

III.8 The Hveding Conjecture: Optimal Operation of Hydro Power

The thinking about how to operate hydro generation facilities in an integrated system has developed considerably over time, with ideas from economics gradually becoming more influential. In this project this history will be revisited, with particular emphasis on the relevance and success of the so-called Hveding Conjecture.

III.9 Integration of, and Competition between, Electricity Market Places

A new phase in the integration of the European electricity industry has been initiated with the coupling of physical trade on different regional market places. Some developments have already taken place, mostly based on bilateral agreements between regional players, but a more comprehensive approach is currently being taken by regulators in North-Western Europe, with the aim of subsequently extending the process to the rest of Europe. The coupling of trade not only raises question about how to harmonise market places and efficiently utilise physical interconnectors, but also how to handle competition between different market places. Such competition is already present in the UK, as well as in certain regions of Germany, but further integration may increase the extent of rivalry between market places. In this project, we study challenges raised by market coupling.

III.10 Flexibility in Electricity Markets

Consumption and demand of electricity must be balanced at all times. Achieving this balance requires a high degree of flexibility, either on the supply side, on the demand side or both. Achieving the warranted flexibility has become more challenging with the increased share of intermittent and distributed generation. A fundamental question is whether this requires new ways of organising and governing the electricity market, including the availability of contracts and market places to allow market participants, as well as system operators and other decision makers, to operate efficiently. In this project we aim to study such questions.

III.11 Conflicts and price contagion on resource and energy markets

Whether the world market will make the transition to renewable energy sources and clean technologies by itself, largely depends on long-run prices of fossil energy and mineral inputs such as silicon and lithium which are needed in the new technologies. Likewise, to be able to analyse the efficiency of various policy measures curbing climate change or directed at renewable technology it is central to understand the long-run workings of fossil energy markets. Now, exhaustible resource markets are notoriously politicised. Yet there is virtually no literature on how world markets for these resources interact with national and international political incentives. The current project on contagious resource conflict aims to take a step in bridging this gap.

A well-known feature of many of these markets is that property rights are either not defined or not practically upheld. This is in particular the case for many minerals which are abundant in non-stable countries and which are necessary for production of renewable energy technologies. This would also be true for renewable energy resources such as wood in some countries. How does this feature of the world market affect global supply and prices? This is essential to understand when thinking about a future market for renewable energy relying on technologies whose supply is unpredictable. This project intends to study theoretically how world prices of such resources affect the prevalence of violence and conflict in unstable countries, how this feeds back to affect world prices and how this in turn may lead to conflict in other countries or regions. Apart from the theoretical part, the project intends to test the predictions using a new dataset of reserves and production of all resources in all countries over the last 20 years.

III.12 Finders keepers

Related to the ongoing projects on Natural Resources and Sovereign Expropriation is the question of public policy and taxation. Governments do not only have the possibility to expropriate the resource but can also change the tax schedule. Few governments can make promises on behalf of future governments several decades into the future, hence this is a real concern for private investment.

But what is the optimal tax scheme incentivizing exploration and investments that will provide the government with a large share as possible of the profits? Investments in hydropower, solar power installations and new resource deposits of oil and gas typically create incentives for a government to increase taxation after a major investment has been made. This in turn may lead to underinvestment. Another complication is that, normally, investments are made in the most profitable projects first. Then, if the tax scheme remains the same over time, projects with lower expected profits, but which are still profitable enough to warrant investment, may remain undeveloped due to the distortionary tax.

This new project intends to analyse theoretically what the optimal taxation will be in such a case of limited commitment to future taxes, how the tax will change after findings have been made and how it will change over time as investments become less and less profitable. It also aims to study how this depends on the type tax used (royalty, profit tax, etc).

Table 3: Planned work months, WP3

Activity	Primary institution	Planned work months	Cree funded work months
III.3 Integration of intermittent power	Frisch Centre	1.2	1.2
III.4 Green certificates	Frisch Centre	1.2	1.2
III.5 Reduced nuclear power	Frisch Centre	1.0	1.0
III.6 Natural resources and sovereign expropriation	Dep. of economics	5.2	5.2
III.7 Should fosters forecast?	Dep. of economics	2.0	1.0
III.8 The Hveding conjecture	Dep. of Economics	2.0	0
III.9 Competition between electricity market places	Dep. of economics	1.0	0.6
III.10 Flexibility in electricity markets	Dep. of economics	1.0	0.6
III.11 Conflicts and price contagion on resource and energy markets	Dep. of economics	5.0	3.0
III.12 Finders keepers	Dep. of economics	5.0	3.0

WP4: Evaluation of Environmental and Energy Policy Measures

In the first three years, the activities in WP4 have focused on four research topics:

a) Rebound and adverse effects of energy efficiency measures.

b) The households' response to soft policy measures.

c) Environmentally friendly transportation.

d) Indoor temperature and energy consumption in families with children.

During the next three years, the analyses on these four topics will be finished, and we will start working on six new topics:

i) Effects on household energy consumption and transportation of governmental policies to increase the use of electric vehicles.

ii) Effects on energy use of changes in building regulations (such as energy labelling and low-energy building standards) aimed at increasing energy efficiency and reducing energy consumption.

iii) Effects on energy use of new technologies that provide information on a household's energy consumption.
iv) Behavioural potentials and barriers for achieving increased energy savings from energy efficiency measures in heating systems.
v) Which policy instrument induces the best environmental performance? A firm level study comparing effects of market and non-market based instruments.
vi) Are there secondary benefits of CO2 regulation? A comprehensive firm level study on Norwegian emissions.

Research communities and methods

The work on WP4 is focused on four research communities: economists from Statistics Norway (SSB), social anthropologists from Centre for Development and the Environment (SUM), and economists from the Frisch Centre/University of Torino and the Department of Economics at the University of Oslo (ØI). The different research communities will apply a variety of methods to analyze the research questions listed above. The economists at SSB apply micro econometric analysis to estimate how policy tools affect household energy demand based on micro data from the Norwegian Survey of Consumer Expenditure. The social anthropologists from SUM apply social practice theory to describe how energy is a part of daily tasks, and how policy measures affect habits and the interrelation between household members, and through this its effects on household energy consumption. The economists at Frisch/Torino/ØI will build a micro simulation model for car purchases based on estimations on vehicle purchase data. Simulations will be done to analyze how the goals for a reduction in CO_2 emissions in 2020 may be achieved. In addition, economists from the Frisch Centre will use experimental economics method to perform a field experiment, aiming to explain more in depth some specific aspects of the households' decisions.

During the first couple of years, each research community will apply its own methods to the research questions. The aim is to learn from the traditional research approaches within each field, discuss differences in results and assess the strengths and weaknesses of each approach. We want to learn from each other's disciplines, with the final goal of combining the analytic approaches. The first collaboration is planned between SSB and SUM, and a joint study is planned when the first economics and anthropological analyses are finished.

Results in 2013

In 2013, several studies have been finalized. Below we first present a brief summary of the main results, and then provide more discussion of these analyses.

Summary

The analyses in SSB have progressed as planned. Five articles have been published in international journals on topics related to work package 4. We have also written two new articles (on research topic a) aimed for publication in international journals, which have so far been published in Statistics Norway's Discussion Papers series and in CREE's Working paper series. Three popular science articles on rebound effects and indoor temperature and household energy consumption are published in Norwegian journals (research topic a and d). One Master thesis on topic d) is financed by CREE, which is also published as a CREE Working paper. Finally, a paper on topic b) intended for international publication was submitted and presented at the 37th International IAEE Conference in Daegu, South Korea, in June 2013.

The anthropological research by SUM was delayed in 2012 due to legal matters that needed to be clarified prior to getting access to the same sample of households as is used in SSB's economic analyses. The work of collecting the data has been going on in 2013 and will proceed in 2014. This includes 28 in-depth interviews with families who are using heat pump at home (research topic a). Also, displays that visualize electricity consumption have been installed in 26 homes in Oslo (research topic b). We will monitor consumption and conduct interviews with a sample of the test families to see if consumption goes down. A control group will consist of families who live in the same blocks and who do not take part in the study. A master thesis (Misha Jemsek) has been completed in 2013 (research topic a). SUM presented a draft paper during CREE's conference in September and will have this published in an international journal.

Results

IV.1 Rebound and adverse effects of energy efficiency measures.

Lately, there has been an increased focus on energy efficiency in Norwegian households, and several policy measures have been implemented to increase efficiency. Whether or not these policy measures achieve the anticipated reduction in energy consumption depend on how the households respond to these measures. Several studies on energy efficiency show that energy consumption is not reduced as much as the energy savings potential embedded in the efficiency measure suggest because efficiency increases spur households to change their behaviour (rebound effects). The rebound effects reflect that increased efficiency reduces the cost of using the energy source, which changes the relative prices of using different energy goods and reduces the cost of producing a given household service (heating, cooking, etc.). Bøeng m.fl. (2013) discusses the effects these rebound effects may have on household energy consumption, illustrated by the effect on household electricity consumption of increased use of heat pumps to heat Norwegian homes. The data indicates that there are considerable rebound effects in the introduction of heat pumps in Norwegian homes, and these rebound effects are as large as the energy savings potential embedded in the heat pumps, see Bøeng,

A.-C., B. Halvorsen og B.M. Larsen (2013): ”Fører effektiviseringstiltak til uønskede adferdsendringer?, RØST nr 1.

To understand why these large rebound effects occur, Halvorsen, B. and B.M. Larsen (2013) examines different changes in energy consumption that has resulted from the increased use of heat pumps in Norwegian homes. The article looks at how heat pump ownership affects consumption of electricity, firewood and fuel oils, as well as how it affects indoor temperature. We find that households owning a heat pump use less firewood and fuel oils compared to households without a heat pump, as well as keeping a higher indoor temperature in the living room when it is not in use (on cold winter mornings). Only households with several alternatives to electricity used for space heating have a lower average electricity consumption than households without a heat pump, presumably because they have alternatives to electricity for heating in periods during the winter when it is so cold that the heat pump does not work properly. On average, the entire energy savings potential of electricity embedded in the heat pump is taken out in increased welfare by the households. However, total energy consumption is reduces and energy efficiency has risen. See Halvorsen, B. and B.M. Larsen (2013): ”How do investments in heat pumps affect household energy consumption?”, *Discussion Papers no. 737*, Statistisk sentralbyrå, Halvorsen, B. and B.M. Larsen (2013): ”Hvem eier varmepumpe og hva gjør det med strømforbruket?”, *Økonomiske Analyser 2/2013*, Statistisk sentralbyrå, og Halvorsen, B. and B.M. Larsen (2013): ”How do investments in heat pumps affect household energy consumption?”, CREE Working Papers 6/2013.

IV.2 The households' response to soft policy measures.

The effectiveness of soft policy measures is often analysed based on stated preference surveys. Most humans have strong preferences with respect to how they like to present themselves and how others perceive them. This wish to present an image may bias results from stated preference surveys, depending on the underlying social norm in the questionnaire and the norms of the interview object. In an article published in Environmental Economics, we model how moral and social norms affect how we answer questions from stated preference surveys. The model is illustrated by using data from a survey on environmentally friendly household behaviour, which was simultaneously conducted in ten different OECD countries. We find clear indications that norms and how we like to be perceived by others affect how much we over- and understate our actual behaviour. These misrepresentations of behaviour occur both by respondents that want to appear environmentally friendly and those who oppose to this norm. The over- and under reporting of environmentally friendly behaviour appears to be evenly distributed, so that the mean seems to be relatively unbiased. See Halvorsen, B. (2012): ”Good Girl – Bad Boy: Do identity statements bias results from stated preference questionnaires”. *Environmental Economics*, 3(2), 65 - 79.

In an article titled ”Households response to multiple energy policy instruments”, presented at the 37th International IAEE Conference, June 16-20, 2013 in Daegu, South Korea, the households’ response to a combination of policy tools, both soft (energy labelling, energy economising advice and other information tools) and hard (energy taxes), are modelled. The model is illustrated by a data set from the Norwegian consumer expenditure survey for the years 1986 to 2009 to see if changes in energy policies during this period have changed household electricity consumption. We find that energy taxes are very effective, and that several soft policy tools reinforce this effect. We also find that the direct effect of most soft policy tools are modest, with the exception of energy labelling of household appliances, which seem to have a significant but decreasing effect on household energy consumption over time.

IV.3 Environmentally friendly transportation.

In 2014 a PhD student at the economics department at the University of Oslo will analyze the impact of the purchase tax on new cars; this reform was announced in connection with the Government Budget in October 2006 (effective from 1 January, 2007). Sales data revealed there was a strong increase in the sales of cars with high CO_2 emissions during the fall of 2006. Thus the announcement of the new policy had an impact on CO_2 emissions in the fleet of cars after October 2006. But it also seems that the total sales of cars were not changed very much. Thus cars that otherwise would have been bought with somewhat lower CO_2 emissions in the fall of 2006 were replaced by bigger cars with higher potential CO_2 emissions. Sales in 2007 did not drop. For that reason the policy implemented since January 1st 2007 had a lasting impact on CO_2 emissions in the fleet of new cars after this date.

IV.4 Indoor temperature and energy consumption in families with children.

Each year, the Norwegian Research Council and Network for environmental studies at University of Bergen, organize a research project called “Forskningskampanjen for skolene” in which children from all over Norway are involved in research. In the 2012 Research campaign, the pupils measured the temperature in four rooms (the living room, the bathroom, their own bedroom and their parent’s bedroom) in the morning and evening, and registered the electricity consumption. In addition, the pupils interviewed family members about how pleased they are with the indoor temperature in different rooms, what they do to save energy, as well as attitudes and nagging about energy savings in the household. We find that almost half of the family members state that they hold a lower temperature in the living room and their own bed room than they find comfortable, and the mothers are the ones that freeze the most. The data also indicate that this is intentional, and that the reason many of these household choose to keep the room a little cooler than they find comfortable is to save money, energy and/or resources.

We also find that the indoor temperature varies with the heating equipment. The group with the highest indoor temperature is households with a common central heating system, followed by households with a heat pump, whereas households that use a lot of firewood for heating have a lower average temperature in the living room than other households, see Dalen H.M. and B. Halvorsen (2013): "Vi fryser for å spare energi", *Økonomiske analyser 2/2013*, Statistisk sentralbyrå; Dalen H.M. and B. Halvorsen (2013): "Ta hjemmetempen: Rapport fra Forskningskampanjen 2012", *Rapporter* 2013/19, Statistisk sentralbyrå; Birkelund, H. (2013): "Oppvarming og innetemperaturer i norske barnefamilier. En analyse av husholdningenes valg av innetemperatur", Masteroppgave ved UiO; and Birkelund, H. (2013): "Oppvarming og innetemperaturer i norske barnefamilier. En analyse av husholdningenes valg av innetemperatur", CREE Working Papers 13/2013.

Related analyses

We have also conducted several analyses that fall within this work package but that were not part of the 2013 work plan, that is, these did have any CREE funding. The main results from these analyses are reported below.

IV.5 Residential end-use electricity demand

A large share of policies aiming to reduce household energy consumption is related to specific end-uses, such as heating. It is very expensive and difficult to measure how much electricity that is used in different household activities, such as space and water heating, lighting, washing, etc. We have developed a model for estimating electricity consumption in different end-uses that use cross sectional household data. The model is applied on three different data sets for the years 1990, 2001 and 2006 to compare the distribution of electricity on different end-uses over time. We find that electricity for basic use, such as washing, cooling of food and heating of water, does not vary much over the period. However, electricity for heating may vary considerably across years, depending on relative energy prices, temperature, etc. , see Dalen, H.M. and B.M. Larsen (2013): "Residential end-use electricity demand: Development over time". Discussion papers 736, Statistisk sentralbyrå. This work is invited for a resubmission in *Energy Journal*.

IV.6 Energy consumption and stocks of firewood

Policy measures applied during the last few decades aims to (i) reduce the households' consumption of fuel oils and electricity and (ii) increase the use of solid biomass to heat residences. One major problem in evaluating these policies is that many households may have large stocks of fuel oils and firewood. This means that there will be a difference between the purchased amount of these energy sources and consumption. Since we only have information on purchases, not consumption, it may be difficult to evaluate the effects of these policies. Thus, a method for estimating the price- and income effects on consumption and changes in stocks based on information about purchases, and whether this equipment has been used, is

developed. This method is illustrated on data from the Norwegian Consumer Expenditure Survey. See Halvorsen, B. (2013): "Estimating consumption and changes in stock of storable goods applying micro expenditure data", *Environmental Economics* 2, pp. 42 - 53.

IV.7 Bioenergy

In cooperation with a project at the Norwegian University of Life Science called "Bioenergy markets" we have written two papers published in a special issue of *Biomass and Energy*. The first examines motives for purchasing air-to-air heat pumps and also four different types of heating equipment; either based on firewood, wood pellets, electric floor heating or panel ovens. We analyse how this choice depends on how the households value the aesthetics of the equipment, its effectiveness, its utilisation and investment costs, its effects on the environment, in addition to time spent on applying the equipment. The article analyses how these factors affect the choice of heating equipment. Different factors tend to favour the purchase of different equipment. For instance, households concerned about costs tend to invest in heat pumps more than others, whereas environmental concerns are paramount in explaining purchase of wood pellets stoves. However, the most important explanatory factors are characteristics of the household and the residence, see Lillemo, S.C., F. Alfnes, B. Halvorsen and M. Wik: (2013): "Households' Heating Investments: The effect of motives and attitudes on choice of equipment ", *Biomass and Energy*, February.

The second article analyses what influences demand for fuel wood. This analysis focuses on how different factors, such as live style and environmental consciousness, in addition to characteristics of the household and the residence, affect demand. The analysis applies data from the Norwegian Survey of Consumer Expenditures for the years 1997 and 1998, where the latter contains additional information on attitudes, lifestyles and energy consumption. We find that an urban lifestyle and a focus on comfort reduce demand for firewood. We also find that the price of firewood, as well as characteristics of the household and the residence, have a large and significant effect on firewood demand, see Lillemo, S.C. and B. Halvorsen: (2013): "The impact of lifestyle and attitudes on residential firewood demand in Norway", *Biomass and Energy*, February.

IV.8 Aggregation

When evaluating the effect of a policy measure on energy demand for the entire household sector, we face the problem of aggregation; that is, whether results from analyses on micro data are valid also for the effect on aggregate demand. Likewise, econometric analyses on aggregate demand will include more than the behavioural effect of the policy tool. The reason is that preferences and behaviour differ across households, which has to effects: First, the properties of the micro functions are not representative of aggregate behavioural effects, and second, it is not possible to indentify behavioural effects based on analyses of aggregate functions only. This seems like a Catch 22 situation, but it is not, as it is always possible to calculate both micro and aggregate properties based on analyses on micro data. In an article

published in *Applied Economics*, a method for a theoretically consistent aggregation of micro properties to macro. The method is illustrated on household electricity consumption data from the Norwegian Survey of consumer expenditures. We find relative large aggregation biases, especially when estimating on aggregate data. See Halvorsen, B. and B.M. Larsen (2013): "How serious is the aggregation problem? An empirical illustration". *Applied Economics* 45, pp. 3786–3794.

Analyses planned for 2014

The plans for 2014 is connected both to ongoing and new activities. Table 6 provides information on planned analyses of the three research questions in 2014, by research topic and institution. We plan to write articles for publication in international journals for each research question reported in the table, and also write one report on research question a). SSB plan to submit the drafts written in 2013 on research topic a) for publication in international journals, and write two articles on research topic b) in 2014, using the information collected in 2012 about the policy tool aimed at changing household energy consumption. Researchers from the Frisch Centre/Torino/University of Oslo plan to publish two articles in 2014 on research question c), and researchers from SUM plan to publish two articles on the research questions a) and b). To increase the availability of the research at an early stage, all papers aimed for publication in international journals will also be published in working paper series. Finally, we plan to write two articles for international publication on research questions v) and vi).

Table 4: Planned analyses in WP4 for 2014.

Research questions	*Institution*
IV.1 Rebound and adverse effects of energy policy.	
– Empirically examine and use social practice theory for analyzing rebound effects in relation to heat pumps among households	SUM
– Report comparing estimation results of the effects on household energy consumption of heat pump ownership using data from the Consumer Expenditure Surveys of 2009 and 2012	SSB
IV.2 Response to soft policy measures	
– How has energy labelling on household appliances affected household electricity consumption?	SSB
– How do soft policy measures affect the efficiency of an increase in electricity taxation?	SSB
– How do soft policy measures affect practices and attitudes among households?	SUM
IV.3 Environmentally friendly transportation	
– How may we reduce the emission per km through changes in the car fleet?	Frisch/Torino/ØI
IV.9 Energy consumption and building regulations	
– Effects on energy use of changes in building regulations (aimed at increasing energy efficiency and reducing energy consumption	SSB
IV.10 Effects on energy use of new technologies	
– Field experiment	Frisch
IV.11 Which instruments induces better performance in firms?	
– Compare the effects from market-based and non-market-based regulations	SSB
IV.12 Are there secondary benefits of CO_2 regulation in firms?	
– Are CO_2 emissions and other pollutants substitutes or compliments?	SSB

Ongoing activities

In 2013, Statistics Norway started up analyzing the effects of soft policy measures on household energy consumption, and how soft policy tools may affect the efficiency of hard policy measures (research topic IV.2). We have prepared two analyses where we use micro data from the Norwegian Survey of Consumer Expenditure for the period 1986 to 2009, in combination with information on historical policy use (collected in 2012). The first study uses these data to trace the effects of various policy measures, both hard and soft, on household energy consumption. The other analysis is examining the effect on household electricity consumption of introducing energy labelling of household appliances in 1996. The plan is to finish both articles and submit them for international publication in 2014. In 2013, we also wrote several articles analyzing the effects of heat pump ownership on household electricity consumption (research topic IV.1) using data from the Norwegian survey of consumer expenditures 2009. To test if our results are stable over time, we will conduct a similar analysis on the SCE for 2012, where the number of households is three times as large as in the 2009 survey. These results will be presented in a Norwegian Report.

SUM will publish a peer-reviewed paper on the rebound effect of heat pumps (research topic IV.1). SUM will also complete the field study that visualizes electricity consumption for the consumers and produce a draft paper on the potential for using displays as a tool to reduce electricity consumption (research topic IV.2). This will be published in 2015. SUM will also provide input to interdisciplinary discussions with SSB where we compare the research approaches and findings from the economic and anthropological studies on research topics IV.1-2. The aim is to write a synthesis paper to be submitted in 2014 on the rebound effects of heat pump ownership on household energy consumption.

The Frisch Centre/Torino/University of Oslo: In 2014, the work on the impact of taxes on the purchases of new cars will be finalized and a paper will be submitted to an international journal. In another paper we will analyze the impact of an announcement of new polices on purchase decisions

New activities

IV.9 Effects on energy use of changes in building regulations

Building regulations of e.g. insulation, ventilation, energy recovery and chimneys affect energy use and emissions from buildings. In recent years, we have seen several changes in building regulations. For example, requirements for heat recovery systems in all new residences and energy labelling of all residences put up for sale, were introduced in 2010. The empirical economic literature on how these regulations and standards affect household energy consumption is very limited. Statistics Norway plan to start examining how various changes in building regulations have affected household energy consumption using data from the Norwegian survey of consumer expenditures and applying various statistical methods (econometric models). The results from these analyses will be presented in an article intended for international publication, planned in 2015.

IV.10 Effects on energy use of new technologies

For households, there exists many ways to reduce energy consumption. Because electricity consumption is invisible, most people are neither aware nor motivated to reduce their energy use. In 2013 researchers from SSB, SUM and the Frisch Centre have applied for financing for the project "Household adaption to climate policies" from the NRC program KLIMAFORSK. Contingent on the outcome of application, a randomized field experiment will be conducted in 2014 to test the effect on electricity consumption of smart switches plugged to various devices, such as heaters and lighting, a sensor measuring temperature and an app for smart phones which automatically communicates with the switches and sensors. This system for controlling energy consumption utilizes GPS technology in smart phones to learn the habits, and changes in habits, of household members

IV.11 Which policy instrument induces the best environmental performance in firms?

The aim of this paper is to compare the effects from various environmental regulations on environmental efficiency. In particular, we seek to compare the effects from so-called "incentive-based" (market-based) and "command-and-control" (non-market-based) regulations. Conventional theory predicts that incentive-based policy instruments provide cost-efficient emission reductions. However, there is disagreement about which policy instrument has the largest effect on environmental efficiency. Our rich data allow us to compare the effects from different types of regulations such as tradable emission allowances (EU ETS); environmental taxes; and non-tradable emission quotas and technology standards. The former two regulations are typically referred to as incentive-based, whereas the latter is referred to as command-and-control. The unique Norwegian firm level panel data set spanning over the years 1993-2010 include information about different types of environmental regulations, the entire population of Norwegian pollutant emissions, and a large number of control variables for all polluting Norwegian incorporated firms. Environmental efficiency – emissions intensity – is measured as the monetary value of the marginal damages of the yearly pollution of the firm relative to the yearly energy use (KWh) of the firm. Previous studies are typically conducted on a small subset of pollutants since comparable marginal damage estimates have typically not existed. Unlike studies using overly aggregated industry level, data we are able to take into account important firm level control variables and thereby reduce the common problem of omitted variable bias.

IV.12 Are there secondary benefits of CO_2 regulations of firms?

This paper provides new evidence on the effects of CO_2 regulations on emissions other than CO_2. When a firm reduces its CO_2 emissions, other emissions, also related to the consumption of fossil fuels, can potentially decrease with no additional cost. This view of emissions as complements is often advocated by macro economists. A contrasting view, proposed largely by micro economists, is that when CO_2 emissions are reduced, other emissions increase as

dirty emissions are claimed to be substitutes. Knowing whether these pollutants are substitutes or compliments to CO_2 emissions is of great importance to environmental policy. If such effects are present, they must be taken into consideration when analyzing gains from CO_2 regulations. Using a unique Norwegian firm level panel data set that includes information about different types of environmental regulations, the entire population of Norwegian pollutant emissions, and a large number of control variables for all polluting Norwegian incorporated firms, we are able to conduct a comprehensive study of the effect of CO_2 regulations on all types of emissions. Unlike previous empirical studies that are conducted as case studies or numerical simulations because of lack of data, we are able to make a consistent analysis using emissions data.

2014 budget

This research is planned financed through a combination of CREE funding and own funding through other RCN projects. The resource use and share financed by CREE are indicated in Table 7, and the funding financed by CREE in NOK is indicated in Table 8 (by institution and subject). Own funding is still very uncertain, as the activities under research question ii) are subject for a grant application to the KLIMAFORSK program. Thus, the shares in the tables are given under the assumption that this project is funded. If not, the plan needs to be revised.

Table 5: Planned work months, WP4

Activity	Primary institution	Planned work months	Cree funded work months
Administration	Statistics Norway	1	1
IV.1 Rebound and adverse effects of energy efficiency	Statistics Norway	2.5	2.5
IV.2 The households' response to soft policy measures	Statistics Norway	6.5	4.5
IV.3 Environmentally friendly transportation	Dep. of economics	3.2	3.2
IV.9 Effects of energy use of changes in buildings regulations	Statistics Norway	0	0
IV.11 Which policy instrument induces the best environmental performance in firms?	Statistics Norway	3.0	2.0
IV.12 Are there secondary benefits of CO2 regulations?	Statistics Norway	3.0	2.0

WP5: The Next Generation of Numerical Models

To analyze policies that stimulate innovation and diffusion of new environmentally friendly technologies, integrated economy-energy-environment models are necessary tools. In 2013 we have developed and updated our energy market model LIBEMOD, and this work will be completed in 2014. Next year the work will concentrate on using this new model version for different policy analyses.

In 2013 we have also continued our work with establishing and building a new family of integrated macroeconomic Computable General Equilibrium (CGE) models; the SNoW-models (Statistics Norway World models). In 2014 we will continue our development and sophistication of this family of models and use them for long-term emission projections and policy analyses.

We will continue our work on all the main topics in WP5 as described in the project application from 2011, see Table 9 for detailed plans. Most of the policy analyses based on numerical model simulations are mentioned under WP1, WP2 and WP3; these activities are listed in Table 9. Below we concentrate on projects that are not part of other WPs.

LIBEMOD

In 2013 we have continued to update and extend the LIBEMOD model; the model base year is changed from 2000 to 2009, and more countries, energy goods and energy technologies have been included. Research assistant Hilde Hallre (Frisch Centre) together with Finn Roar Aune (Statistics Norway) have completed the data work and the programming of the model is almost finished (but has been delayed). The new model version will be documented in a report. Once the new model version is operative, we will continue the project with SINTEF Energy to identify the extent to which output from LIBEMOD and SINTEF's Samkjøringsmodell (Europe version) differ when input data are harmonized as much as possible. We will also use the two models to examine an environmental policy issue. This project will be completed in 2014. Finally, in 2013 we obtained funding to develop the stochastic version of LIBEMOD under ENERGIX – extensions and applications of this model will take place over the next three years.

SNoW models

In 2013 we have continued to develop our new family of integrated macroeconomic Computable CGE models for energy and environmental policy analyses; the SNoW-models (Statistics Norway World models). SNoW_No is our new CGE model for Norway. A static version of this model (42 industries) based on the GTAP database structure (a global database on trade, environmental and energy) was established in 2013 and the model was programmed in GAMS. The database for SNoW_No builds on the National accounts, and also the Energy and the Environmental statistics, all from Statistics Norway. We have extended the GTAP

database by including Norwegian process emissions of CO2. The model has been tested by simulating a carbon cost curve for Norway for different unilateral carbon emissions reductions.

In 2014 we will extend the model to incorporate dynamic investment and consumer behavior, and we will continue improving the model structure, especially by modeling new abatement technologies, including more efficient energy technologies. In 2014 we also plan to extend the SNoW-family of models by linking the SNoW_No model to the global model system. In this project we are cooperating extensively with Christoph Böhringer (University of Oldenburg), who is part-time funded by CREE.

Policy analyses

In 2013 we finalized a study on the impact of policies, like direct investment support, that aim to spur diffusion of climate technologies. This study uses the MSG-TECH model, which is a detailed CGE model for Norway that contains different abatement technologies across industries. In 2014 we will finalize a study on diffusion of climate technologies in a small open economy. This study applies the ITC-model, which is an empirical growth model with endogenous technological change. Both studies are financed by the (finalized) Renergi program; see Table 9 for details.

In 2014 we will use the dynamic version of the SNoW_No model to analyze environmental and economic efficiency effects of policies that aim at improving energy efficiency. This is part of the EU project ENTRACTE. Here we model energy efficiency measures and technology costs based on a report by IFE on long-run scenarios for energy efficiency investment costs in buildings. This continues our cooperation with IFE on energy efficiency in buildings.

Model Forum

In 2013 we organized two model forums. In the first one (April 2013) CREE presented the new versions of LIBEMOD and SNoW_No. The other model forum (October 2013) was arranged jointly with CenSes. Both CREE and CenSes presented their models and model analyses. We plan to have the next CREE model forum in April 2014.

Table 9 describes our plans for the coming years, while Table 10 describes the amount of resources that will be spent on each project in 2014 and how they are financed.

Table 6: Time schedule for subprojects under WP5, 2014 – 2015

Topic	*2014*	*2015*	*Institution*
LIBEMOD - development			
Finalizing the upgrading of LIBEMOD	X		Frisch and SSB
Stochastic version of LIBEMOD (ENERGIX)	X	X	Frisch
LIBEMOD – applications			
Promotion of CCS in power generation (WP2)	X		Frisch and SSB
Phasing out nuclear power in Europe (WP3)	X		Frisch
Comparative model project with harmonized data	X		Frisch, SSB and SINTEF
Applications of stochastic version of LIBEMOD (ENERGIX)	X	X	Frisch and SSB
CGE-development			
Improving data/modeling of SNoW_No	X	X	SSB
Dynamic investment and consumer behavior	X		SSB
Modeling energy efficiency measures	X		SSB
Testing the model	X	X	SSB
Incorporating new parameters from quant. studies (WP4)	X	X	SSB
Linking the SNoW_No to the global SNoW family	X	X	SSB
CGE- applications			
National and international climate policies; welfare and carbon leakage effects, SNoW-model (WP1)	X	X	SSB
Energy efficiency policies in SNoW_No	X	X	SSB
Innovation and diffusion processes and policies for new energy- and climate technologies (MSG-TECH/ITC) (WP2)	X	X	SSB
Model Forum			
Meeting point for development of integrated environmental- and economy models with a rich presentation of energy- and environmental technologies	X	X	Frisch, SSB, Frisch, SSB
Presentation of empirical model analyses of energy- and environmental policies	X	X	Frisch, SSB

Table 7: Planned work months, WP5

Activity	Primary institution	Planned work months	Cree funded work months
Administration		1.0	1.0
LIBEMOD – development and applications			
	Frisch Centre	11.2	1.2
	Statistics Norway	10.0	1.0
	SINTEF	4.4	4.4
SNoW – development and applications	Statistics Norway	13.5	3.8
	IFE	0.9	0.9

Total funding

Table 8 summarizes the total funding for all 5 working packages in 2014. We also include the numbers from the Work Plan for 2012 and 2013. Note that these are budget numbers and do not reflect the exact accounts for these years. One main difference between 2012/13 and 2014 is related to our post. doc; from 2014 all his activities are allocated to work package 3. Table 9 shows costs of the working packages by institution in 2012, 2013 and 2014.

Table 8: Cost plan funding in 2012- 2014 by working package (1000 NOK)

Budget	2012	2013	2014
Frisch hosting			
Administration	1 321	1 257	1 133
Conferences	300	300	215
Scholarship for students	60		40
MILEN's research school	100	100	0
WP1	2601	2821	1 894
WP2	1270	1025	1 044
WP3	881	1047	1 449
WP4	1221	1489	1 697
WP5	1911	1982	2 108
	9 665	**10 021**	**9 580**

Table 9: Cost plan for 2012 – 2014 distributed to institutions (1000 NOK)

Budsjett	2012	2013	2014
Frisch hosting			
Administration	1 314	1 257	1 133
Conferences	300	300	215
Scholarship for students	60	40	40
MILEN's research school	100	100	
Frisch research partner	3 403	3 042	2 797
SSB	1 641	1 538	1 570
ØI	1 398	1 723	1 795
TSC	250	250	250
Subcontractors	1 200	1 770	1 780
	9 665	**10 021**	**9 580**

The external funding of CREE is shown in Table 9 by institution and year (2012-2014). The table provides information about type of funding, which is typically either a project funded by the Norwegian Research Council or own funding. Applications to be determined in 2014, for example, to the Klimaforsk program, are *not* included; CREE is part of 10 applications submitted to this program. CREE has also applied to three Joint Program Initiative (JPI).

Table 9: Own funding (1000 NOK)

Program	Source	Institution	2012	2013	2014
Uncertainties in the European Energy Market: Modelling Approaches and policy issues	NFR	Frisch		520	2 535
PETROSAM: Petroleum industry research in economics and economic management	NFR	Frisch	1 509		
Export of Natural Gas from Russia	NFR	Frisch	317	152	
SAMFUNN: Norms, green agents and environmental policy	NFR	Frisch	500	250	
Managing Thresholds and Uncertainty in Resource Economics	NFR	Frisch	1 664	1 435	10
Intergenerational and intragenerational equity in climate policy	NFR	Frisch	1 348	1 308	335
Improving international cooperation on emission abatement	NFR	Frisch	1 826		
Managing Risk in Climate Change - A Dynamic Perspective	NFR	Frisch	1 864		
Stimuleringsmidler til EU-prosjektet ENTRACTE	NFR	Frisch	38	382	304
Forskningskampanjen 2012 – CREE	NFR	Frisch		90	
Intergovernmental Panel on Climate Change	KLIF	Frisch	150	27	
ENTRACTE: EU-midler	EU/Inter.	Frisch/SSB	147	1 118	1 414
PETROSAM: Petroleum markets	NFR	SSB	800		
RENERGI: Diffusion of climate technologies	NFR	SSB	2 500	1 100	
RENERGI: Household response to multiple environmental policy instruments	NFR	SSB	1 200	1 000	
Frie midler: Sustainable biofuels	NFR	SSB	1 300		
MSG-Contract	Ministry of Finance	SSB	400	400	400
Own funding		SSB	400	700	700
Nordic funding	Inter.	SSB		750	750
Own funding		ØI	1 000	1 000	1 000
Own funding	Inter.	Tilburg	250	250	250
Total			**17 212**	**10 481**	**7 689**

As indicated by the line "total" in Table 9, the external funding of CREE by far exceeds the requirement of 25 percent. For 2014, the total budget of CREE is NOK 17.269.000.

Other activities

Like previous years, in 2014 CREE will organize a user conference (joint with CICEP), a model forum and a research work shop, as well as meetings/events with the CREE users.