



**Oslo Centre for Research on Environmentally friendly Energy**

# Annual Report 2014



## **Executive Summary**

CREE – Oslo Centre for Research on Environmentally friendly Energy was established in 2011 as a social science based energy research centre funded by the Research Council of Norway (FME Samfunn) with an annual grant of NOK 8 million for 5 years, with a possible 3 years extension. The centre started its activities in August 2011. The midterm evaluation takes place the spring 2015, and the decision whether the centre will get funding for the period 2016-2019 will be made before summer 2015.

The main focus is on economic research as the research partners include the Frisch Centre, Department of Economics (ØI) at the University of Oslo (UoO), the Research department at Statistics Norway (SSB), and Tilburg Sustainability Center, the Netherlands. Cooperation with Centre for Development and Environment (UoO), Faculty of Law (UoO), SINTEF Energy Research and Institute for Energy Technology broadens the research perspective. 2014 was the last year of the subcontractor contract with SINTEF. The user perspective is ensured by several partners from industry and government.

The main aim of the centre is to collect and develop knowledge on the effects of regulatory conditions in the energy market and how these affect technological improvements such as innovation in and diffusion of technology for renewable energy, energy efficiency and carbon capture and storage. The centre provides a basis for better regulatory strategies and for policy instruments designed to reach energy and climate goals established nationally and internationally. CREE will also strive to develop methodological frameworks appropriate for achieving these goals.

Our portfolio is divided into five working packages that cover international climate and energy policy, innovation and diffusion, markets and regulation, evaluation of policy measures, and development of numerical models.

2014 has been the third full year of CREE activities. The activities have been concentrated on the research in the different working packages, the annual research workshop, CREE seminars, model forums and several user activities including the annual user conference. In 2014 we published 28 papers in international peer reviewed journals, 6 articles in books, 20 working papers and 7 popular science articles. The CREE scientists have held about 80 conference and

seminar presentations in 2014, and they have been mentioned numerous times in the media. While the number of published papers in international peer reviewed journals has increased significantly from 2013, the numbers of working papers, popular science articles and presentations have gone down. This reflects the funding situation at CREE, where we have been less successful in our research proposals the last few years, and more time is spent on writing proposals. Thus, CREE researchers need to get involved in other topics where the funding situation is better, and less time is devoted to research in environmental and energy economics. However, this also reflects that the quality of our research has increased measured in the quality of the journals that we publish in. A higher quality publication requires more time.



## **1 CREE**

There is increasing evidence that the global climate is changing, and that this change is mainly due to human activities. As has been stressed by the latest IPCC assessment report published in 2014, climate change can have a substantial impact on the economy, ecosystems and human welfare, and may have catastrophic impacts for parts of the world. Thus, there is a need to reduce greenhouse gas emissions as well as to adapt to inevitable changes. Technology improvements are widely held to be essential if we are to achieve the required emission cuts and to transform our economy to a carbon free society at the end of this century.

However, there are several challenges beyond the purely technological. The research and development effort, as well as diffusion and utilization of new, environmentally friendly energy sources, require appropriate incentives. Another important challenge is to design climate and energy treaties that will help achieving a better social outcome. In this respect effective policy instruments and fair outcomes are important. The aim of CREE, Oslo Centre for Research on Environmentally friendly Energy, is to provide a solid base for policy making on these questions. CREE will also contribute to the collection and establishment of

knowledge on how different regulations affect both the energy market and technological development. The centre studies policy instruments designed to reach the goals established in national and international energy and climate policy, while also examining how international treaties could be designed differently to better achieve broad participation and deep abatement.

The research of the centre is primarily grounded in economics, as reflected by the main research partners: Department of Economics at the University of Oslo, the Research Department at Statistics Norway, the Frisch Centre and the Tilburg Sustainability Centre. In addition, in 2014 the centre has drawn on other disciplinary perspectives through cooperation with researchers from other disciplines within the social sciences, law and technology.

The centre has the following vision which is stated in our Strategic Plan for 2011-14:

- We want to be a leading international research centre within energy, environmental and resource economics.
- We will generate knowledge that can contribute to a cost-effective and sustainable exploitation of Norwegian and international energy resources by industry and governments, as well as an effective and fair climate and energy policy, both nationally and internationally.
- We will contribute to recruitment and training at the master, doctoral and post doctoral levels in energy and environmental economics at the University of Oslo. Recruiting women to research will have a particular focus.

This report summarizes the activities and the achievements of the centre in 2014.

## **2 Research plan and strategy**

CREE organizes its research into five different working packages:

### ***Working Package I: The International Politics of Climate and Energy***

***(Research Directors: Michael Hoel, Department of Economics, University of Oslo, and Mads Greaker, Statistics Norway)***

The research questions in this working package focus on the following issues:

- Improving the current climate regime – increase incentives to join and comply

- Alternative treaty forms – sector based treaties; research and development (R&D) treaties
- Dealing with non-signatories – preventing carbon leakage
- Equity issues – intergenerational vs. intragenerational
- Implications of the above for energy market policies

***Working Package II: Innovation and Diffusion policy***

***(Research Director: Rolf Golombek, Frisch Centre)***

Important research questions in this working package are:

- What is the optimal mix of policy instruments to achieve innovation of environmentally friendly technologies?
- What is the optimal R&D policy for a small country with limited demand for carbon capture and storage (CCS), but with good technological competence?
- What types of market failures may arise in the application and diffusion of environmentally friendly technologies and how can we overcome them?

***Working Package III: Regulation and Market***

***(Research Director: Nils-Henrik M. von der Fehr, Department of Economics, University of Oslo)***

This research package focuses mainly on the electricity markets:

- Is there a contradiction between the policy to develop more green energy and regulations that will provide more efficiency in the energy market?
- Which policies can provide a sustainable use of energy?
- What is a reasonable level of energy security and how can we ensure that it is achieved?

***Working Package IV: Evaluation of Environmental and Energy Policy Measures***

***(Research Director: Bente Halvorsen, Statistics Norway)***

This is an empirical part of the project and studies the success of environmental and energy policy measures so far. Important questions are:

- What amount of energy savings is eaten up by increased consumption (rebound-effect)
- Can regulation of a good have unintended effects on close substitutes?
- What are the effects of soft policy measures?

- Focus on transportation: Does CO<sub>2</sub> taxation lead to higher demand for energy efficient vehicles? How does the increase in cars that run on biofuels and electricity affect emissions from road traffic?

### ***Working Package V: The Next Generation of Numerical Models***

***(Research Director: Brita Bye, Statistics Norway)***

This working package focuses on developing our numerical models by updating the data, improving the modeling of new technologies, and making innovation processes endogenous. The models will be used to study research questions in the other working packages. We use and develop

- The energy market model LIBEMOD
- Computable general equilibrium (CGE) models at Statistics Norway; the MSG-TECH model, the ITC (Induced Technological Change) model, and the SNoW-models (Statistics Norway World models).
- The new petroleum market model PETRO2

Our strategy is to follow the plans put down in the annual research plans, see

<http://www.cree.uio.no/projects.html>. The research will benefit from close contact with subcontractors and user partners. For the vision and strategy of the total CREE activity, see the CREE strategy plan

[http://www.cree.uio.no/adm/Strategi\\_Komunikasjon/CREE%20strategic%20plan%20March%202013.pdf](http://www.cree.uio.no/adm/Strategi_Komunikasjon/CREE%20strategic%20plan%20March%202013.pdf), which was finalized in 2013. A new plan for 2015-19 is being prepared.

## **3 Centre organization**

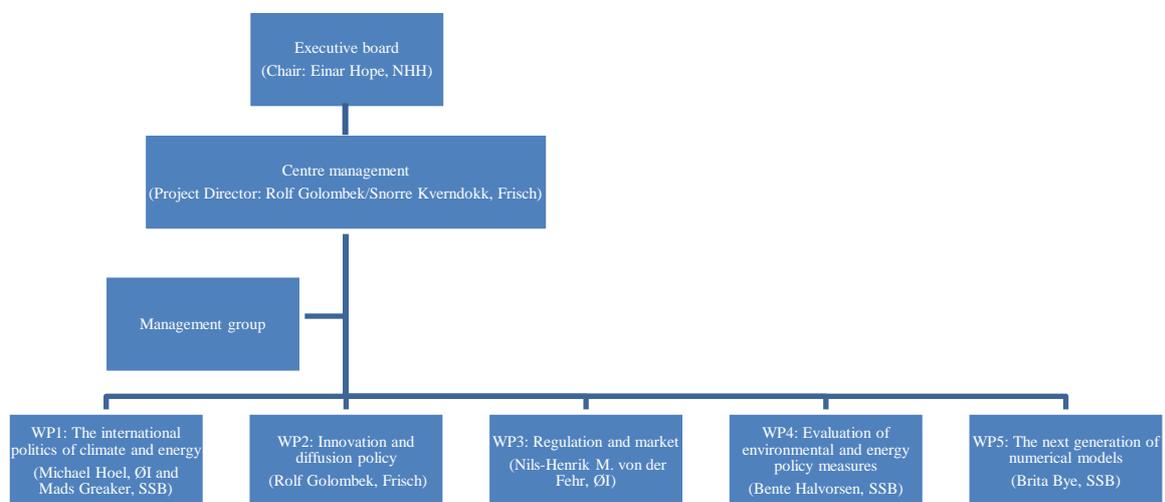
The organization of the centre in 2014 was as shown in the figure below.

The chair of the executive board (Einar Hope, The Norwegian School of Economics - NHH) does not represent any of the research partners, user partners or sub-contractors, and is therefore independent of the partners in CREE. The board also consists of one member from each of the three Norwegian research partners (Oddbjørn Raaum, Frisch; Taran Fæhn, SSB; Karine Nyborg, ØI), while the user partners are represented by two members, one from industry (Tor Kartevold, Statoil) and one from Government (Guro Børnes Ringlund, The

Norwegian Environment Agency). The board had three meetings in 2014, see [http://www.cree.uio.no/board\\_meetings.html](http://www.cree.uio.no/board_meetings.html).

The administration of CREE is located at the Frisch Centre. Dr. Rolf Golombek served as the temporarily Centre Director from 1 January to 31 March. In the remaining part of 2014, Dr. Snorre Kverndokk was the Project Director. Jørg Gjestvang was the Centre Manager.

The administration has regular meetings with the management group consisting of all the working package leaders to discuss matters of importance for the centre.



The partners of CREE are divided into research partners and user partners. The research partners are:

Ragnar Frisch Centre for Economic Research (Frisch Centre), Oslo (host institution)  
Research department, Statistics Norway, Oslo  
Department of economics, University of Oslo  
Tilburg Sustainability Center, Netherlands

CREE has seven user partners:

Gassnova SF  
Norwegian Environment Agency  
Norwegian Ministry for Petroleum and Energy  
Norwegian Water Resources and Energy Directorate  
Statkraft Energy AS  
Statnett SF  
Statoil ASA

The user partners of the centre contribute with funding and with members on the board, but also to the research with detailed knowledge about markets, technologies and politics.

Like in earlier years, we have a CREE luncheon about every second month that brings together the CREE network and contributes to unify the Norwegian CREE research institutions.

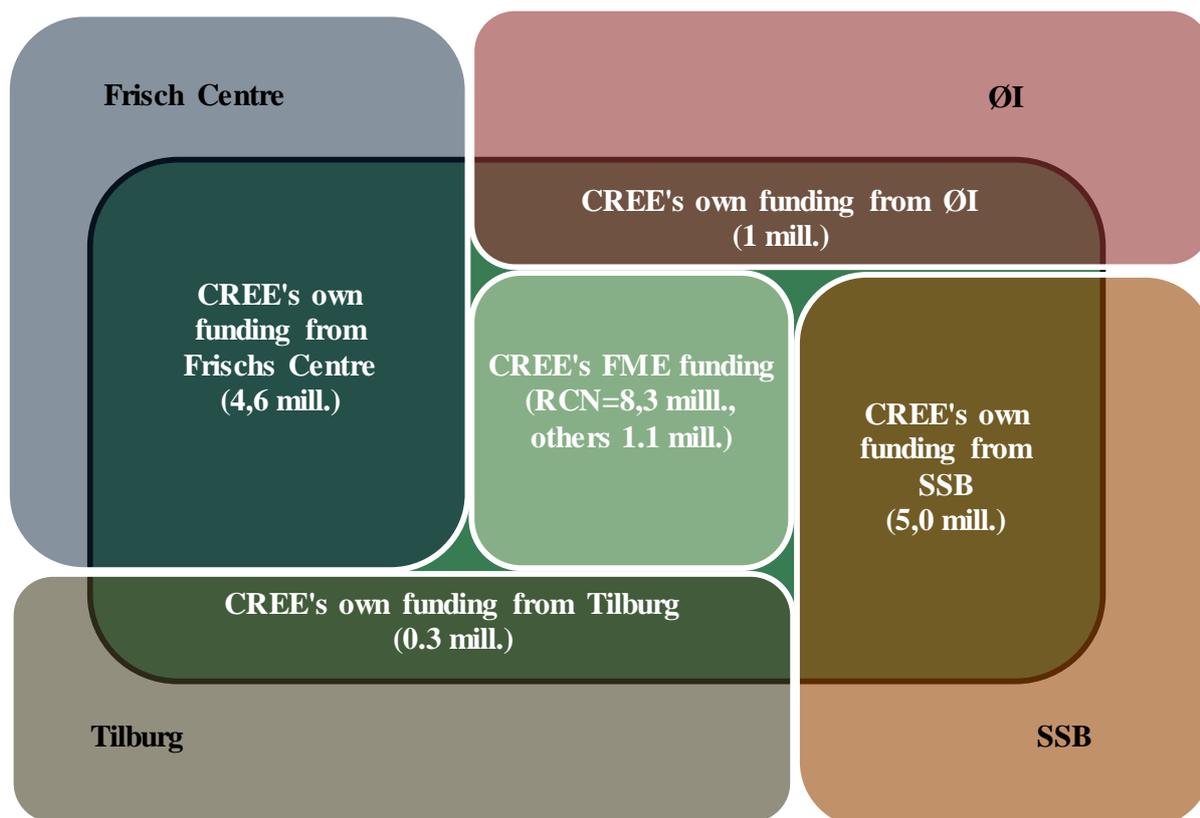
## **4 Funding**

The funding of CREE in 2014 comes from various sources. The centre has an annual contribution from the Research Council of Norway (RCN) of NOK 8 millions, user partner funding of NOK 600.000, and funding from the University of Oslo (UoO) of NOK 500.000. In addition, the centre has secured its own funding through other programs under RCN and international research programs. The figure below gives an overview of the total funding in 2014. Note that in the figure, the funding from RCN is NOK 8,3 million, which is more than the annual grant. The reason is that some of the money is transferred from 2013. For more

detailed information, see Appendix A2, which also shows the distribution of costs by CREE research partners and other units affiliated to the centre. Note that costs cover activities directly funded by RCN as well as activities financed by own funding, for example, funding through other research council programs.

### CREE funding in 2014

Total CREE centre funding incl. own funding. (20,2 mill.)



Own funding = professional work that is beneficial to the CREE centre, but is not part of CREE's direct funding from The Research Council of Norway. Own funding should be at least 25% of the total budget of CREE.

#### FUNDINGS

The Research Council of Norway	8,3
Others	1,1
<i>Public funding (UoO)</i>	0,5
<i>Privat funding (User partners)</i>	0,6
Own funding	10,9
<i>Frisch</i>	4,6
<i>SSB</i>	5,0
<i>ØI</i>	1,0
<i>Tilburg</i>	0,3
<b>Sum total funding</b>	<b>20,2</b>

## 5 Professional activities and results

The professional activities in 2014 have been concentrated on the research in the different working packages described above, the research workshop, CREE seminars, a common workshop with the other FME-S centres and several user activities including the user conference.

The CREE workshop took place in Oslo (Lysebu hotel) on 22-23 September. About 35 people attended the workshop, mainly researchers from the research partners and sub-contractors in CREE, but also from our international network. Presentations covered research from all our work packages, and on subjects related to the work packages. The program is available at [http://www.cree.uio.no/Workshop\\_Sem\\_Conf/4th\\_research\\_workshop.html](http://www.cree.uio.no/Workshop_Sem_Conf/4th_research_workshop.html).

A joint workshop was organized for all the FME-S centres (CREE, CICEP and CenSES). The workshop was held in Trondheim in November and the topic was uncertainty and investment risk in the energy sector.

The CREE seminar series included 17 seminars in 2014, among them 5 international visitors. The seminars were given at Statistics Norway, Frisch Centre and University of Oslo. For a list of all seminars, see [http://www.cree.uio.no/seminars\\_earlier\\_years.html](http://www.cree.uio.no/seminars_earlier_years.html).

We did not hold any model forum meetings in 2014 as we had to forums in 2013, and because the work package leader of WP 5 who is responsible for the model forums were abroad in the fall 2014. However, a new model forum is planned for 2015.

The user conference was held in April and was co-organized with CICEP, another social since FME centre. The conference was in Norwegian and the topic was the EU climate and energy policy towards 2030. About 50 people attended the conference. For more information about the conference, see [http://www.cree.uio.no/Workshop\\_Sem\\_Conf/Bruerkonferanse\\_CREE\\_CICEP\\_240414.html](http://www.cree.uio.no/Workshop_Sem_Conf/Bruerkonferanse_CREE_CICEP_240414.html). CREE also organized a half-day seminar with all its user partners; see [http://www.cree.uio.no/Workshop\\_Sem\\_Conf/minibrukerseminar\\_141110.html](http://www.cree.uio.no/Workshop_Sem_Conf/minibrukerseminar_141110.html), as well as seminars for the Ministry of the Environment and the Norwegian Environment Agency.

When it comes to publications, we had 28 papers published in international peer reviewed journals, see the Publications table below and Appendix A3. We have also published 6 articles in books and produced 20 CREE working papers. Further, we have published 7 popular science articles and 2 other publications. The CREE scientists have also held about 80 conference and seminar presentations. They have also been mentioned at least 23 times in the media.

As seen from the table, the number of published papers in international peer reviewed journals has increased significantly from 2013, while the numbers of working papers, popular science articles and presentations have gone down. This reflects the funding situation at CREE, where we have been less successful in our research proposals the last few years, and more time is spent on writing proposals. Thus, CREE researchers need to get involved in other topics where the funding situation is better, and less time is devoted to research in environmental and energy economics. However, this also reflects that the quality of our research has increased measured in the quality of the journals that we publish in. A higher quality publication requires more time.

#### **Publications 2011-2014**

	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>
Journal papers:	8	16	21	28
Books and article in books:		2	7	6
Working Papers:	9	21	30	20
Popular scientific articles:	4	10	12	7
Other publications:		5	3	2
Conference and seminar presentations:		100	100	74
CREE in the media:	9	41	31	23

For more information about the publications, see <http://www.cree.uio.no/publications.html>

Below we give an overview of the research in the five different research packages in 2014.



## **5.1 The International Politics of Climate and Energy (WP I)**

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

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”.

We are also concerned about how climate policies both directly and indirectly through for instance technical change affect global energy markets.

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

### **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 fewer 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 project started in 2013, but most of the work has been done in 2014. A first draft is written and is presented at several workshops and seminars. This will be finalized, published as a CREE Working Paper and submitted to a journal in 2015.

We have applied KLIMAFORSK for a continuation of this project, but did not get funding.

*Project leader: Snorre Kverndokk, Frisch*

## **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 that are traded internationally 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, the model was refined and a draft of a working paper was produced. In 2015, the working paper will be finalized. This is a joint project between the Frisch Centre and the University of California at Berkeley.

*Project leader: Rolf Golombek, Frisch*

## **I.3 Climate treaties with reciprocal preferences**

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

A reciprocal person is not generally kind. Rather, reciprocity is about anger and gratitude, retaliation and reward. Although reciprocity may help secure cooperation, it can also be very destructive.

The present project develops a simplified theoretical analysis of participation in international environmental agreements if countries behave as if they have reciprocal preferences. It is shown that when few others are expected to abate, reciprocal countries are even less willing to abate than countries with standard preferences.

However, if all countries have strong preferences for reciprocity, the grand coalition of all countries can be stable as well. The reason is that others' abatement increases the individual country's motivation to contribute. Moreover, if not all countries are reciprocal, a large (but less than full) coalition can be stable if the share of reciprocal countries is strictly more than half, and if these countries are sufficiently strongly reciprocal.

In addition, a stable minority coalition can exist which is larger than the maximum coalition size with standard preferences. In this situation, each coalition member is disappointed with others' behavior and is willing to sacrifice own material welfare to punish them. In spite of this, the minority coalition is stable, for the following reason: Each coalition member knows that if it leaves, the coalition will dissolve. It will then choose to stay, because this is the only way it can keep a small island of kindness in a world of meanness; if it leaves, the world becomes universally mean.

In 2014, a discussion paper has been published:

*Nyborg, K.: Reciprocal Climate Negotiators: Balancing Anger against Even More Anger, Memorandum, 17/2014, Department of Economics, University of Oslo.*

In 2015 the paper will be revised to include a more systematic discussion of results in light of empirical findings from behavioral and experimental economics, possibly also an extension of the formal results to include the case of heterogeneous country size.

*Project leader: Karine Nyborg, ØI*

#### **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 weakened 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 paper has been accepted for publication:

*Battaglini, M. and B. Harstad: Participation and duration of environmental agreements, forthcoming in Journal of Political Economy.*

*Project leader: Bård Harstad, ØI*

## **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.

In 2014 the project finalized a discussion paper:

*Böhringer, C., B. Bye, T. Fæhn and K. E. Rosendahl: Output-based rebating of carbon taxes in the neighbor's backyard - Competitiveness, leakage and welfare, CREE WP 06/2014.*

In 2014/2015 the carbon leakage project work with another paper that concerns possibilities, limitations, and implications of various border carbon adjustment (BCA) systems designed particularly for targeting the emission intensities of foreign producers. Succeeding to design and implement such systems would improve the efficiency and effectiveness of BCAs. The final working paper will be submitted to an international journal by March 2015. This project is part of the ENTRACTE-project and the WILL project financed by the RCN through its Klimaforsk program. The results will also be included in a synthesis report from the ENTRACTE project, together with ZEW (Mannheim) by May 2015. See also WP5 for more information on this.

*Project leader: Brita Bye, SSB*

## **I.6 Inequality aversion and trade**

Widespread skepticism towards tradable 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.

A lesson often drawn in the experimental economics literature is that social preferences like inequity aversion are not triggered in market settings. Our experiment tests whether people willingly “leave money on the table” rather than trade at inequality increasing terms. The results indicate that, in a simple two-person trade game with fixed prices, a significant amount of trade is withheld when it creates strong inequality, in spite of trade being Pareto-improving in monetary outcomes. This behavior is consistent over 10 rounds of experience for the favored and disfavored player compared with the neutral treatment when no inequality is created by trading resources. We conclude that fairness concerns may affect outcomes in a fixed price trade setting, even when there are no strategic or retaliation motives present for restricting trade.

This project is part of Alice Ciccone’s PhD project and will be finalized in 2015.

*Project leader: Ole Røgeberg, Frisch*

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

An alternative hypothesis to the one explored in I.6 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.

A paper by Kjell Arne Brekke, Ragnhild Bråten and Ole Røgeberg will be published as a CREE WP and is now to consideration in a journal.

*Project leader: Kjell Arne Brekke, ØI*

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

Bargaining is central to many economic applications and certainly a key to an international climate agreement. To better understand bargaining, Alice Ciccone and Kjell Arne Brekke at UiO/CREE together with Leif Helland and Tom-Reiel Heggedal at BI have conducted a series of experiment. The experiments are designed to test the effect of earning either an outside option or earning a share of the pie, prior to alternating offer bargaining. We have solved for the subgame perfect equilibrium with loss-aversion preferences and the model prediction is that earning an outside option should not matter, unless the option is binding, while subjects who earned a larger share of the pie should also end up with a larger share. This latter prediction is contrary to most other models of bargaining, but supported by the experimental results. We are in the process of collecting more data and testing our model rigorously

This is part of Alice Ciccone’s PhD project and will be finalized in 2015.

*Project leader: Kjell Arne Brekke, ØI*

### **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.

This project finished in 2014 and is now published as:

*Kverndokk, S. and C. Hagem (2014): «Klimaendringer» (Climate change), chapter 8 in O. Flåten and A. Skonhoft (eds.): Naturressursenes økonomi (Natural resource economics), Gyldenda Akademisk.*

*Project leader: Snorre Kverndokk, Frisch*



## 5.2 Innovation and diffusion (WP II)

Atmospheric greenhouse gas stabilization targets as low as 450 ppm CO<sub>2</sub> 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.

### **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 rationale 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.

This paper will be published in 2015 in a book on climate and technology policy, funded by the World Bank. A working paper will be published parallel with the book chapter.

*Project leader: Mads Greger, SSB*

### **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 working paper has been published:

*Fischer, C., M. Greaker and K. E. Rosendahl: Robust Policies against Emission Leakage: The Case for Upstream Subsidies, CESifo Working Paper No. 4742.*

This paper has also been submitted to an international journal in 2014. The work in 2015 will be to follow up review comments.

*Project leader: Mads Greaker, SSB*

### **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 subsidies to EU producers are preferable, though in some cases these should be combined with downstream subsidies.

In 2014 a robustness analysis of the numerical part of the paper was undertaken. Here we focus on the importance of i) number of suppliers within the EU and outside the EU, ii) the importance of whether CCS suppliers offer two technologies – CCS coal and CCS gas – or only one type of CCS technology, and iii) the range of variation in upstream and downstream subsidies. A draft paper has been written and will be published in the WP series. It will also be submitted to an international journal in 2015.

*Project leader: Rolf Golombek, Frisch*

#### **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 2015 a draft paper will be written that covers topics described above.

*Project leader: Michael Hoel, ØI*

## **II.5 Optimal timing of clean energy policies**

Should technology subsidies be used as a climate policy instrument in addition to imposing a price on GHG emissions, or is pricing of GHG emissions sufficient in order to obtain a socially desirable outcome? If also technology subsidies should be offered, how should the path of subsidies be designed? A paper that examines these questions within a theoretical model where abatement requires use of environmentally friendly technologies and R&D makes these technologies more productive were published in JEEM in 2014.

*Gerlagh, R., S. Kverndokk and K. E. Rosendahl (2014): «The Optimal Time Path of Clean Energy R&D Policy When Patents Have Finite Lifetime», Journal of Environmental Economics and Management, 67(1): 2-19.*

*Project leader: Reyer Gerlagh, Tilburg*

## **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 insulation 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, researchers at the Tilburg Sustainability Centre (TSC) 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 the government is naïve as it mistakenly assumes that it can control future governments. In a refinement, a recursive Integrated Assessment Model is specified. This model can be used to study innovations as a commitment device for climate policy by deriving the Markov equilibrium, that is, the current government correctly anticipates the response of the future governments. In 2014, the main task has been to calibrate and test the model.

In 2015 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. This model will also be used in an EU project (Entracte) where both TSC and CREE participate.

*Project leader: Reyer Gerlagh, Tilburg*

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

This project provides new evidence on the role of direct (“command-and-control”) regulations in relation to innovations in environmental technologies. While pricing is generally considered the first-best policy instrument, direct regulations, such as technology standards and non-tradable emission quotas, are common when a regulator faces multiple emission types and targets, heterogeneous recipients, or uncertainty with regard to marginal damages. 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 Norwegian incorporated firms, we are able to conduct a comprehensive study of the effect of direct 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 in our analysis. 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.

An earlier version of this paper is published as:

*Klemetsen, M. E., B. Bye and A. Raknerud: Can non-market regulations spur innovations in environmental technologies? A study on firm level patenting, CREE WP 16/2013.*

A revise-and-resubmit based on the earlier version of this paper has been submitted to Scandinavian Journal of Economics.

This project is part of Marit Klemetsen’s PhD project at SSB.

*Project leader: Brita Bye, SSB*

## **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 was published as a chapter in a book in 2014.

*Hoel, M. and de Zeeuw, A. (2014): Technology Agreements with Heterogeneous Countries, in Todd L. Cherry, Jon Hovi and David McEvoy (editors): Toward a New Climate Agreement: Conflict, Resolution and Governance. Routledge.*

As indicated in the 2013 CREE work plan, the level of activity will depend on whether this subproject obtains external funding. So far no funding has been available. Potential future activity will be related to research questions like: 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?

*Project leader: Michael Hoel, ØI*

## **II.9 Obstacles to dissipation of environmentally friendly technology**

In 2014 the literature survey, within the fields of behavioral and experimental economics, on energy efficiency investment was published in *Samfunnsøkonomen*:

*Hauge, K. E. (2014): Når Viljar, Egil og Rasmus skal investere i energibesparende teknologi. Samfunnsøkonomen, Nr 1/2014.*

The starting point of the review is the so-called energy paradox: several studies claim that it is possible to save between 10 and 25% of our total energy consumption through profitable investment. This claim is discussed within the framework of behavioral economics.

*Project leader: Karen Hauge, Frisch*

## **II.10 Innovation policies, patenting and technological quality**

Note that this project is changes from what was reported last year, and so is the title of the project.

The contribution of this paper is to examine the magnitude of the effect of the Norwegian R&D tax credit program, known as SkatteFUNN, on firm patenting as well as on patent quality measured using patent citations. We are also interested in investigating whether the R&D tax credit is sufficient in order to reduce the externalities and create incentives for patenting of environmental technologies. Concerns have been raised that R&D support must be specifically targeted towards clean technology development as innovations in clean technologies are exposed to more externalities than innovation in general. Innovation in general faces knowledge externalities from R&D, whereas environmental innovation in addition faces the environmental externality exerted by dirty input producers. Acemoglu (2012) thus finds that an optimal policy involves directing R&D towards clean technologies. We investigate whether the R&D tax credit scheme – which is generic in the sense that it offers the same R&D support for any type of technology (clean, dirty or other) – thus has the same effect on environmental and non-environmental technology patenting. We will also investigate the effects of R&D support specifically targeted towards environmental technology development. Through this study we seek to contribute to the policy discussion on the effectiveness of the various R&D support alternatives. We have access to a detailed Norwegian firm level patent data set including both domestic and foreign patent citations where we identify the patenting firms through official organizational numbers, allowing a better match with other important firm level data. We are thus able to control for firm size, the education level of each firm's employees, capital intensity, economic performance, industry affiliation, and more.

This project is part of Marit Klemetsen's PhD project in SSB.

A draft paper will be written in 2015.

*Project leader: Brita Bye, SSB*

## **II.11 Should environmental R&D be prioritized?**

There are at least two reasons to support private R&D: First, the R&D process generates knowledge spillovers from which all future innovators will benefit. Second, even if the innovator succeeds to patent her new idea, she will not be able to appropriate the full social benefit of her innovation. This project focuses on the appropriability problem for supporting R&D.

The point of departure is two innovations of equal social value; one lowers the cost of producing an ordinary market good that has no particular impact on the environment, whereas the other reduces the cost of pollution abatement. In the market good case, demand for a patented technology is given from the underlying preferences of consumers or the technology of firms. Governments seldom interfere with demand for a standard market good even if society could benefit from such an intervention. In contrast, in the environmental technology case the government is bounded to interfere with demand for the new technology through its environmental policy. No research has so far investigated whether this asymmetry implies that environmental R&D should be prioritized in public R&D budgets.

In order to analyze this question we apply a game theoretic model. In the first stage of the game an innovator invests in R&D under uncertainty. If the innovator succeeds, she obtains a patent and can market her idea as a technology improvement. If the new idea is a new production process for some market good, the government does not intervene and the innovator simply maximizes profit. To the extent that the realized increase in social surplus exceeds the value of the patent, there will be too little R&D and hence R&D should ideally be subsidized.

On the other hand, if the innovation is a new pollution abatement technology the government will want to change its environmental policy since the cost of reducing emissions has become smaller. Thus, the government affects demand for the innovation, and our research question is

whether this intervention makes the discrepancy between the social value of the innovation and the private value of the patent larger than in the market goods case. A larger discrepancy implies that environmental R&D should receive a higher subsidy.

*Project leader: Mads Greaker, SSB*

## **II.12 Transitions to clean technologies**

Jointly funded by the EU Entracte project and CREE, researchers at the TSC have set up a series of lab experiments to study the effect of various instruments on the transition from a benchmark to a clean technology. The lab experiments have been carried out in 2014. An early assessment of outcomes suggest that both communication and the availability of commitment mechanisms support the transition, while a first-mover leadership is less effective as support. Framing the transition as ‘green’ increases overall support but makes subjects also less responsive to feedback from other group members.

In 2015, TSC will analyze the experiment outcomes and produce a working paper to be submitted to a journal. The research question is whether communication, commitment devices, leadership, and framing can support a transition to a clean energy system. The underlying structure of the problem is that the transition is costly, and the payoff for support by individual members is risky.

*Project leader: Reyer Gerlagh, Tilburg*

## **II.13 Effective climate policies with trade and international technology spillovers**

TSC has studied the consequences of international innovation spillovers between open economies when countries have heterogeneous environmental preferences. A key result is that the size of a coalition (both in terms of its number of researchers as well in terms of its market for demand) determines whether it is optimal to stimulate foreign clean production and innovation, or to follow a protective policy for domestic clean production and innovation. In 2014 a paper was submitted to a journal.

*Project leader: Inge van den Bijgaert, Tilburg*

## **II.14 The market potential of new clean energy technologies**

In the future, electricity supply may be dominated by carbon-friendly technologies like floating windmills, solar power and Carbon Capture and Storage (CCS) electricity technologies. Governments are currently involved in the development of these technologies, and support basic research, demonstration facilities and market diffusion. It is hard for governments to know what role these technologies might play in the future, and hence to allocate their support optimally; there are plenty of different Carbon Capture on Storage power technologies, see, for example, Golombek et al. (2011), and also a number of renewable electricity technologies (floating wind mills, thermal solar, tides, stationary batteries, etc.).

According to standard economic theory, the social value of a new technology can be approximated by the area under the demand curve that exceeds the price of the technology. If the demand curve for a new technology is flat, the social value will typically be low, and vice-versa if the demand curve is steep. In general, the social value depends on a number of factors, in particular the price of GHG emissions. LIBEMOD determines investments in the energy industry for all European countries under uncertainty, including investment in climate-friendly technologies. By running Libemod with different sets of capital investment costs for climate-friendly technologies and prices of GHG emissions, we can estimate a system of demand functions for these technologies (one system for each price of emissions), and thus identify the social value of each technology. This project is funded by ENERGIX. See also WP5 for information.

*Project leader: Mads Greaker, SSB*



### **5.3 Regulation and Market (WP III)**

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<sub>2</sub>. The work is planned mainly as theoretical and empirical studies, but will also utilize numerical models, either already existing or developed in other work packages. As such, part of the work within this package will be conducted in cooperation with or as part of Working Packages 4 and 5.

#### **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.

*Project leader, Finn Førsund, ØI*

#### **III.4 Green Certificates and Competition in Electricity Markets**

A number of studies have analyzed 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 was documented in 2013 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.

*Project leader: Nils-Henrik von der Fehr, ØI*

#### **III.5 Effects of Reduced Nuclear Capacity in Europe**

Following the Fukushima accident in 2011, some EU member states decided to phase out nuclear power. We explore the impact of an EU-wide nuclear phase out provided the proposal of the EU Commission to reduce GHG emissions by 40 percent in 2030 relative to 1990 is implemented. Using a numerical simulation model of the European energy industry (LIBEMOD), we find that a complete nuclear phase out in Europe by 2030 has a moderate impact on total production of electricity and only a tiny impact on total consumption of energy. Lower nuclear production is to a large extent replaced by more renewable electricity production, in particular wind power and bio power. More generally, the equilibrium composition of electricity technologies reflects the stringency of the climate target, which

climate instruments that are imposed and whether some technologies are being promoted, either directly through subsidies or indirectly through a tailor-made policy goal.

A draft paper suitable for submission to a journal has been written.

*Project leader: Rolf Golombek, Frisch*

### **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 2014, 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. As planned, we have during 2014 developed a suitable model and finalized a first draft of a paper (Fridrik Baldursson and Nils-Henrik von der Fehr, Natural Resources and Sovereign Expropriation). In 2015, the paper will be further developed, with the aim of publication in a scientific journal. The project will also be extended in various directions, including studies of underlying issues concerning political economy.

Another part of this subproject is undertaken by Daniel Spiro who is a Post Doc at UiO funded by CREE. He studies how resource owners will behave with a risk of losing their resource due to nationalization, how this in turn affects the incentives for governments to nationalize such resources and how world prices for resources may be affected by such interaction. The central result in this work is that nationalization in one country will be closely

linked to nationalization in other countries. The analysis shows that if one country nationalizes its resource then resource prices will rise making it worthwhile for others to nationalize too, thus raising the price further. This way the model predicts waves of nationalization in correlation with price surges. The novelty of this paper is that it would be one of the first to analyze the interaction between political processes and world prices. While the main mechanism is in place, the remaining work relate to analyzing alternative equilibria and some extensions of the model.

*Project leaders: Nils-Henrik von der Fehr, ØI/Daniel Spiro, ØI*

### **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.

This has been published as a CREE WP:

*Gars, J. and D. Spiro: Should Foresters Forecast?, CREE WP 11/2014.*

Still, some work will be done to publish this in a journal.

*Project leader: Daniel Spiro, ØI*

### **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.

This has resulted in a CREE WP in 2014:

*Førsund, F. R.: Hveding's Conjecture: On the Aggregation of a Hydroelectric Multiplant – Multireservoir System, CREE WP 17/2014.*

Still, some work will be done to publish this in a journal.

*Project leader: Finn Førsund, ØI*

### **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 harmonize market places and efficiently utilize 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.

*Project leader: Nils-Henrik von der Fehr, ØI*

### **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 organizing 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.

A preliminary analysis (Nils-Henrik von der Fehr: Market Time Unit) was developed in 2014 and presented at various conferences. In 2015, the work will be developed.

*Project leader: Nils-Henrik von der Fehr, ØI*

### **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 analyze 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 politicized. 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.

*Project leader: Daniel Spiro, ØI*

### **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 project analyses 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).

*Project leader: Daniel Spiro, ØI*

### **III.13 Systems for refunding emission payments**

We analyze two mechanism designs for refunding emission payments to polluting firms: Output Based (OB) and Expenditure Based (EB) refunding. In both instruments, emissions fees are returned to the polluting industry, typically making the policy more politically acceptable than a standard tax. The crucial difference between OB and EB is that the fees are refunded in proportion to output in the former, but in proportion to the firms' expenditure on abatement equipment in the latter. We show theoretically that to achieve a given abatement target, the fee level in the OB design exceeds the standard tax rate, whereas the fee level in the EB design is lower. Furthermore, the use of OB and EB refunding may lead to large differences in the distribution of costs across firms. Both designs imply a cost-ineffective provision of abatement as firms put relatively too much effort into reducing emissions through abatement technology compared with reducing output or improving management. However, maintaining output may be seen as a political advantage by policymakers if they seek to avoid activity reduction in the regulated sector. A first version of this paper is about to be finalized (Hagem, C. Hoel, M. Holtmark, B. and Sterner, T., Refunding emission payments), and we will soon submit it to an international journal.

*Project leader: Cathrine Hagem, SSB*



## **5.4 Evaluation of Environmental and Energy Policy Measures (WP IV)**

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.

The work on WP4 is undertaken in 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 analyse 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 analyse how the goals for a reduction in CO<sub>2</sub> 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.

In 2014, analysis of the effects of energy efficiency and soft policy measures on household energy consumption has continued both at Statistics Norway and at SUM. Some of these

studies were finished in 2014, and some will continue into 2015. The work package also includes the works on three PhD-theses (Dalen, Klemetsen and Ciccone).

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

In quantitative studies by SSB Norway, a rebound effect has been detected after households have installed a heat pump. In this paper we use an interview sample with 28 households to attempt to identify and interpret changes in practices that may have contributed to rebound in electricity consumption after a heat pump is taken into use. The results show that a comfort rebound effect (direct rebound) is at work in two specific senses. First, people expand the time period in which they heat the home (both daily and seasonally). Second, users expand the total space of the house heated after heat pumps are taken into use. We point to a general attitude among many of the respondents that these changing practices were justified because of their investments in and anticipated savings from the heat pump. Finally, the study found that people did not keep a close accounting of money saved by the heat pump nor could they associate any particular investment or purchase with the savings. This lack of accounting by the users makes it difficult to pin down indirect rebound effects. See:

*Winther, T. and H. Wilhite (2014): An analysis of the household energy rebound effect from a practice perspective: spatial and temporal dimensions, Energy Efficiency, 7(5). DOI 10.1007/s12053-014-9311-5.*

Several ongoing studies on this topic will be completed in 2015. First, researchers at Statistics Norway have analyzed the effects of heat pump ownership on household energy consumption (reported last year). This paper will be processed further for publication in an international in 2015.

In addition, economists at Statistics Norway have conducted an analysis of the main drivers for the sharp increase in the proportion of households that have acquired heat pumps in Norway. This development has occurred very rapidly and almost without public subsidies. We have not seen similar structural changes in heating technology in Norwegian homes since the transition from wood and oil to electricity in 1970 - and 80's. We study the characteristics of households that have acquired a heat pump. Preliminary results indicate that this increase is largely driven by economic conditions to reduce fuel costs, and a change in heating technology appears to have occurred in all walks of life. This paper will be finished and

submitted for international publication in 2015. The paper will also be published in CREE's working paper series.

In an interdisciplinary paper, economists and anthropologists study the perplexing case of the Norwegian heat pump ownership, a technology that theoretically should reduce household heat consumption by up to 25%, but when taken into use results in little or no change in electricity consumption. Our two coordinated studies find a major change in how households heat their residences after acquiring a heat pump. The anthropological study shows that many households increase the heated living area and no longer turn down the heat at night and when away. The economic study quantifies large effects of heat pump ownership on the consumption of all energy sources. On average, households with and without a heat pump use approximately the same amount of electricity, implying that the changes in behavior discussed in the anthropological study completely offsets the savings potential of the heat pump. However, total energy consumption is lowered and energy efficiency is increased since the consumption of firewood and fuel oils are reduced. A first draft of this paper is finished, and invited to be submitted to a special issue of *Journal of Indoor and Built Environment*. The paper will also be published in CREE's working paper series.

*Project leaders, Bente Halvorsen, SSB/Tanja Winther, SUM*

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

Anthropologists at SUM, in collaboration with economists at CICERO, have tested how households adapt to visual in-home displays of their electricity consumption. The displays were tested out in 26 homes at a housing cooperative at Røverkollen in Oslo. The study analyzed how the different members of the household reacted and interacted with the new technology, and recorded how they used it to monitor and control their consumption of electricity. The study found that many households were surprised by how much (or little) electricity different appliances used. Several of the households changed their habits based on the new information, by changing electric ovens or light bulbs. The collection of empirical material has been completed, and the work will result in two international scientific papers in 2015. A summary in Norwegian has been published on our webpage under [http://www.cree.uio.no/publications.html#Other\\_publications](http://www.cree.uio.no/publications.html#Other_publications).

*Project leader: Tanja Winther, SUM*

### **IV.3 Environmentally friendly transportation.**

As part of Alice Ciccone's PhD project funded by CREE, she analyzed 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<sub>2</sub> emissions during the fall of 2006. Thus the announcement of the new policy had an impact on CO<sub>2</sub> 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<sub>2</sub> emissions in the fall of 2006 were replaced by bigger cars with higher potential CO<sub>2</sub> emissions. Sales in 2007 did not drop. For that reason the policy implemented since January 1<sup>st</sup> 2007 had a lasting impact on CO<sub>2</sub> emissions in the fleet of new cars after this date.

This has resulted in the following publication:

*Ciccone, A.: Is it all about CO<sub>2</sub> emissions? The environmental effects of a tax reform for new vehicles in Norway, CREE WP 9/2014.*

In 2015 we will work to get this published in a journal.

Reyer Gerlagh and Inge van den Bijgaart (jointly with Hans Nijland and Thomas Michielsen,) at Tilburg Sustainability Center have studied the effects of fiscal personal vehicle policies on the CO<sub>2</sub> emissions-intensity of new bought cars in the EU. They find clear empirical evidence that CO<sub>2</sub> sensitive registration taxes and fuel taxes shift the car fleet additions to more fuel-efficiency. A manuscript will be submitted for a WP before December 2014. The plan is to extend the research on the effects of fiscal policies on new car sales in 2015, looking more closely to the response by car manufactures, in terms of their price setting. One result so far is that there is evidence that car prices excluding taxes are structurally different between countries in response to fiscal measures.

*Project leaders: Alice Ciccone, ØI/Reyer Gerlagh, Tilburg*

### **IV.5 Residential end-use electricity demand**

It is costly and difficult to meter electricity consumption for different end uses, e.g. space heating, lighting and household appliances. We deduce a model for using cross-sectional data for total annual electricity consumption for a sample of households, together with information from energy surveys, to estimate the end uses within an econometric demand model

conditional on appliance ownership. By applying a consistent method to Norwegian data for 1990, 2001 and 2006 (repeated cross-sections), we compare results over time and detect possible trends. We find that electricity consumption for many end use necessities such as washing, water heating and refrigeration varies somewhat from year to year, but they show no trend. We find a steady increase in electricity used for more untraditional end uses and newer types of appliances. Total energy consumption for heating purposes is quite stable over the time period. See:

*Dalen, H.M. and B.M. Larsen (2013): "Residential end-use electricity demand: Development over time". Discussion papers 736, Statistics Norway, forthcoming in Energy Journal.*

*Project leader, Bodil M. Larsen, SSB*

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

We study the effects of various environmental regulations on environmental performance measured as emission intensity. Moreover, we aim to test whether any such effects are persistent or only temporary. Conventional theory predicts that indirect regulations as opposed to direct regulations provide continuous dynamic incentives for emission reductions. Our unique Norwegian firm level panel data set allow us to identify effects from different types of regulations such as environmental taxes, non-tradable emission quotas and technology standards. The data includes information of different environmental regulations, all kinds of polluting emissions, and a large number of control variables for all polluting incorporated firms. Empirically we identify positive and significant effects from both direct and indirect policy instruments. We also investigate whether the regulations provide continuous dynamic incentives that lead to persistent effects. In contrast to what the literature suggests, we find evidence that direct regulations promote persistent effects. Indirect regulations will, on the other hand, only have potential persistent effects if environmental taxes are increasing over time. See:

*B. Bye and M.E. Klemetsen (2014): The impacts of alternative policy instruments on environmental performance: A firm level study of temporary and persistent effects, CREE WP 14/2014.*

This is part of Marit Klemetsen's PhD project, and the paper is submitted to *Energy Journal*.

*Project leader: Brita Bye, SSB*

#### **IV.13 Agent based modelling**

In Dalen's PhD-thesis, the construction of a simulation model based on the agent based modeling framework is planned for 2015. The model will be used to analyze the diffusion and consumption of energy efficient household cooling appliances. The model is further complemented with econometric analyses of the effect of energy labeling and standards for cooling appliances on household electricity consumption. The results from these analyses will be presented in Dalen's PhD-project that is planned finished in 2015. The results are further planned to be presented in two articles intended for international publication.

*Project leader: Hanne Marit Dalen, SSB*

#### **IV.14 Development in the households' stock of heating equipment**

As many policy instruments are attached to household energy consumption for heating purposes, information about what heating equipment the households own and how they use it, is of greater importance. On request from the Norwegian Water Resources and Energy Directorate, Statistics Norway have documented data describing the development of the stock of heating equipment and the use of this equipment, based on the Consumer Expenditure Surveys of 1993, 1994, 1995, 2001, 2004, 2006, 2009 and 2012. It also includes a literature study, describing the main results from various Norwegian studies on related topics. The tables will be documented in Statistics Norway's Notater series. See:

*A.C. Bøeng, B. Halvorsen and B.M. Larsen (2014): «Kartlegging av oppvarmingsutstyr i husholdningene - En dokumentasjon av data fra Forbruksundersøkelsen», forthcoming as Notater, Statistics Norway.*

*Project leader: Bente Halvorsen, SSB*



## **5.5 The Next Generation of Numerical Models (WP V)**

To analyze policies that stimulate innovation and diffusion of new environmentally friendly technologies, integrated economy-energy-environment models are necessary tools. At CREE we have the energy market model LIBEMOD, the petroleum market model PETRO2, and the new family of integrated macroeconomic Computable General Equilibrium (CGE) models; the SNoW-models (Statistics Norway World models).

Development and updating of numerical models are very resource-intensive activities. Outputs from these activities will materialize as papers under the other work packages. Below we concentrate on projects that are not part of other WPs.

### **LIBEMOD**

In 2014 the activities to update and upgrade the numerical model LIBEMOD were finalized. Building on economic theory, this model provides a detailed modeling of the energy markets in 30 European countries. It encompasses all activities in the energy markets: investment, extraction of fossil fuels, production of bioenergy and electricity, trade in energy and consumption of energy. LIBEMOD produces a consistent set of quantities and equilibrium prices.

In the new version of the model more countries have been added (13 East-European countries); the end-user sectors have been refined (the service and public sector has been separated from the household segment); the modeling of wind power has been changed and more renewable technologies have been included (run-of-river hydro and solar power); the modeling of natural gas has been refined; bioenergy has been split into biomass and biofuel; all data have been updated (the data year has been changed from 2000 to 2009) and the

complete model has been recalibrated. A detailed documentation of the new version of LIBEMOD is now available at <http://www.frisch.uio.no/ressurser/LIBEMOD/>

The new version of LIBEMOD has been converted into a stochastic model. Here we build on stochastic programming where a crucial distinction is made between decisions made before the uncertainty is revealed, and decisions made afterwards. To this end the stochastic LIBEMOD has two periods. In period 1, some actors make decisions under uncertainty, that is, to determine their future capacities through investments. In the beginning of period 2, the uncertainty is revealed and all actors learn the true state of the economy, that is, which scenario that has materialized. Then all actors make decisions; producers determine how much to produce (given the predetermined capacities), arbitrators determine how much to trade, and consumers determine how much to consume.

For each realization of the uncertainty, the model determines supply of, and demand for, all goods from all agents and the corresponding vector of prices that clears all markets. In fact, the stochastic equilibrium model determines simultaneously all quantities (investment, production, trade and consumption) and all market clearing prices for all possible future states. The determination of quantities and prices are based on the assumption that all actors have rational expectations, that is, when investment decisions are taken in the first period actors take into account the probability distribution over the scenarios and the equilibrium prices of all scenarios. So far, the source of uncertainty is future climate policy – political uncertainty – but more applications are planned, see below.

*Project leader: Rolf Golombek, Frisch*

## **SNoW models**

In 2014 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 with 41 industries, based on the GTAP database structure (a global database on trade, environmental and energy) and programmed in GAMS. The model is continuously being developed to make the model more like SSB's earlier version of a computable general equilibrium model for Norway, the MSG-model, which has been used by the Ministry of Finance for decades. Many of these new properties have not been implemented in GTAP-based models before, and examples are modelling of process emissions and a more detailed consumer system.

*Project leader: Taran Fæhn/Orvika Rosnes, SSB*

## **The petroleum market model – PETRO2**

PETRO2 is a dynamic simulation model that analyses how market conditions and/or climate-/energy-policies affect the oil market. PETRO2 models oil as a non-renewable resource implying that the oil price contains a scarcity rent. PETRO2 further models OPECs degree of market power. The main outputs from the model are short and long run oil prices and production/consumption.

PETRO2 has seven demand and supply regions: OPEC, Western Europe (EU/EFTA), USA, Rest-OECD, Russia, China and Rest of the World. In each region there are seven sectors demanding oil: Industry, Household, Other sectors (private and public services, defense, agriculture, fishing, other), Electricity, Inland transport (road and rail), Aviation and domestic and International shipping. This division into demand regions and sectors permits us to consider more closely developments for example in the transport sector in some selected regions. PETRO2 includes six energy commodities: Oil (which is an aggregate of different oil products), Gas, Electricity, Coal, Biomass and Biofuels for transport. The oil price is endogenous and the other energy prices are exogenous. This feature of the model permits users to study how changes in demand and/or price of these five non-oil energy goods may influence the oil market. A crucial feature of the model is that it makes both short and long term adjustments to supply and demand taking into account that responses to changes in the oil market often are delayed or sluggish.

Non-OPEC regions (the fringe) are modeled as perfect competitors and OPEC has market power. OPEC may be modeled to either include all OPEC countries OR to include just the OPEC-core (the Gulf States: Saudi Arabia, Kuwait, Qatar, UAE). OPEC maximizes profit over time and takes into account that demand is price sensitive and therefore produces less than a perfect competitor would do.

PETRO2 has a rich data foundation from multiple sources and is calibrated to match the New Policies price scenario of the International Energy Agency. The start-year is 2007 and the time-period is one year.

*Project leader: Kristine Grimsrud, SSB*

## **Policy analyses on the SnoW models**

In 2014 Snow-No has been used to analyze emission scenarios for Norway dependent on different assumptions on important exogenous variables as international oil-price, international business cycles, and population forecasts. The scenarios are documented in an article submitted to *Samfunnsøkonomen*.

*Greaker, M. and O. Rosnes (2014): Robuste norske klimamålsetninger (revised version submitted to Samfunnsøkonomen).*

*Project leader: Mads Greaker, SSB*

In another project we use the dynamic version of the SNoW\_No model to analyze environmental and economic efficiency effects of climate- and energy efficiency policies. This is part of the EU project ENTRACTE. We model energy efficiency measures and technology costs based on a report by IFE on long-term scenarios for energy efficiency investment costs in buildings. This continues our cooperation with IFE on energy efficiency investments. The project is going to be presented at a workshop in Milan in February 2015, and synthesized in a report with FEEM (Milano) in May 2015.

*Bye, B., T. Fæhn og O. Rosnes (2014): Energy efficiency and European carbon policies: A CGE-analysis with endogenous investments in new technologies, Manuscript.*

*Project leader: Brita Bye, SSB*

The global model has been used in two different projects analyzing policies to curb carbon leakage, see project I.5 above. The first paper investigates how carbon taxes combined with output-based rebating (OBR) in an open economy perform in interaction with the carbon policies of a large neighboring trading partner. This paper is submitted to an international journal. The other paper concerns possibilities, limitations, and implications of various border carbon adjustment (BCA) systems designed particularly for targeting the emission intensities of foreign producers. Succeeding to design and implement such systems would improve the efficiency and effectiveness of BCAs. The final working paper will be submitted to an international journal by March 2015.

*Böhringer, C., B. Bye, T. Fæhn and K.E. Rosendahl (2014a): Output-based rebating of carbon taxes in the neighbor's backyard: Competitiveness, leakage and welfare, CREE Working Paper 6/2014. Submitted to Canadian Journal of Economics.*

*Böhringer, C., B. Bye, T. Fæhn and K.E. Rosendahl (2014b): Targeting border carbon adjustments: Welfare and leakage effects of firm specific tariffs, Manuscript.*

*Project leader: Brita Bye, SSB*

## **6 International cooperation**

Each of the Norwegian research partners in CREE has a large international network and it will be difficult to give a comprehensive and detailed report of all the collaboration with foreign researchers. Below we give some examples of this activity.

There is an international research partner in CREE, Tilburg Sustainability Center, and we also have contracts with several foreign researchers who have part-time positions paid by CREE:

Fridrik Baldursson, Reykjavik University

Christoph Böhringer, Oldenburg University

Jared Carbone, University of Calgary.

CREE organizes an annual research workshop where we invite our international research partners, those having a part-time position in CREE, as well as other relevant researchers from our network.

Our seminar series also has presentations by foreign scholars; see our website <http://www.cree.uio.no/seminars.html>, and our researchers are active presenting their research at seminars at different international research institutes and universities, and at conferences and seminars. We also have an exchange of researchers as our researchers and PhD students regularly visit foreign universities for shorter and longer stays, and foreign researchers visit our institutions.

We have ongoing collaborative projects with foreign researchers in CREE. Some of these projects are reported in the CREE working paper series, while others have been reported in other series and in international publications. We also have cooperation that has not yet resulted in publications, for example through the CESifo network where several of our researchers are research fellows (Michael Hoel is also area director of Energy and Climate

Economics at CESifo), both under projects that are directly funded by CREE, and also under projects that count as our own funding (ENERGIX, MILJØ2015 and NORKLIMA).

CREE is part of the ENTRACTE project (Economic iNsTRuments to Achieve Climate Targets in Europe) funded by the seventh EU Framework Programme. The project group consists of a consortium of nine European applied research centers, and is headed by Zentrum für Europäische Wirtschaftsforschung (ZEW). CREE heads one of the work packages and three research tasks, which involve collaboration with researchers from the other research centers. CREE further has achieved funding from the Research Council of Norway to deepen the collaboration with the ENTRACTE network. We are also involved in other international consortiums that are planning proposals for HORIZON2020 and Nordic Flagship Projects (Nordic Energy Research).

Climate change is the underlying factor of all the research in CREE as this creates the need for environmentally friendly technology, and IPCC (Intergovernmental Panel on Climate Change) is setting the agenda for most debate and policy making on this issue. CREE researchers have been involved in the IPCC process since the second assessment report (published in 1995). In the fifth assessment report (published in 2013 and 2014), CREE researchers have been involved in working group III (Mitigation of Climate Change). Reyer Gerlagh (Tilburg Sustainability Center) has been a coordinating lead author, Annegrete Bruvoll (Vista Analyses/Statistics Norway) has been a lead author, and Snorre Kverndokk (Frisch Centre) has been a review editor. In addition, Gerlagh also contributed to the Synthesis Report. These researchers have also been active in the media activity following the publications of the reports.

An important arena for our research is the European Association of Environmental and Resource Economists (EAERE). One CREE researcher - Karine Nyborg - at the University of Oslo was the president of the European Association of Environmental and Resource Economists (EAERE) in 2012 and 2013, and CREE researchers have received international prizes for their research by EAERE the last few years (Hoel, Harstad, Nyborg). Due to the importance of this conference for our researchers, CREE (together with CICEP and UiO Energy) has applied for organizing the EAERE conference in 2017.

As most of our researchers have an international network, we do not have a coordinated policy on internationalization, apart from helping PhD students to get contacts abroad.

## 7 Recruitment

The overall aim for CREE has been to recruit three PhD students and one post-doc researcher over the lifetime of CREE. Originally the plan was to recruit two post-doc researchers, but due to lack of external funding as well as satisfactory funding of post docs at the Department of Economics, University of Oslo, we decided to only fund one post doc directly. Two PhD students were recruited in 2011 and one in 2014, while we recruited one postdoc researcher in 2012. The research recruits are studying at the PhD program at the Department of Economics, University of Oslo. The Post Doc is also employed at the same department. In addition, we contribute to the funding of one PhD student at Statistics Norway and one Post Doc at Tilburg University.

CREE gives a master scholarship of NOK 20.000 to up to three master students annually. These are offered an office at one of the Norwegian research partners, supervision by one or two of the CREE researchers, access to all CREE arrangements, and the possibility to publish their thesis in the CREE Working Paper series.

In connection with the recruitment of candidates, we are also engaged in research training through teaching and supervising at the Tilburg University and the University of Oslo, both at the masters and PhD level. Further, we were involved in MILEN's research school, an interdisciplinary research school for PhD candidates in energy and environment at the University of Oslo that existed until 2014. At this research school, we gave seminars, lectures, and also organized a one-week PhD course on integrated assessment models in 2013. In 2014, we have also financially supported a PhD course at SUM (Centre for Development and the Environment, University of Oslo) called 'Consumption, Capitalism and Everyday Life: Understanding the Social Dimensions of the Growth Imperative'. Finally, we contributed to the research school of all the FME centers; NORREN, by providing lecturers.

When it comes to recruitment of women, two out of three PhD students funded by CREE have been women. Also, the majority of students receiving a master scholarship has been women. At the moment no special attention is needed to recruit women, as a significant part of PhD students in economics are women. For instance, at the Frisch Centre, six out of seven PhD students are women. When it comes to permanent research positions, the situation is different, however, environmental and energy economics seems to be one of the most attractive fields for women within economic research. Due to the difficult funding situation at the CREE

partners, we have not been able to employ permanent researchers within this field the last few years.

## **8 Cooperation with other FME centres**

CREE has a close collaboration with CICEP, one of the other social science-related energy research centers (FME Samfunn) funded by the Research Council of Norway. CICEP has many overlapping projects with CREE as both have a large interest in international climate negotiation and agreements. Every spring CREE and CICEP organize a user conference together for our research partners and other interested institutions. We also organize research workshops together, write joint research proposals and have some joint research projects. CREE and CICEP have also sent an expression of interest to organize the EAERE conference in 2017 together with UiO Energy. EAERE is the European Association of Environmental and Resource Economists.

In addition, we have some common interests with CenSES, the third FME Samfunn, in numerical modelling of energy markets, and we organize workshops and Model Forums together. In 2014 a joint workshop was organized for all the FME-S centres (CREE, CICEP and CenSES). The workshop was held in Trondheim in November and the topic was uncertainty and investment risk in the energy sector.

When it comes to the technological FME centers, we do not have any formalized cooperation as we work in quite different fields, use very different methodologies and address quite different research questions. However, we do have regular meetings with them, both during the RCN contact meetings for FME centers and also by inviting them to CREE seminars. In addition, our technological subcontractors, IFE and SINTEF Energy, are partners in some of these FME centers, and we, therefore, have input from the technological research through them.

## **9 Communication and dissemination**

The main users of CREE are, in addition to the research community, industry, Government and the general public. The communications to users are mainly through the following channels:

- Dissemination of research and media activity through our webpage ([www.cree.uio.no](http://www.cree.uio.no))
- Hold an annual user conference (April). This is organized together with CICEP. In addition we give a seminar for all users every fall (November)
- Organize user activities such as meetings and seminars
- Organize a Model Forum (once or several times a year) where users together with researchers in other disciplines can make contributions to economic modeling.
- Publish in Norwegian-language journals such as Samfunnsøkonomen and Økonomiske analyser.
- We contribute to hearings in the Parliament and public debates.

CREE has invested heavily in communication, for instance through an internal reward system for communicating through the media. We have dedicated a website for news on CREE research, see [http://www.cree.uio.no/CREE\\_in\\_the\\_news.html](http://www.cree.uio.no/CREE_in_the_news.html), and had more than 25 reports in the media in 2014. Researchers from CREE have been involved in key debates in the media over the past year on subjects such as global warming, electric vehicles and the effect of reduced extraction of oil as climate policy.

When it comes to user-oriented communication measures, we usually give about 80-100 presentations each year. This includes meetings with all user partners, seminars, workshops and conferences. In addition to the two regular user arrangements in the spring and the fall, we organize seminars for users that are interested in certain topics. In 2014 we organized a seminar at the Ministry of Climate and Environment.



## **CREE - Oslo Centre for Research on Environmentally friendly Energy**

**Name:** CREE

**Address:** Frisch Centre, Gaustadalléen 21, 0349 Oslo, Norway

**Phone:** 22 95 88 10

**E-mail:** [cree-admin at frisch.uio.no](mailto:cree-admin@frisch.uio.no)

**Web:** [www.cree.uio.no/](http://www.cree.uio.no/)

**Annual report: CREE**  
**Appendix: A1 Personnel**

**Key Researchers**

<b>Name</b>	<b>Institution</b>	<b>Main research area</b>
Golombek, Rolf	Frisch Centre	Environmental Economics, Energy Economics, Applied Game Theory
Hallre, Hilde	Frisch Centre	Environmental Economics
Hauge, Karen	Frisch Centre	Environmental Economics
Kittelsen, Sverre	Frisch Centre	Production theory, Efficiency measurement, Regulation, Health Economics, Energy Economics
Kverndokk, Snorre	Frisch Centre	Environmental and Resource Economics, Health Economics
Nævdal, Eric	Frisch Centre	Resource Economics, Economic management of ecological systems, dynamic optimization, modeling of the risk of disasters, animal behavior
Røgeberg, Ole	Frisch Centre	Welfare analysis, endogenous preferences, rational addiction theory, consumer theory
Strøm, Steinar	Frisch Centre	Microeconomics
Asheim, Geir	Department of Economics, University of Oslo	Game theory, intergenerational justice, green national accounting
Brekke, Kjell Arne	Department of Economics, University of Oslo	Behavioral Economics, Experimental Economics, Resource and Environmental Economics, Real options and stochastic analysis
Førsund, Finn	Department of Economics, University of Oslo	Resources, energy, environment, production theory, productivity
Framstad, Nils Christian	Department of Economics, University of Oslo	Stochastic optimization
Harstad, Bård	Department of Economics, University of Oslo	Political Economics, Public Economics, Contract Theory, Environmental Economics
Hoel, Michael	Department of Economics, University of Oslo	Energy and climate economics, environmental economics, resource economics
Lund, Diderik	Department of Economics, University of Oslo	Resources, energy and environment, economics
Nyborg, Karine	Department of Economics, University of Oslo	Environmental economics, economic analysis of social and moral norms, behavioral economics.
Vislie, Jon	Department of Economics, University of Oslo	Microeconomics, environmental economics, incentives, public economics
Von der Fehr, Nils	Department of Economics, University of Oslo	Microeconomics, Industrial Economics, Regulation, Competition Policy.
Aune, Finn Roar	Research Department, Statistics Norway	Energy and environmental economics
Bye, Brita	Research Department, Statistics Norway	Macroeconomic
Fæhn, Taran	Research Department, Statistics Norway	Macroeconomic
Greaker, Mads	Research Department, Statistics Norway	Energy and environmental economics
Grimsrud, Kristine M.	Research Department, Statistics Norway	Energy and environmental economics
Hagem, Cathrine	Research Department, Statistics Norway	Energy and environmental economics
Halvorsen, Bente	Research Department, Statistics Norway	Energy and environmental economics
Holtmark, Bjart	Research Department, Statistics Norway	Energy and environmental economics
Isaksen, Elisabeth	Research Department, Statistics Norway	Energy and environmental economics
Thuestad		
Larsen, Bodil Merethe	Research Department, Statistics Norway	Energy and environmental economics
Rosnes, Orvika	Research Department, Statistics Norway	Energy and environmental economics
Storrøsten, Halvor B.	Research Department, Statistics Norway	Energy and environmental economics
de Zeeuw, Aart	Tilburg Sustainability Center	Sustainability, Dynamic game theory, Environmental economics, Environmental policy, Mathematical economics
Gerlagh, Reyer	Tilburg Sustainability Center	Climate Change, Economics, Energy economics, Environmental economics
van der Heijden, Eline	Tilburg Sustainability Center	Risk behaviour and time preferences, behavioral economics

**Associated Researchers**

Baldursson, Fridrik	Reykjavik University	Financial Economics, Industrial Economics, Environmental and Resource Economics
Böhringer, Christoph	University of Oldenburg	Energy Economics
Carbone, Jared	University of Calgary	Environmental and Resource Economics
Eyckmans, Johan	Hogeschool-Universiteit Brussel	Economics of climate change, emissions trading, applications of game theory to the formation of international environmental agreements, cost benefit analysis, general equilibrium and integrated assessment modeling, evaluation of environmental policies, economics of waste management, industrial organization and normative economic theory
Green, Richard	Imperial College London	Energy markets
Liski, Matti	Aalto University School of Economics	
Rosendahl, Knut Einar	Research Department, Statistics Norway	Energy and environmental economics

**Post Doc students with financial support from the Centre budget**

Name	Funding	Nationality	Period	Sex M/F	Topic
Spiro, Daniel	CREE	Swedish	2012-2016	M	Energy and environmental economics
Okullo, Samuel Jovan	CREE	Dutch		M	Energy economics, resource economics, climate economics, and firm behavior

**PhD students with financial support from the Centre budget**

Name	Funding	Nationality	Period	Sex M/F	Topic
Ciccione, Alice	CREE	Italian	2011-2015	F	Economic of the climate change with econometric
Klemetsen, Marit	CREE	Norwegian	2011-2015	F	Innovation in energy- and environmental technology industries: Identifying knowledge externalities and effects of policies
Wahlquist, Henning	CREE	Norwegian	2014-2018	M	Energy markets and uncertainty.

**PhD students working on projects in the centre with financial support from other sources**

Name	Funding	Nationality	Period	Sex M/F	Topic
Midttømme, Kristoffer	Department of Economics, University of Oslo	Norwegian	2011-2014	M	Technology diffusion
Dalen, Hanne Marit	Research Department, Statistics Norway	Norwegian	2009-2014	F	The use of multiple instruments in energy and environmental policy.
Mideksa, Torben	Department of Economics, University of Oslo	Swedish	2012-2016	M	Primary Concentration: Contract Theory Secondary Concentrations: Environmental Economics and Political Economics
Holtsmark, Katinka Kristine	Department of Economics, University of Oslo	Norwegian	2012-2016	F	Development Economics, Natural Resource Economics, Microeconomics
van den Bijgaart, Inge M.	Tilburg Sustainability Center	Dutch	2012-2016	F	Innovation, technological change, environmental policy

## A2 Statement of Accounts

(All figures in 1000 NOK)

### Funding

	Amount
The Research Council	8 309
<b>Research Partners (own funding)</b>	
Frisch Centre (Host Institution)	4 569
Statistics Norway	5 039
Department of Economics,UoO	1 000
Tilburgs Sustainability Center	250
<b>User partners</b>	
Statkraft Energy AS	100
Statnett	250
Statoil ASA	250
<b>Public partners</b>	
University of Oslo	500
<b>Total</b>	<b>20 267</b>

### Costs

<b>Research Partners</b>	
Frisch Centre (Host Institution)	8 878
Statistics Norway	6 609
Department of Economics, UoO	2 421
Tilburgs Sustainability Center	500
Centre for Development and the Environment, UoO	530
The Faculty of Law - Natural Resources Law, UoO	155
Institute for Energy Technology (IFE)	200
SINTEF	974
<b>Total</b>	<b>20 267</b>

## A3 Publications

### Journal papers

([http://www.cree.uio.no/publications.html#Scientific Journals](http://www.cree.uio.no/publications.html#Scientific_Journals))

**Barrett, S., T.M. Lenton, A. Millner, A. Tavoni, S. Carpenter, J.M. Anderies, F.S. Chapin III, A.-S. Crépin, G. Daily, P. Ehrlich, C. Folke, V. Galaz, T. Hughes, N. Kautsky, E.F. Lambin, R. Naylor, K. Nyborg, S. Polasky, M. Scheffer, J. Wilen, A. Xepapadeas and A. de Zeeuw (2014):** Climate engineering reconsidered, *Nature Climate Change* 4, 527–529.

**Böhringer, C., B. Dijkstra and K.E. Rosendahl (2014):** Sectoral and regional expansion of emissions trading, *Resource and Energy Economics*. Volume 37, August 2014, Pages 201–225

**Böhringer, C., C. Fischer and K.E. Rosendahl (2014):** Cost-Effective Unilateral Climate Policy Design: Size Matters, *Journal of Environmental Economics and Management*. Volume 67, Issue 3, May 2014, Pages 318–339

**Böhringer, C., K.E. Rosendahl and J. Schneider (2014):** Unilateral Climate Policy: Can OPEC Resolve the Leakage Problem?, *The Energy Journal* 35 (4), 79-100.

**Braaten, R. H. (2014):** Land Rights and Community Cooperation: Public Goods Experiments from Peru, *World Development Volume 61*, September 2014, Pages 127–141

**Braaten, R. H. (2014):** Testing deontological warm glow motivation for carbon abatements, *Resource and Energy Economics*, Volume 38, November 2014, Pages 96-109, ISSN 0928-7655

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**Nyborg, K.(2014):** Reciprocal climate negotiators: Balancing anger against even more anger, CREE working paper no 20

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**Weidle, M. K.(2014):** Is low carbon taxation optimal climate policy for a developing country? A numerical simulation of technology adoption, Thesis for the Masterdegree, CREE working paper no 5

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Fæhn, T. (2014): Innenlandske klimatiltak: Skal vi kutte forbruk eller utvinning av olje? Seminar i Finansdepartementet, April 7., 2014

Fæhn, T. (2014): Output-based rebating and competitiveness: Optimal unilateral carbon policies when playing with others. IAEE/USAEE Conference, New York, 14-18-June 2014

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Fæhn, T. (2014): Tre modeller for studier av klimapolitikk. Seminar i Klima og miljødepartementet, Oslo 31. mars 2014

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Førsund, F. R. (2014): Hveding's conjecture: Conditions for aggregating a multiple-plant hydro system to a single plant – single reservoir system, Bergen economics of energy and environment research conference BEER, NHH, 12 – 13, May 2014

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Kverndokk, S. (2014): Climate Change 2014: Mitigation of Climate Change. Presentasjon av IPCC-rapporten, Finansdepartementet, 12. mai.

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Kverndokk, S. (2014): Rettferdighet i klimapolitikken. Diskusjon mellom Karen O'Brien, Asuncion Lera St.Clair og Snorre Kverndokk, Frokostseminar om innføring i nye rapporter fra FNs Klimapanel, Miljødirektoratet, 7. mars.

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- Midttømme, K. (2014): On the dynamics of cooperation. 4th CREE research workshop, September
- Nyborg, K. (2014): An economist's view on moral responsibility, social norms and environmental behavior. BENN (Behavior, Economics and Nature Network) Workshop, Beijer Institute of Ecological Economics, Royal Swedish Academy of Sciences, Stockholm June 2-4.
- Nyborg, K. (2014): Reciprocal Climate Negotiators. Environmental and Energy Economics Seminar (joint initiative of Université Paris 1-Paris School of Economics, Université Paris Ouest Nanterre la Défense, Université Paris Dauphine, Agro ParisTech, Ecole Polytechnique, Ecole des Mines, Ecole des Ponts, CEA, CIRED, Climate Economics Chair and IFP School), Paris, 13.03.14.
- Nyborg, K. (2014): Reciprocal Climate Negotiators: Balancing Anger Against Even More Anger. Research seminar, Grantham Institute, London School of Economics, May 28.
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- Nyborg, K. (2014): Reciprocal Climate Negotiators: Balancing Anger Against Even More Anger. CREE Workshop, Lysebu 22-23.09.
- Nyborg, K. (2014): Reciprocal Climate Negotiators: Balancing Anger Against Even More Anger. Departmental seminar, Department of Economics, Lund University.
- Nyborg, K. (2014): Reciprocal Climate Negotiators: Balancing Anger Against Even More Anger. Advanced Seminar Series in Environmental and Resource Economics, Graduate Institute, Geneva, 30.11.14.
- Nyborg, K. (2014): What does Cost-Benefit Analysis Really Measure? Workshop on progress and challenges in applied BCA of government policies, Toulouse, 15-16.12.
- Rosendahl, K.E. (2014): Carbon leakage: Pay or not pay the polluter? 36th Meeting of the Norwegian Association of Economists (Forskermøtet), BI (Oslo): Januar 2014:
- Rosendahl, K.E. (2014): Petroleum Policy as Climate Policy. BEEER-konferansen, Bergen: Mai 2014:
- van den Bijgaart, Inge M. (2014): The Unilateral Implementation of a Sustainable Growth Path with Directed Technical Change., World Congress of Environmental and Resource Economics, Istanbul, June 28
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- Voigt, C. (2014): Environmentally Sustainable Development and Peace: The Role of International Law. International Law and Peace; University of Wisconsin, Madison, USA, 2014-04-06.
- Voigt, C. (2014): REDDpluss - Building Consensus in the UN climate negotiations. Faglungs; 2014-03-06, UiO

Voigt, C. (2014): Up in the Air - Aviation in the EU Emissions Trading Scheme and the Question of Sovereignty. Faglunnsj; 2014-05-21, UiO

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Winther, T. (2014): Hvorfor er kunnskap om mennesker viktig for bærekraftig utvikling? University of Oslo, 10-12 September.

## **CREE in the news**

[http://www.cree.uio.no/CREE\\_in\\_the\\_news.html](http://www.cree.uio.no/CREE_in_the_news.html)

-Dyrt klimatilskott? CREE forskerne Taran Fæhn (SSB), Cathrine Hagem (SSB) Lars Lindholt (SSB), Knut Einar Rosendahl (NMBU) anslår kostnader og CO<sub>2</sub> innsparinger ved å ikke bygge ut Johan Castberg feltet. *Aftenposten 03 Des. 2014.*

-Klimautslipp øker raskt. CREE forskeren Knut Einar Rosendahl (Professor NMBU) imøtegår myten om klimavennlig norsk produksjon. Se også artikkel i Samfunnøkonomen nr 8 om temaet. *Dagens Næringsliv 18. Nov. 2014.*

-Strømsparing opp i varme. CREE forskeren Bente Halvorsen (SSB) er med å uttrykke seg om folks adferd ved ENØK-tiltak. *Bergens Tidende 5. Nov. 2014.*

-Debatt om langsiktige elbilkostnader. Startet av CREE forskerne Mads Greaker (SSB) og Snorre Kverndokk (Frischsenteret). *Aftenposten Sep/Okt 2014.*

-UTSLIPP PÅ SOKKELEN Disse 5 feltene slipper ut minst på sokkelen. CREE forsker Knut Einar Rosendahl, professor NMBU, omtal og intervju i Teknisk Ukeblad om CO<sub>2</sub>-utslipp på norsk sokkel. *Teknisk Ukeblad 26 aug 2014.*

-Tror ikke norsk oljekutt gir utslippskutt. I en artikkel om forskjellige meninger av konsekvensen av et oljekutt gir Taran Fæhn, forsker SSB og CREE, uttrykk for uenighet med overskriften. *Aftenposten 25 aug 2014.*

-Hvem tror på sin egen propaganda, sa du? Bjart Holtsmark nevnt i en artikkel av Kurt Oddekalv. *NRK 22 juli 2014.*

-Ett år i klimakrigen. SSB-rapporten Norsk olje- og gassproduksjon nevnt i en artikkel av Pia Martine Gautier Bjerke. *Stavanger Aftenblad 21 juli 2014.*

-Et spel for galleriet. Bjart Holtsmark nevnt i en artikkel av Rune Skarstein. *Klassekampen 16 juli 2014.*

-En tid for store oljetanker. Intervju med Taran Fæhn, forsker SSB og CREE. *Nationen 27 juni 2014*

- LIBEMOD modellen utarbeidet av forskere ved Frischsenteret og Statistisk sentralbyrå blir referert til i Stavanger. *Aftenblad 16 mai 2014.*
- CREE forsker Knut Einar Rosendahl, professor NMBU, Intervju i Dagens Næringsliv, om elektrifisering av sokkelen og prisprognoser på CO2 og kraft. *Dagens Næringsliv 10 mai 2014*
- Utsirahøyden. Nok et klimapolitisk paradoks. Debatt om elektrifisering av sokkelen. Michael Hoel, professor Universitetet i Oslo og forsker CREE i debatt om temaet. Diverse innlegg
- Fire klimapolitiske paradokser. Bjarte Holtsmark, forsker, Statistisk sentralbyrå og CREE i debatt om temaet. Diverse innlegg
- Oppslag rundt FNs klimapanel. Snorre Kverndokk, seniorforsker Frischsenteret og CREE har vært med på å skrive tredje delrapport av FNs klimapanel (IPCC) Diverse oppslag
- Hva gjør politikerne nå? Jan Fuglestad, forskningsleder CICERO, Edgar Hertwich, professor, NTNU og Snorre Kverndokk, seniorforsker Frischsenteret og CREE skriver en kronikk om veien viderer innen klimapolitikken. *Aftenposten 13 apr. 2014 og Klima 2-2014 CICERO*
- Kan vi få til rettferdig klimakutt? - Snorre Kverndokk og Eric Nævdal, seniorforskere ved Frischsenteret og CREE og Linda Nøstbakken, førsteamanuensis, Norges Handelshøyskole argumenterer for at de rike landene må ta utslippskuttene. *Aftenposten 02.04.2014*
- Utvinning för allmän vinning – en ESO-rapport om svenska mineralinkomster. Rapport skrevet av Jesper Roine (Stockholm School of Economics) og Daniel Spiro (Post doc ØI og CREE). Rapport og flere presseoppslag.
- Sammen med andre forskere var CREE forsker Karine Nyborg (Professor UiO) med i EKKO *Ekko, NRK P2, 04.02.14.*
- Fornuft og føleleser. Portrettintervju av CREE forsker Karine Nyborg (Professor UiO) i *Forskerforum nr 2 Februar 2014*
- He's dead, but he won't lay down. Debatt i Nationen om hogst av skog er bra for klimaet. Bjart Holtsmark, forsker SSB og CREE, kommer med motinnlegg til Gaute Nøkleholms kronikk i *Nationen 1 tert. 2014*
- Den industrielle revolusjon skjer. Bjart Holtsmark, forsker SSB og CREE, kommenterer Ole Mathismoens artikkel. *Aftenposten jan. 2014*
- Diverse innslag om Elbiler. Både fra 2013 og 2014. Mye knyttet til Bjart Holtsmark. Diverse innslag om elbiler