RAPPORT 4/2010

Social science research on energy

International and Norwegian studies

Antje Klitkou, Trond Einar Pedersen, Vera Schwach and Lisa Scordato

Rapport 4/2010
ISBN 978-82-7218-658-5
ISSN 1504-1824

The publications of NIFU STEP are available at www.nifustep.no

Norsk institutt for studier av innovasjon, forskning og utdanning
Norwegian Institute for Studies in Innovation, Research and Education
Wergelandsveien 7, 0167 Oslo
Tlf. +47 22 59 51 00 • www.nifustep.no

RAPPORT 4/2010

Antje Klitkou, Trond Einar Pedersen, Vera Schwach and Lisa Scordato

Social science research on energy

International and Norwegian studies

NIFU STEP

Preface

This report is the result of the research project "Vurdering av forskningsfronten på den samfunnsvitenskapelige energiforskningen". In July 2009 the Research Council of Norway (RCN) invited several social science groups to send in proposals for an analysis of state-of-the-art social science studies on environmentally friendly energy. NIFU STEP's proposal was one of two accepted proposals, and the project was funded by the research programme RENERGI under the RCN.

The objective of the project was to map the current situation in terms of international, state-of-the-art social science research, on environmentally friendly energy, including renewable energy production, hydrogen and carbon capture and storage, energy system and energy use. In addition the project maps relevant Norwegian research groups and their contribution to social science research on the above mentioned selected energy subjects.

The report consists of seven chapters:
1. Introduction
2. Bibliometric analysis of the international state of the art
3. International social science research projects on new environmentally friendly technologies
4. An overview of the state of the art in energy research
5. Central topics in the international discourse
6. Norwegian research projects and publishing
7. Final conclusions

A separate dokument describing the empirical basis and classifications of the report is available on demand.

The report is authored by Antje Klitkou (project leader), Trond Einar Pedersen, Lisa Scordato and Vera Schwach. Liv Langfeldt has commented on the draft manuscript.

NIFU STEP thanks the Research Council of Norway by Stian Nygård for critical and valued remarks to the manuscript. Thanks are also due to Rachel Sweetman for her improvements on the English writing style.

Oslo, 19 February

Sveinung Skule
Director

Taran Thune
Head of Research and Innovation Studies

Table of Contents

List of tables

List of figures

Sammendrag

Denne rapporten er resultat av forskningsprosjektet ”Vurdering av forskningsfronten på den samfunnsvitenskapelige energiforskningen”, finansiert av RENERGI-programmet i Norges forskningsråd. Analysen viser at energifeltet, og spesielt miljøvennlig energi, har fått økt fokus i den samfunnsvitenskapelige forskningen både i Norge og i verden for øvrig. Det er en økt politisk bevissthet om behovet for å innføre og bruke nye energiteknologier, redusere energiforbruk og utvikle et effektivt og sosialt energimarket. Disse utfordringene er synlige både i den norske og den internasjonale offentlige debatten. Med dette som utgangspunkt gir denne rapporten en oversikt over den samfunnsvitenskapelige energiforskningen.

Rapporten tar for seg følgende spørsmål:

- Hvordan behandler de forskjellige samfunnsvitenskapelige disiplinene miljøvennlig energi som et empirisk forskningsfelt?
- Hvilke problemer er sentrale, hvilke metoder anvendes og hva er de viktigste resultatene?
- Hvilke norske forskningsmiljøer arbeider på dette feltet og hva er deres hovedfokus?

Miljøvennlig energi som forskningsfelt i samfunnsforskningen

Prosjektet har undersøkt forskningsfronten gjennom å analysere internasjonale og norske forskningsprosjekter og forskningspublikasjoner med et samfunnsvitenskapelig fokus på miljøvennlig energi. Tre samfunnsvitenskapelige disipliner skiller seg ut: økonomiske studier som også inkluderer studier med et bedriftsøkonomisk eller ledelsesperspektiv, samfunnsvitenskapelige studier av miljø og økologi, og statsvitenskapelige studier, som også omfatter planlegging, offentlig administrasjon og internasjonal politikk. Forskningsbidragene er allikevel ofte tverrfaglige, siden tidsskriftene har en tverrfaglig karakter. Noen av studiene er tverrfaglige per definisjon, slik som samfunnsvitenskapelige studier av miljø og økologi. Mange av de internasjonale forskningsprosjektene kombinerer teknologiske og samfunnsvitenskapelige tilnærminger til energifeltet.

Rapporten undersøker videre den internasjonale og nasjonale fagdebatten om miljøvennlig energi. Denne analysen viser at den samfunnsvitenskapelige energiforskningen så langt har konsentrert seg om noen tematiske områder. Energibruk er det feltet med flest samfunnsvitenskapelige publikasjoner, etterfulgt av karbonhåndtering og vindteknologi. Det er dessuten et økende antall publikasjoner innen alle energitemaer, men den sterkeste veksten hadde publisering om energibruk og bioenergi.

Miljøvennlig energi, energibruk, energisystem og energimarket er temaer som har fått økende oppmerksomhet verden over. Antallet publikasjoner er skjevt fordelt mellom ulike land. USA har derimot en mindre dominerende posisjon innen dette feltet enn innen samfunnsvitenskap for øvrig. Både Nederland og Sverige har bidratt med en høy andel av

publikasjonene, sammenlignet med hva deres andel av samfunnsvitenskap ellers skulle tilsi. Noen land har forskningsmiljøer som er aktive i alle energitemaer, slik som USA, Storbritannia, Nederland, Sverige, Tyskland, Canada, Hellas, Østerrike og Frankrike. Andre land er mer spesialiserte i noen utvalgte felt, slik som Japan, Kina, Australia og Danmark.

Sentrale forskningsspørsmål, metoder og viktige resultater

Prosjektet har også analysert prosjektporteføljen til tre internasjonale forsknings- og utviklingsprogrammer innen energiforskning: EUs 6. rammeprogram, Nordisk energiforskning (NER) og programmene til Det internasjonale energibyrået (IEA). Selv om disse programmene overveiende gir støtte til teknologiorientert forskning er samfunnsvitenskapelige problemstillinger også i noen grad blitt adressert.

Under EUs 6. rammeprogram finnes det ikke mange energirelaterte prosjekt som har en ren samfunnsvitenskapelig profil. Samfunnsforskning er ofte en del av mer teknologidominerte prosjekter. De fleste slike prosjekter inneholder en vurdering av eksisterende politisk praksis eller policyanbefalinger, for eksempel vurderinger av sosialøkonomiske effekter av innføring og bruk av nye energiteknologier eller styringen av en slik innføring. Befolkningens støtte til vindenergi er et annet tema som blir ofte behandlet i EUs 6. rammeprogram, men også i prosjekter støttet av IEA. De fleste prosjekter støttet av IEA er konsentrert om bioenergi og her er følgende temaer sentrale: sosialøkonomiske drivkrefter og effekter av innføring av et bioenergimarked, retningslinjer og anbefalinger for politikere og holdinger mot bioenergi. Bioenergi er også et av temaene som er viktig i prosjektporteføljen til NER. Her anvendes både kvantitative og kvalitative tilnærminger: casestudier er utbredt, men også studier av de nasjonale bioenergimarkedene og de politiske rammebetingelsene for dette markedet. NER har støttet en del policystudier og ønsker at disse studiene blir tatt i bruk av politikere som kan påvirke forsknings- og innovasjonspolitikken for miljøvennlig energi.

Følgende problemstillinger som er sentrale i den pågående internasjonale forskningen blir utdypet i rapporten i separate kapitler: bruk av fremtidsscenarioer for å forstå kompleksiteten i utviklingen av energisystemer, befolkningens støtte til nye energiteknologier, vurdering av miljømessige effekter, innovasjonssystem og transformasjon av energisystemer og bærekraftige energisystemer og energibruk.

Norske forskningsmiljøer

Norsk samfunnsvitenskapelig energiforskning er preget av to typer studier: *økonomiske studier*, spesielt studier av energimarkedet og energiforbruk, og *klima- og miljøpolitiske studier*. Den sterke nasjonale og internasjonale oppmerksomheten omkring energimarkedsrelatert forskning er begrunnet i de spesielle markedsbetingelsene i Norden som tillater forskerne å studere en fungerende deregulert nordisk kraftmarked. Vi mener at dette

markedsanalytiske perspektivet bør også forbindes med forskjellige typer policyanalyser. Andre samfunnsvitenskapelige studier ser ut til å være forholdsvis lite utviklet i Norge.
Flere forskningsorganisasjoner driver med energirelatert samfunnsvitenskapelig forskning i Norge: Hovedaktører er NTNU, Statistisk sentralbyrå, Universitetet for miljø og biovitenskap og Universitet i Oslo, inkludert CICERO. Det finnes også flere forsknings-institutter som bidrar til denne forskningen, men i mer begrenset omfang med tanke på prosjekter og publikasjoner. Dette kan neppe forklares med manglende finansiell støtte til samfunnsvitenskapelig energiforskning, men heller at forskningsmiljøene har et annet strategisk fokus. Interessant er at de tekniske forskningsmiljøene spesialisert i energi, SINTEF Energi og Institutt for energiteknikk, har en økende interesse for samfunns-vitenskapelig energiforskning.

Samfunnsvitenskapelig forskning har fått økt offentlig støtte de siste årene og spesielt etter at energiforskningsstrategien Energi21 ble lansert og RENERGI har økt sin finansielle støtte til slike prosjekt. Det kan antas at denne økte støtten på sikt vil bidra til at flere norske forskere er aktive på dette feltet, gjennom økt deltagelse i nordiske og europeiske forskningsprosjekter og gjennom økt publisering.

1 Introduction

Social science research on energy is one of the key priority areas in the energy strategy Energi21. The Research Council of Norway (RCN) is committed to strengthening social science research in this field and therefore launched this project in June 2009. This project offers an explorative study of the international state of the art for social science research on environmentally friendly energy, focussing on developments over the last 5 to 10 years. The following research questions have been addressed:

- How have social science disciplines targeted environmentally friendly energy as an empirical field of research?
- Which problems have been addressed, which methods have been applied and which main results have been accomplished?
- Which Norwegian research environments have worked in this field and what is their main focus?

In order to analyse how social science disciplines have targeted environmentally friendly energy as an empirical field of research, and to enable an identification of key topics and research questions that have been addressed, we first set out to frame and define this field of knowledge. Social science research has been broadly and pragmatically defined, and we include all publication covered by the ISI Social Citation Index in the bibliometric study (see Table 1). Note that Tthe study does not take account of all social science research on energy, but concentrates on social science research on environmentally friendly energy, energy systems and energy use. Environmentally friendly energy as discussed in this study includes renewable energy technologies, hydrogen and carbon capture and storage.

Mapping the state of the art within social science research on environmentally friendly energy is a complex task and we address it using a variety of approaches. A bibliometric analysis can give a snapshot of the field, but should be supplemented by other research methods. We combine a bibliometric analysis of publications in this field with a mapping of relevant international research projects and a more qualitative exploration of highly cited papers and other relevant publications.

To clearly map the current situation within this field we identify themes, research questions, key methods used and main findings and interpretations. On the basis of this we identify central topics in the international discourse on environmentally friendly energy. Finally, we explore the Norwegian situation: we look at Norwegian activities in the field, both in terms of publications and international and national research projects, and we highlight central issues in the Norwegian discourse and relate them to the international discourse.[1]

---

1 As NIFU STEP has (a limited number of) research projects and publications on environmentally friendly energy, NIFU STEP is itself part of the study. Compared to other Norwegian research

NIFU STEP realized the project in the following way:

1. *Compiling existing state-of-the-art studies*

Our first step involved searching for existing state-of-the-art studies using bibliographic databases, to build on our previous work in this area (Klitkou, Pedersen et al. 2008a; 2008b; 2008c; 2008d). This gave a starting point for analysing the research field, in terms of themes, research questions and scholarly approaches and placed our report in a broader knowledge context. However, few state-of-the-art studies on environmentally friendly energy were identified through this step and we had to expand our analysis based on the results of the bibliometric study, the mapping of the international research projects and a qualitative analysis of highly cited papers.

2. *Bibliometric study*

The aim of this part of the study was to establish an initial overview of the field, by applying bibliometric methods. Some of these results were also used as an input into other elements of the study. We started with a definition of the energy related subjects and of the relevant social science fields. An analysis of the addresses of the authors of relevant papers was then conducted to identify important research organisations, especially those active in Norwegian research environments. This analysis was conducted within each of the energy subjects. The distribution of papers by country and energy subject reveals differences between countries in terms of specialisation in selected energy subjects. The highly cited papers and key Norwegian research publications identified in this stage were also used further on in the study, as part of more detailed analysis.

3. *International research projects*

The aim of this workpackage was to get an overview of relevant international research within this field, based on an exploration of international R&D programmes. An analysis of three portfolios of international R&D programmes has identified important research environments active in environmentally friendly energy, the main problems addressed by these programmes, their research methods and their main results. The three portfolios are the EU's 6th Framework Programme (FP6), Nordic Energy Research and Implementing Agreements of the International Energy Agency (IEA). A matrix of relevant projects has been created.

4. *Overview of the international state of the art of social science studies*

This chapter provides an overview of the international state of the art within social science studies by analysing the identified highly cited papers (item 2 above). A matrix of these papers has been developed based on thematic areas, energy subjects, social science disciplines, objectives, methods, main findings and research environments.

5. *Central topics in the international discourse*

The themes identified as most important or widely discussed include: foresight studies, public acceptance, environmental impact assessment, the innovation system approach and energy system transformation and sustainable energy systems and use. These themes have

organisations, NIFU STEP's activities in the area are minor, and not deemed to involve any conflicts of interests when performing the present kind of review.

been summarised based on the analysis of different types of sources, including the highly cited articles (item 2 above), international research activities (item 3 above), and selected books and reports.

6. Norwegian activities

The project aims to assess the position of Norwegian research in this area. Therefore results from across the report relevant to Norway, such as those in the chapters on international and national research projects and the bibliometric analysis, are summarised and discussed in this section. An additional, important element of this study was to map publishing of Norwegian papers in Norwegian journals and magazines, to see if more Norwegian social science publications on environmentally friendly energy appear in a national context and if the topic of environmentally friendly energy has gained more public attention recently.

Identifying the international state-of-the-art: Review articles

To assess the state of the art in terms of environmentally friendly energy research, we conducted a bibliometric analysis which identified 67 review articles on climate mitigating energy technologies,[2] but initial reading revealed that not all were relevant to this study.

Within the field of *technological change and environmental policy* a particularly interesting review article was published by Jaffe, Newell and Stavins (2002). In the subject area *energy and environmental policies* a review paper by Greening and Bernow (2004) addresses the challenges of formulating and coordinating a set of policies for energy and environmental goals, and argues for the wider use of multi-criteria decision-making methods. Furtheremore, formulation of energy and environmental policies involves large numbers of stakeholders with differing views and preferences, and those views and preferences cannot always be determined in advance or with certainty since many of the attributes of these policy alternatives are non-market valued. In light of these challenges, using multi-criteria decision-making (MCDM) methods in an integrated assessment framework offers a far better alternative to cost/benefit approaches or similar methods. To facilitate understanding of MCDM methods, the authors offer a typology for this broad class of models, suggest the types of problems that may be analyzed with these methods and recommend the implementation of several MCDM methods in currently evolving integrated assessment frameworks. Depending upon the choice of method, a wide range of attributes associated with multipollutant reduction and energy system development strategies, and a diversity of stakeholder preferences may be incorporated into the analysis. The resulting policy space can then provide a basis for comparison of, and selection of, policy alternatives in a political or negotiated process.

---

[2] The review articles were published in 35 journals, but the distribution of them over the different journals was rather skewed as three journals published 30 of the 67 articles, namely: Energy Policy (12), Annual Review of Environment and Resources (11) and Ecological Economics (7).

Other particularly relevant review articles, which have also have received a great deal of attention among the scholars, are two articles by Jacobsson et al. on the *transformation of the energy sector*, based on a technological innovation system model (Jacobsson and Bergek 2004; Jacobsson and Lauber 2006). The purpose of the first paper is to contribute to the policy debate, and to the management of transformation within the energy sector (Jacobsson and Bergek 2004). The second paper addresses the need for a rapid transition to a low carbon economy (Jacobsson and Lauber 2006). Further details on these papers can be found in section 5.4.

In chapter 5 we discuss selected topics which are central in the international discourse. They include often also an analysis of the existing state of the art within these topics.

Involved disciplines: Social sciences and multidisciplinary research

Many of the publications on environmentally friendly energy studied in this project involve a multidisciplinary approach, combining economics, political sciences and environmental studies. Fairly few pure sociological studies have been identified. However, studies using a pure economic approach are quite common.

When analysing the European and IEA research projects we could find very few pure social science studies on environmentally friendly energy: mostly social science approaches were integrated into more technological projects. However, this was not the case in projects funded by Nordic Energy Research (NER) or by RENERGI in the Research Council of Norway, where several projects can be identified that use a clear social science approach, such as the policy projects funded by NER and the economic market studies by RENERGI.

2 Bibliometric analysis of the international state of the art

This bibliometric study maps social science research articles on environmentally friendly energy that have been published in international journals over the last ten years. The study combines keywords and journal samples. A set of energy subjects were defined by keywords, including: bio-energy, geothermal energy, hydrogen, hydropower, solar photovoltaic, wind, CCS, renewable energy in general, energy use and energy system, among others. A set of groups of social sciences was defined based on groups of journals to assess the importance of different social sciences for studies of environmentally friendly energy.

The purpose of the study was to identify important players in the field, to see what positions Norwegian research groups have, to see the relative importance of the different social science fields and the different energy subjects. Finally the study examines the importance of the identified international research groups.

Authors' addresses have been analysed in order to identify important research organisations and especially the Norwegian research environments active. This has been done in each of the energy subjects. The distribution of papers by country and energy subject reveals differences between countries in the specialisation in the selected energy subjects. Highly cited papers are also identified.

2.1 Methods and data

The starting point for this bibliometric analysis of the international state-of-the-art was the index of scientific publishing in the Thomson Reuters ISI Web of Science. The study is based on the Social Science Citation Index and includes all publications published from 1999 to 2008. The types of documents included are articles, letters, meeting abstracts, notes, proceeding papers and reviews.

The social science fields are defined on the basis of a selection of journals within the Social Science Citation Index, while the energy related subjects are identified by keywords.

2.1.1 Identification of social science fields

The scientific journals which are covered by the Social Science Citation Index are classified by the Journal Performance Indicators (JPI). The classification used by JPI has been applied on the identified journals. Many journals are classified in several fields which are interrelated and therefore the main fields of social sciences have been grouped in 13 groups of social science fields, and the distribution of articles is based on weighted shares and not on absolute counts (Table 1). The publications identified by the renewable energy related keywords are concentrated in three groups of social science disciplines: economics, business and management studies; environmental studies and ecology; and, political sciences, including planning, public administration and international relations. There are also interdisciplinary fields such as multidisciplinary sciences and interdisciplinary social sciences, and social science studies in relation to certain sectors, such as agriculture and forestry, transportation etc. In addition there are social science studies which apply methods not typical in mainstream social science research, such as mathematical methods or studies in information science and communication.

Table 1: Distribution of scientific articles by groups of social science journals, based on weighted shares of articles. N=2,459.

Agriculture and Forestry	67
Economics, Business and Management	538
Environmental Studies and Ecology	1,469
Geography and Area studies	64
Information Science & Library Science and Communication	12
Law	13
Multidisciplinary Sciences	25
Political science, Planning, Public administration and International relations	139
Social Issues	6
Social Sciences, Interdisciplinary	12
Social Sciences, Mathematical Methods and Computer sciences	17
Sociology and Anthropology	18
Transportation	48
Urban studies and Architecture	32

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

2.1.2 Definition and identification of energy related subjects

Selection of keywords

The following overview shows the selected English keywords that were applied to identify social science studies on environmentally friendly energy and CCS. The commissioner of this study received an early version of the selected keywords and gave valuable feedback which has been implemented.

Table 2: Selected keywords

Energy use

- energy use
- energy usage
- energy consumption
- energy efficiency
- energy-saving technology
- clean technologies

Energy system

- energy system
- energy infrastructure
- energy network
- strategic niche

Hydrogen

- hydrogen production
- hydrogen generation
- hydrogen storage
- hydrogen transport
- hydrogen distribution
- hydrogen use
- hydrogen fuel
- hydrogen economy

Renewable energy production

- renewable energy/power production/generation
- sustainable energy/power production/generation
- green energy/power production/generation
- environmental energy/power production/generation
- ecological energy/power production/generation

Bio-energy

- bio-energy
- bio-fuel
- biomass waste energy
- biomass feedstock energy
- biomass to liquid
- bio-methanol
- bio-ethanol
- bio-gasoline
- biodiesel

Geothermal energy

- geothermal electricity
- geothermal plant
- hot dry rock
- enhanced geothermal system
- geothermal heat pump
- ground source heat pump

Solar photovoltaic

- photovoltaic energy
- PV energy
- solar cells
- solar panels
- PV-module
- photovoltaic system

Solar thermal power

- solar thermal power
- solar thermal energy
- concentrating solar power
- solar thermal power plant

Hydropower

- hydropower
- hydro power
- hydro energy
- hydropower generation
- hydro power turbine
- small hydro power"
- small hydro energy"

Wind energy

- wind energy
- wind power
- wind turbine
- wind mill
- wind onshore
- wind offshore
- wind technology
- Wind farm

CCS

- carbon capture and storage
- CCS
- carbon dioxide capture and storage
- carbon sequestration
- carbon capture
- carbon storage

The selection of keywords aimed at avoiding a too narrow technology focus, as well as avoiding too general searches. The keywords selected describe the relevant technology systems in a more general way than engineers would apply them in their research literature, but engineers should still be able to recognize their subjects from these keywords. Irrelevant keywords had to be excluded and overlaps between keywords had to be taken into account.

2.2 Results – overview

2,459 publications were identified in the Social Science Citation Index for 1999–2008. These papers were published in 303 different journals, the most important being *Energy Policy*, *Energy Economics* and *Ecological Economics* (Table 3).

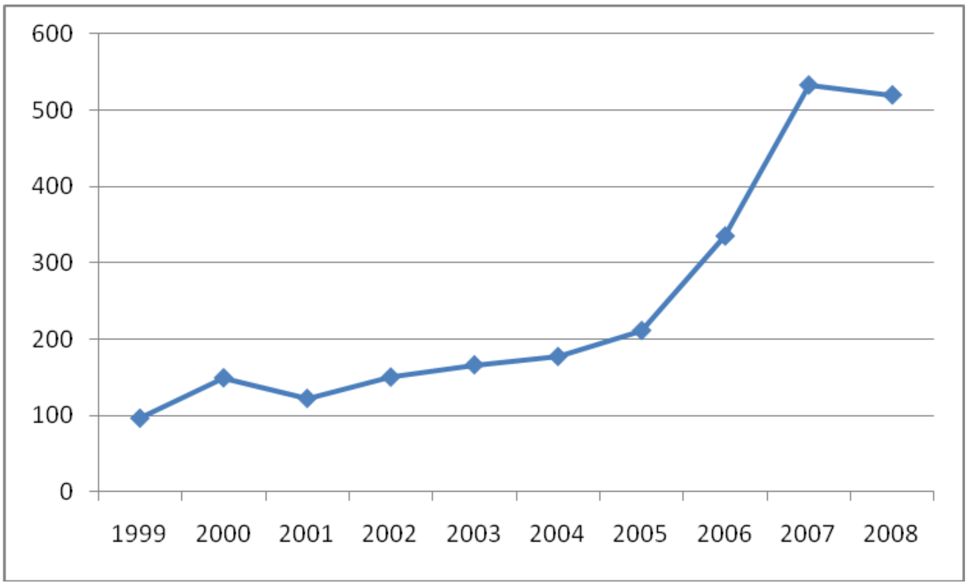
Table 3: Most important journals: journal with a minimum of 10 papers 1999-2008

Journal full title	Number of papers
ENERGY POLICY	1092
ENERGY ECONOMICS	154
ECOLOGICAL ECONOMICS	132
ENERGY JOURNAL	60
CLIMATE POLICY	57
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	43
ENVIRONMENTAL & RESOURCE ECONOMICS	34
TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	30
RESOURCE AND ENERGY ECONOMICS	21
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS	17
JOURNAL OF ENVIRONMENTAL MANAGEMENT	17
GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS	16
LAND ECONOMICS	16
FORBES	15
LANDSCAPE AND URBAN PLANNING	14
ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES	14
FUTURES	13
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	12
CANADIAN JOURNAL OF AGRICULTURAL ECONOMICS-REVUE CANADIENNE D AGROECONOMIE	11
TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	10
ENVIRONMENTAL SCIENCE & TECHNOLOGY	10
ENVIRONMENT AND DEVELOPMENT ECONOMICS	10
JOURNAL OF POLICY MODELING	10
FOREST POLICY AND ECONOMICS	10

Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

The development of social science publishing on environmentally friendly energy is documented in Figure 1. The figure indicates that the subject has increased in importance within social science publishing, especially over recent years. The slight decrease in 2008 may be due to a database artefact (time lag in updating the database) and should not be overemphasised.

Figure 1: Social science publishing on environmentally friendly energy. 1999–2008 (N=2,459)



Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

The energy subject area that accounts for the most publications is energy use. Carbon capture and storage (CCS) and wind technology are the areas with the next highest numbers of publications. Since there is some overlap between the fields, the sum of the single subjects is higher than the total number of publications. The results for the different energy subjects are presented later on in this chapter.

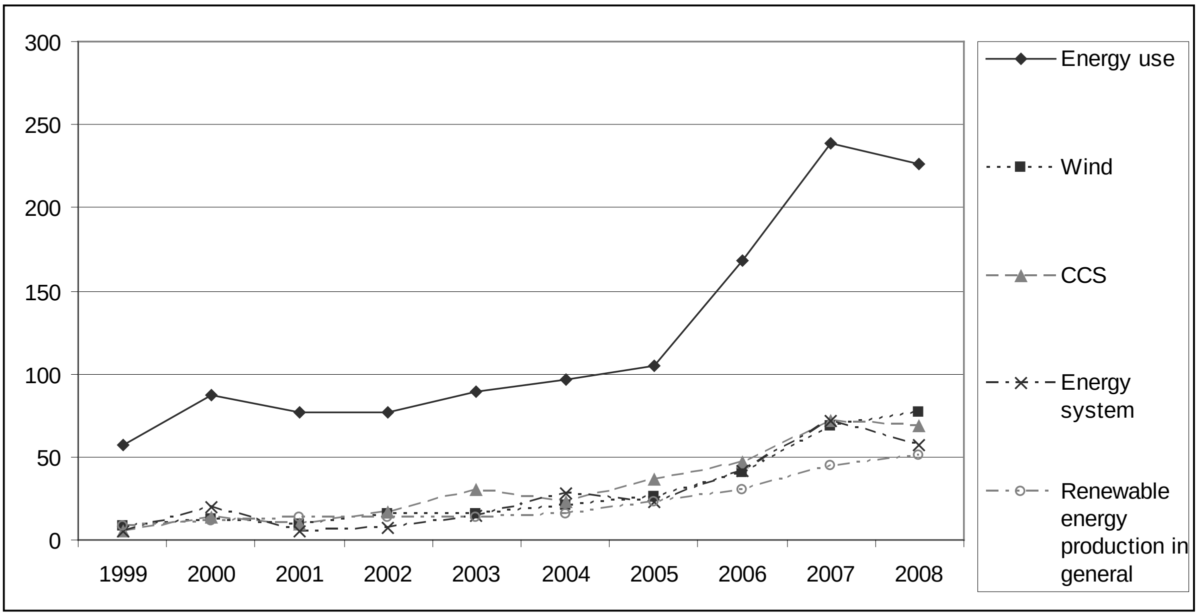
Table 4: Distribution of publications by energy subject (N=2,459)

Energy subjects	Number of papers
Bio-energy	210
CCS	322
Energy system	274
Energy use	1,222
Hydrogen	93
Hydropower	135
Renewable energy production in general	225
Solar PV	147
Solar Thermal	20
Wind	293

Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

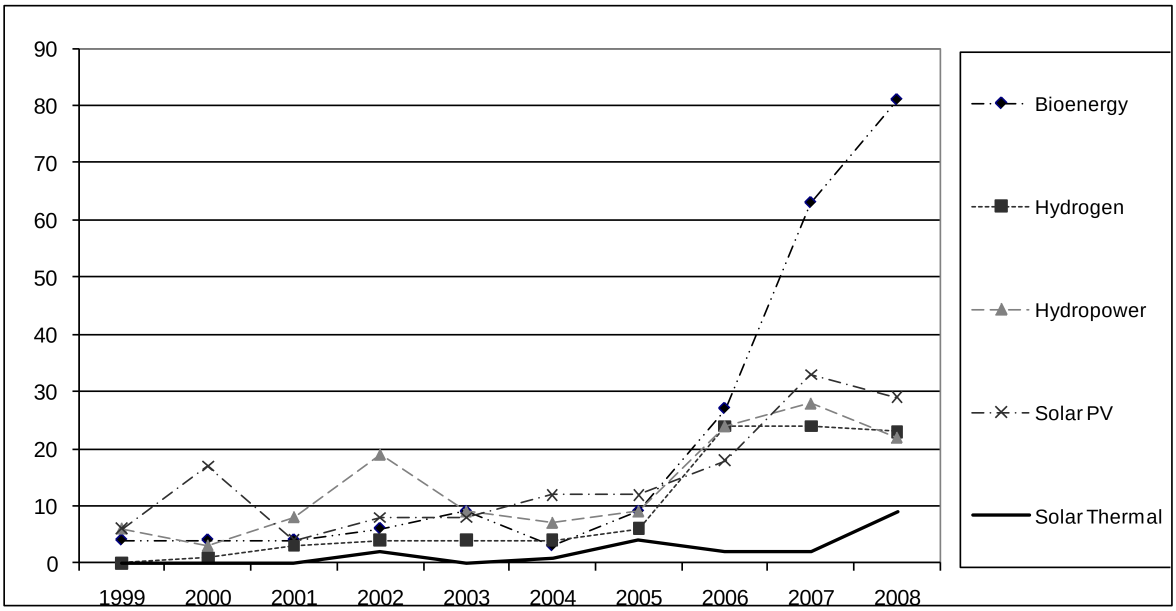
The development of publishing activities in the different energy subjects is documented in the following two figures. They show an overall, upwards trend for all energy subjects. The highest increases can be seen for publications on energy use and bio-energy.

Figure 2: Publishing in the energy subjects Energy use, Wind, CCS, Energy system and Renewable energy production in general. 1999–2008.



Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

Figure 3: Publishing in the energy subjects Bio-energy, Hydrogen, Hydropower, Solar PV, and Solar Thermal. 1999–2008.



Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

The author addresses of the 2,459 papers have been analysed to identify important international research organisations active in the different energy subjects. Of the articles analysed, 93 papers had no addresses listed in the database. Where a paper was linked to several addresses, the shares have been weighted: where a paper was linked to two different addresses each address received a weight of 0.5, for three addresses 0.33, for four addresses 0.25 and so on. As the table below (Table 5) shows, the international distribution of these publications is highly skewed; over 50 percent of the total production of publications comes from just five of the countries represented.

Table 5: Distribution of countries in the sample. Based on weighted address shares. N=2,459

Country	Share
USA	25,8 %
UK	11,4 %
Netherlands	6,9 %
Sweden	4,9 %
Germany	4,2 %
Canada	3,6 %
Australia	3,3 %
Peoples R China	3,0 %
Japan	2,5 %
Turkey	2,4 %
France	2,2 %
India	2,2 %
Spain	2,0 %
Greece	1,9 %
Denmark	1,9 %
Austria	1,7 %
Taiwan	1,7 %
Switzerland	1,6 %
Norway	1,6 %
Brazil	1,6 %
Finland	1,3 %
Italy	1,3 %
South Korea	1,0 %

Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

Analyses of the papers split on countries and subjects demonstrate that while some countries are active across all energy subjects, such as the USA, Great Britain, the Netherlands, Sweden, Germany, Canada, Greece, Austria and France, others are more specialised in selected energy fields, such as Japan, China, Australia and Denmark, among others. The country shares of papers also show some quite striking points: U.S. papers normally account for more that 50 per cent of all social science papers in the world, if we merge all papers in the fields of social sciences, economics and business (2008 National Science Indicators - Deluxe). However, for energy related publications the US's share is only 26 per cent. The relatively high proportion of Dutch or Swedish papers are also noteworthy, as normally Dutch and Swedish social science papers would achieve shares between 3 per cent and 2 per cent respectively. These two countries therefore seem to demonstrate a quite high degree of specialisation within social science publications, focused on the field of energy.

Focusing on Norwegian energy publications, 47 papers could be identified in total, covering seven out of the ten energy subjects. These papers show hydropower and wind to be particular Norwegian publication strongholds. The Norwegian papers have been analysed separately to take account of: the number of papers, the development of publication over time, the main journals involved, the main social science groups publishing, the main energy subjects covered, the main organisations active in publishing in the selected fields and the citedness the papers.

To explore the issue of citations, the median and mean number of citations for all papers in each energy subject was calculated, the two measures being used in parallel as the distribution of citations appears to be rather skewed, and applying the mean as the only threshold would inadequately delimit the sample of most cited papers. The citation calculations were based on total counts of citations, not on citation windows. To identify the key organisations in the various energy subjects, we focused on the authors of the more cited papers in each: for each subject a threshold number of citations was defined (set between the mean and the median), papers with more than this number of citations were then identified, and the organisational affiliation of the authors summarised.[3] Based on this process, the key organisations for each energy subject are summarised in tables showing the key organisations and the number of papers they have produced.

We have identified a sample of 109 highly cited papers, which includes all papers with more than 25 citations. These papers have been used extensively in the rest of this report. The distribution of these highly cited papers over energy subjects is shown in the following table.

Table 6: Highly cited papers. N=109. 1999-2008.

Energy subject	Number of papers
Bio-energy	11
CCS	22
Energy system	12
Energy use	52
Hydrogen	10
Hydropower	3
Renewable energy production	5
Solar photovoltaics	6
Wind	17

Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP
There were no highly cited papers on solar thermal.

3 Only organisations with more than one paper based on weighted addresses shares were included.

2.3 Results for each energy related subject area

To improve comparability, all energy subjects have been studied in a similar way. Each subject area has been analysed in terms of:

- The publication output by country, as measured by weighted address shares;
- The most important international and Norwegian research organisations, as measured by the number of citations combined with weighted address shares;
- The most important journals, as measured by the number of publications;
- The most important social science groups.

Tables presenting the most important journals and social science groups for each energy subject are given in the Appendix (8.1), whereas the main results for each energy subject are summarised in the following subsections.

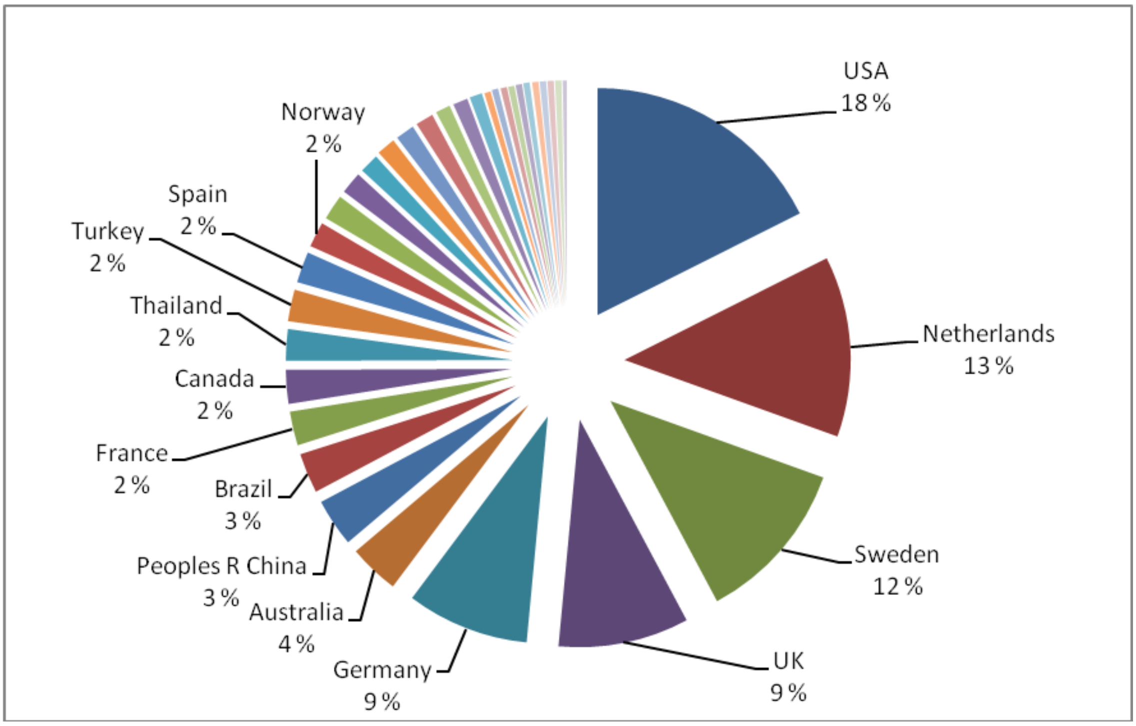
2.3.1 Bio-energy

We identified 210 papers with relevance for the energy subject area of bio-energy. The journal with the highest number of these papers was *Energy Policy*.The most visible social science groups in the sample were environmental studies and ecology. Other important groups were economic studies, agriculture and forestry, and political sciences.

Amongst the publications on bio-energy by country, 16 papers had no addresses and could not be analysed. The publications in this energy subject area are more evenly distributed across countries than for the other technologies, as the following figure shows: 20 per cent of all papers were published by U.S. scientists, while those from the Netherlands contributed 14 per cent of the papers, those from Sweden with 12 per cent and Great Britain and Germany each provided 9 per cent.

The mean number of citations for all bio-energy papers was 5.5, the median was 2. We identified all papers with at least 4 citations and summarised the organisational affiliation of those authors, as shown in the next table (Table 7). Only organisations which had more than one paper based on weighted address shares were included. Research organisations from the Netherlands (such as the University of Groningen, Ecofys, University of Utrecht and Wageningen University), and those from Sweden (the University of Gothenburg, Chalmers, Lund University, KTH and Lund Institute of Technology), are shown to be among the most visible and active research organisations in the field of bio-energy.

Figure 4: International distribution of publishing on bio-energy. Based on weighted address shares. 1999-2008. N=210.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 7: Bio-energy – most important international research organisations.

Sum of papers	Country	Organisation
3,0	Netherlands	Univ Groningen
2,7	UK	Univ London London Sch Econ & Polit Sci
2,3	Netherlands	Ecofys
2,0	Tunisia	Ecole Natl Ingn Tunis
2,0	Germany	Humboldt Univ
2,0	Thailand	King Mongkuts Univ Technol
2,0	Sweden	Univ Gothenburg
2,0	USA	Univ Nebraska
2,0	Netherlands	Univ Utrecht
1,8	Sweden	Chalmers Univ Technol
1,5	Sweden	Lund Univ
1,3	Spain	Inst Environm Sci & Technol
1,3	Sweden	KTH
1,3	Sweden	Lund Inst Technol
1,3	USA	US EPA
1,3	Netherlands	Wageningen UR

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Four Norwegian organisations were also found to be active in the field of bio-energy, when all papers (not just highly cited ones) are analysed based on weighted address shares (see Table 8).

Table 8: Bio-energy - The most important Norwegian research organisations.

Sum of papers	Organisation
1,5	N Trondelag Res Inst
1,5	Norwegian Univ Life Sci
0,5	CICERO
0,5	Norwegian Univ Sci & Technol

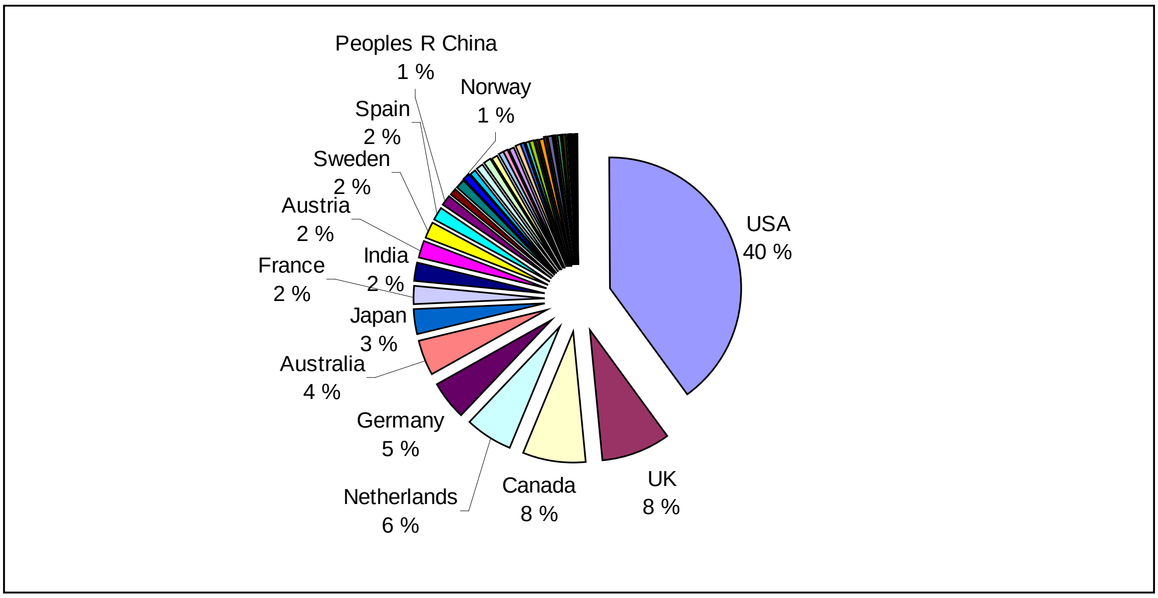
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

2.3.2 Carbon capture and storage

We identified 322 relevant papers on carbon capture and storage (CCS). The journal with the highest number of these papers was *Ecological Economics*, followed by *Climate Policy* and *Energy Policy*. The most visible social science groups in the CCS sample were environmental studies and ecology and economic studies, with agriculture and forestry, and political sciences also shown to be important.

Scientists from the US published 40 per cent of all papers, while scientists from Great Britain and Canada contributed with 8 per cent each. This reveals a stronger pattern of U.S. dominance than in any of the other energy subject areas.

Figure 5: International distribution of publishing on CCS. Based on weighted address shares. 1999-2008. N=322.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The mean number of citations for all CCS papers was 7.6, the median 3. We identified all papers with at least 6 citations, and summarised the organisational affiliation of those authors, as shown in table 8. In line with the large proportion of papers published by authors from U.S. organisations, the most visible international actors in social science studies on CCS are found in the USA, the leading organisations being Carnegie Mellon University, Montana State University, Harvard University and Oregon State University, along with many other U.S. research organisations. This broad activity explains the leading position of the USA compared to the rest of the world in terms of CCS publications.

Table 9: CCS – most important international research organisations.

Sum of papers	Country	Organisation
4,8	USA	Carnegie Mellon Univ
3,9	USA	Montana State Univ
3,6	USA	Harvard Univ
3,4	USA	Oregon State Univ
2,7	USA	World Bank
2,2	USA	Stanford Univ
2,2	USA	Iowa State Univ
2,0	UK	Univ Manchester
1,9	USA	Penn State Univ
1,8	USA	Univ Maryland
1,7	USA	Ohio State Univ
1,7	Canada	Univ British Columbia
1,7	Netherlands	Univ Wageningen & Res Ctr
1,6	USA	USDA
1,5	France	INRA
1,5	Germany	Potsdam Inst Climate Impact Res
1,5	Peoples R China	Tsing Hua Univ
1,5	USA	Resources Future Inc
1,3	Netherlands	Vrije Univ Amsterdam
1,3	Canada	Univ Alberta
1,3	USA	Univ Colorado
1,2	UK	Univ E Anglia
1,1	Canada	Univ Toronto
1,1	USA	Univ Wyoming
1,1	USA	Texas A&M Univ

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The following five Norwegian organisations were also found to be active in the field of social science studies on CCS.

Table 10: CCS – the most important Norwegian research organisations.

Sum of papers	Organisation	Department
1	Fridtjof Nansen Inst Polhogda	
1	Norwegian Univ Life Sci	Dept Ecol & Nat Resource Management
0,5	N Trondelag Res Inst	
0,5	Norwegian Univ Sci & Technol	Dept Econ
0,2	Det Norsk Veritas AS	

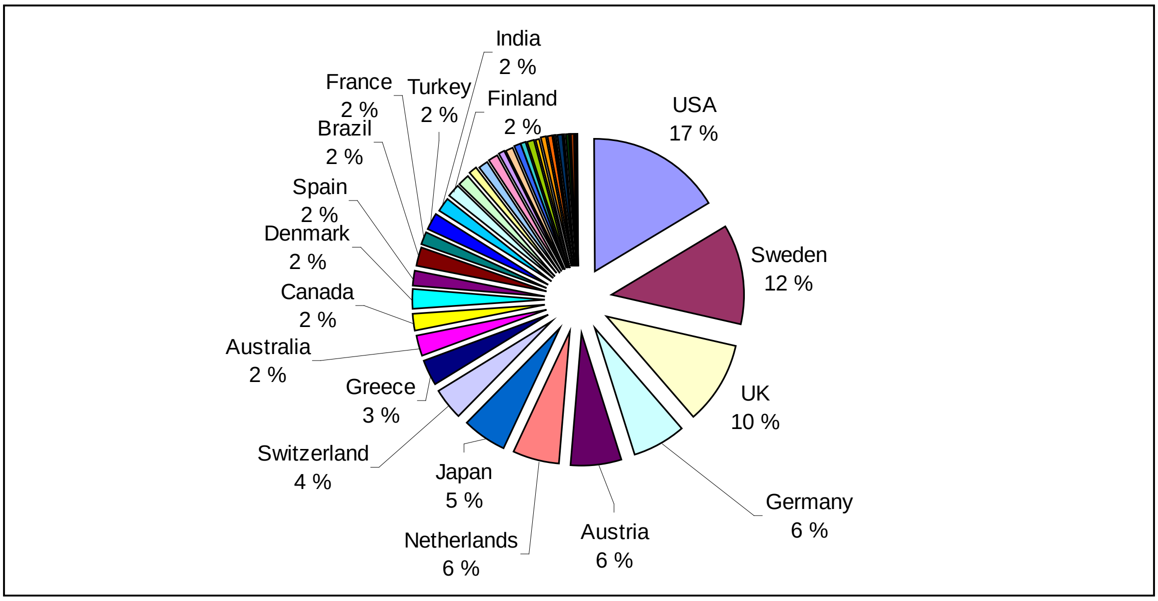
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

2.3.3 Energy system

We identified 274 papers categorised as energy system studies. The journal with the highest number of these papers was *Energy Policy*, followed by *Technological Forecasting and Social Change* and *Energy Journal*, and the most visible social science groups in the energy system sample were environmental studies and ecology and economic studies. The political sciences also showed some importance.

The international distribution is less skewed as the following figure shows. 17 per cent of all papers were published by scientists from the USA, 12 per cent by scientists from Sweden, 10 per cent from Great Britain, and Germany, Austria and the Netherlands contributed with 6 per cent each.

Figure 6: International distribution of publishing on Energy system. Based on weighted address shares. 1999-2008. N=274.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The mean number of citation by all Energy systems papers was 7.0, the median was 4. We identified all papers with at least 6 citations and in the next table the organisational affiliation of the authors is summarised. The most visible international research organisations were the International Institute for Applied Systems Analysis in Austria, Chalmers and Lund University in Sweden, and the University of California, Berkeley in USA.

Table 11: Energy system - most important international research organisations.

Sum of papers	Country	Organisation
5,0	Austria	Int Inst Appl Syst Anal
4,5	Sweden	Chalmers Univ Technol
3,1	Sweden	Lund Univ
2,8	USA	Univ Calif Berkeley
2,1	UK	Univ Sussex
2,0	Spain	Inst Empresa
2,0	Switzerland	Paul Scherrer Inst
2,0	Switzerland	Swiss Fed Inst Technol
2,0	Japan	Tohoku Univ
2,0	USA	US EPA
1,7	USA	Carnegie Mellon Univ
1,7	Netherlands	Univ Utrecht
1,5	USA	Harvard Univ
1,5	Sweden	Linkoping Inst Technol
1,3	Netherlands	Natl Inst Publ Hlth & Environm

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

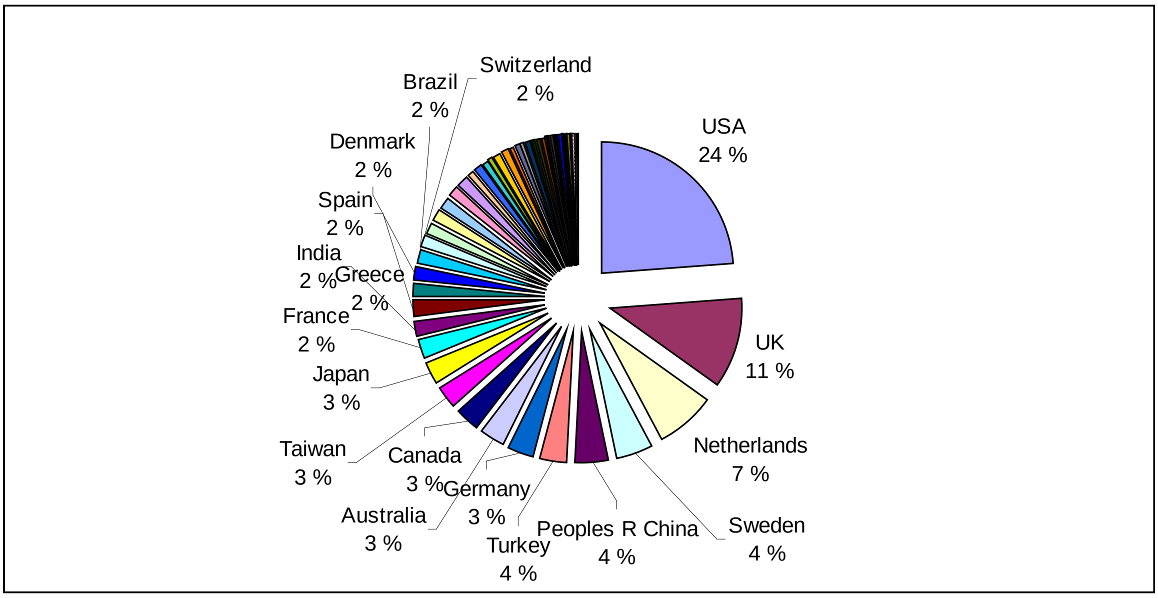
There were no Norwegian papers on energy systems in the sample.

2.3.4 Energy use

The study identified 1,222 papers categorised as energy use studies, making this the energy subject with by far the most papers overall. The journal with the highest number of these papers was *Energy Policy*, followed by *Ecological Economics*, *Energy Economics* and *Energy Journal*. The most visible social science groups in the energy use sample were environmental studies and ecology and economic studies. Some importance had also political sciences.

The international distribution is more skewed than for energy use as the following figure shows. 24 per cent of all papers were published by scientists from the USA, 11 per cent by scientists from Great Britain, 7 per cent by scientists from the Netherlands, while Sweden, Peoples Republic of China and Turkey contributed with 4 per cent each.

Figure 7: International distribution of publishing on Energy use. Based on weighted address shares. 1999-2008. N=1,222.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The mean number of citation by all Energy use papers was 6.6, the median was 4. We identified all papers with at least 5 citations and in the next table the organisational affiliation of the authors is summarised. The most visible international research organisations were the University of California, Berkeley in USA, three Dutch universities – the University of Groningen, the University of Utrecht and the Free University of Amsterdam, and The International Energy Agency, located in Paris, France.

Table 12: Energy use - most important international research organisations.

Sum of papers	Country	Organisation
14,7	USA	Univ Calif Berkeley
7,4	Netherlands	Univ Groningen
6,1	Netherlands	Univ Utrecht
5,8	France	Int Energy Agcy
5,7	Sweden	Lund Univ
5,5	Netherlands	Free Univ Amsterdam
5,3	Australia	Univ Sydney
5,0	USA	Boston Univ
4,8	Taiwan	Natl Chung Hsing Univ
4,7	India	Indira Gandhi Inst Dev Res
4,5	Peoples R China	Tsing Hua Univ
4,0	Finland	Turku Sch Econ & Business Adm
4,0	Ireland	Univ Coll Dublin
4,0	UK	Univ Sussex
3,8	Turkey	Middle E Tech Univ
3,8	Peoples R China	Peking Univ
3,5	Australia	Monash Univ
3,3	Turkey	Abant Izzet Baysal Univ
3,3	Taiwan	Natl Cheng Kung Univ
3,3	USA	Washington State Univ
3,2	Netherlands	Vrije Univ Amsterdam
3,1	Canada	Univ Toronto
3,1	Netherlands	Natl Inst Publ Hlth & Environm
3,1	USA	Carnegie Mellon Univ
3,0	USA	Univ Calif Davis
3,0	Turkey	Karadeniz Tech Univ
3,0	Taiwan	Natl Chiao Tung Univ
3,0	Norway	Stat Norway
3,0	Switzerland	Swiss Fed Inst Technol
3,0	Cyprus	Univ Cyprus
3,0	Jordan	Hashemite Univ
3,0	USA	Oak Ridge Natl Lab
3,0	Australia	Griffith Univ

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Energy use is also a common research subject for Norwegian research organisations as the following table shows. Beside several universities, such as the NTNU, the University of Oslo, the University of Bergen and the UMB, there are also several research institutes quite active in this field: Statistics Norway, SNF and Cicero, but also several other institutes.

Table 13: Energy use – the most important Norwegian research organisations.

Sum of papers	Organisation	Department
1,0	Agr Univ Norway - umb	Dept Econ & Social Sci
0,3	Cent Bank Norway	
1,0	Cicero - Ctr Int Climate & Environm Res Oslo	
1,5	Fdn Res Econ & Business Adm - SNF	
0,5	NUPI - Norwegian Inst Int Affairs	
1,0	Norwegian Univ Sci & Technol	Dept Interdisciplinary Studies Culture
1,0	Norwegian Univ Sci & Technol	Dept Prod & Qual Engn
0,7	Norwegian Univ Sci & Technol	Dept Elect Power Engn
0,2	Norwegian Univ Sci & Technol	Dept Energy
0,2	Norwegian Univ Sci & Technol	Proc Engn & Ind Ecol Programme
0,3	Ragnar Frisch Ctr Econ Res	
4,3	Stat Norway	
1,0	Univ Bergen	Dept Econ
0,5	Univ Bergen	Dept Informat Sci
1,0	Univ Oslo	Dept Econ
0,5	Univ Oslo	Ctr Dev & Environm
0,5	Univ Oslo	Ctr Hlth Adm
0,5	Univ Oslo	ProSus
0,5	Western Norway Res Inst	

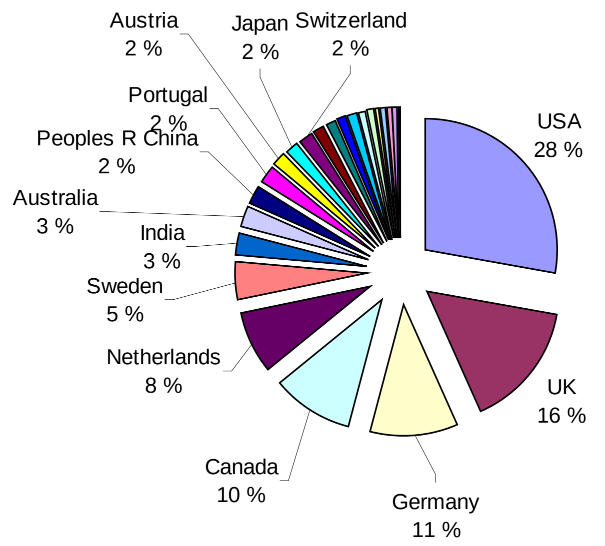
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

2.3.5 Hydrogen

The study identified 93 social science papers on hydrogen, one of the less targeted energy subjects. The journal with the highest number of papers was also here *Energy Policy,* and the most visible social science groups in the hydrogen sample were also here environmental studies and ecology, and economic studies.

Which countries publish most on hydrogen? The distribution is less skewed than for other energy subjects as the following figure shows. 28 per cent of all papers were published by scientists from the USA, 16 per cent by scientists from Great Britain, 11 per cent from Germany, 10 per cent from Canada, 8 per cent by scientists from the Netherlands, while Sweden and Turkey contributed with 5 per cent of the papers, and India and Australia with 3 per cent each.

Figure 8: International distribution of publishing on Hydrogen. Based on weighted address shares. 1999-2008. N=93.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The mean number of citation by all hydrogen papers was 8.4, the median was 3. We identified all papers with at least 5 citations and in the next table the organisational affiliation of the authors is summarised. We include here only those organisations with at least one paper based on weighted address shares. The most visible international research organisations were the University of Utrecht in the Netherlands and Chalmers in Sweden.

Table 14: Hydrogen – most important international research organisations.

Sum of papers	Country	Organisation
3,0	Netherlands	Univ Utrecht
3,0	Sweden	Chalmers Univ Technol
2,0	UK	Univ London Imperial Coll Sci Technol & Med
1,5	Austria	Int Inst Appl Syst Anal
1,5	USA	Univ Calif Davis
1,5	USA	Univ Michigan
1,0	USA	Clark Commun LLC
1,0	USA	Ctr Energy & Climate Solut
1,0	Germany	Fraunhofer Inst Syst & Innovat Res
1,0	USA	Hydrogen Res Inst
1,0	Australia	Murdoch Univ
1,0	USA	Princeton Univ
1,0	Germany	Tech Univ Berlin
1,0	Peoples R China	Tsing Hua Univ
1,0	Canada	Univ Alberta
1,0	UK	Univ Birmingham
1,0	Germany	Univ Hohenheim
1,0	Canada	Univ Toronto
1,0	Canada	Univ Waterloo
1,0	Germany	Wuppertal Inst Climate Environm Energy

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

There were only two social science articles on hydrogen with a Norwegian author address, which were published by NIFU STEP.

Table 15: Hydrogen – the most important Norwegian research organisations.

Sum of papers	Organisation	Country
0,7	NIFU STEP	Norway

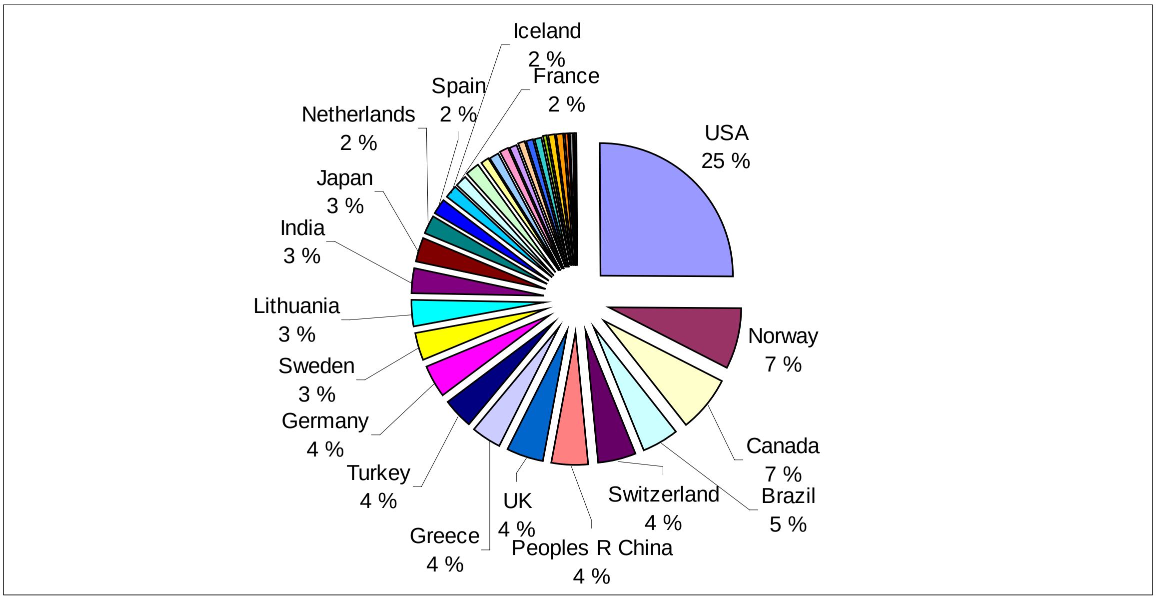
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

2.3.6 Hydropower

We identified 135 papers with relevance for hydropower. The journal with the highest number of papers was *Energy Policy* and the most visible social science groups in the sample were environmental studies and ecology, and to some extent also economic studies.

The international distribution is less skewed than for other energy subjects as the following figure shows. 25 per cent of all papers were published by scientists from the USA, 7 per cent by scientists from Norway and Canada, 5 per cent from Brazil, while Switzerland, Peoples Republic of China, UK, Greece, Turkey and Germany contributed with 4 per cent each.

Figure 9: International distribution of publishing on Hydropower. Based on weighted address shares. 1999-2008. N=135.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The mean number of citation by all hydropower papers was 5.0, the median was 3. We identified all papers with at least 4 citations and in the next table the organisational affiliation of the authors is summarised. The papers with Norwegian addresses are too scattered among different actors and most did not receive enough citations to be included in this table. The most visible international research organisations were the TEI Piraeus in

Greece, the Lithuanian Energy Institute in Lithuania and Tsing Hua University in Peoples Republic of China.

Table 16: Hydropower – most important international research organisations.

Sum of papers	Country	Organisation
3,0	Greece	TEI Piraeus
2,0	Lithuania	Lithuanian Energy Inst
2,0	Peoples R China	Tsing Hua Univ
1,7	USA	Univ Michigan
1,0	Norway	ABB Financial Serv
1,0	Kenya	African Energy Res Policy Network
1,0	UK	Aqua Media Int Ltd
1,0	USA	Calif State Univ Fullerton
1,0	Canada	Consultants LBCD Inc
1,0	Turkey	Cukurova Univ
1,0	USA	Florida Int Univ
1,0	Germany	Free Univ Berlin
1,0	Japan	Hitotsubashi Univ
1,0	Germany	Lahmeyer Int GMBH Consulting Engineers
1,0	Turkey	Mugla Univ
1,0	Peoples R China	Peking Univ
1,0	USA	Stockholm Environm Inst
1,0	Greece	Tech Univ Crete
1,0	USA	Univ Calif Davis
1,0	Tanzania	Univ Dar Es Salaam
1,0	Iceland	Univ Iceland
1,0	USA	Univ Missouri
1,0	UK	Univ Oxford
1,0	Australia	Univ Queensland
1,0	Sweden	Univ Stockholm
1,0	USA	Univ Tennessee
1,0	USA	Univ Washington
1,0	Greece	Univ Western Macedonia
1,0	USA	US Bur Reclamat

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

There were many Norwegian research organisations involved in social science papers on hydropower, but none of them had a dominating position. Important to notice is also the contribution of companies in such papers, such as ABB Finance Service, Statnett or Statkraft.

Table 17: Hydropower – the most important Norwegian research organisations.

Sum of papers	Organisation	Department
2,0	Stat Norway	Res Dept
1,0	ABB Financial Services	Treasury Ctr
1,0	Bodo Univ Coll	Bodo Grad Sch Business
1,0	Norwegian Competition Authority	
1,0	UMB - Norwegian Univ Life Sci	Dept Econ & Resource Management
1,0	Norwegian Univ Sci & Technol	Dept Ind Econ & Technol Management
0,5	CICERO	
0,5	BI - Norwegian Sch Management	Dept Innovat & Econ Org
0,3	Univ Bergen	Dept Econ
0,3	NORAD	
0,3	Statnett	
0,3	Statkraft	
0,3	Univ Oslo	Dept Econ

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

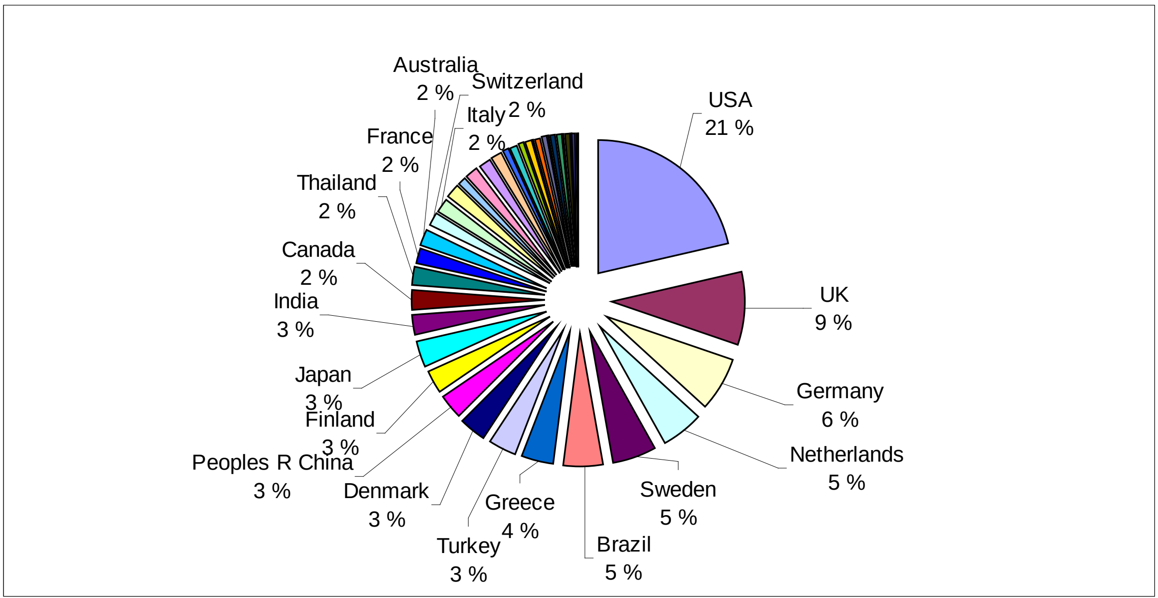
2.3.7 Renewable energy production in general

We identified 225 papers with relevance for renewable energy production in general. The journal with the highest number of papers was *Energy Policy* and the most visible social science groups in the sample were environmental studies and ecology and to some extent also economic studies.

Which countries publish most on renewable energy in general? Despite of the high share of U.S. papers the distribution is less skewed than for many specialised energy subjects as the following figure shows. 21 per cent of all papers were published by scientists from the USA, 9 per cent by scientists from UK, 6 per cent from Germany, while the Netherlands, Sweden and Brazil contributed with 5 per cent each.

The mean number of citation by all renewable energy production papers was 5.1, the median was 3. We identified all papers with at least 4 citations and in the next table the organisational affiliations of the authors are summarised. The most visible international research organisations were the Risø National Laboratory in Denmark (now a part of the DTU), Chalmers in Sweden, the Tokyo Institute of Technology in Japan, the London Imperial College in the UK and the University of Stuttgart in Germany.

Figure 10: International distribution of publishing on renewable energy production in general. Based on weighted address shares. 1999-2008. N=225.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 18: Renewable energy production i general – most important international research organisations.

Sum of papers	Country	Organisation
4,0	Denmark	Riso Natl Lab
2,0	Sweden	Chalmers
2,0	Japan	Tokyo Inst Technol
2,0	Netherlands	Univ Groningen
2,0	UK	Univ London Imperial Coll Sci Technol & Med
2,0	Germany	Univ Stuttgart
1,7	USA	MIT
1,5	Sweden	Lund Univ
1,5	South Africa	Univ Cape Town
1,5	USA	Univ Calif Berkeley
1,3	USA	George Washington Univ
1,3	USA	Univ Oregon

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

There were only few papers published by Norwegian research groups as the following table shows.

Table 19: Renewable energy production in general – the most important Norwegian research organisations.

Sum of papers	Organisation	Department
0,5	CICERO	
0,5	Econ Poyry	
0,5	UMB - Norwegian Univ Life Sci	Dept Econ & Resource Management

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

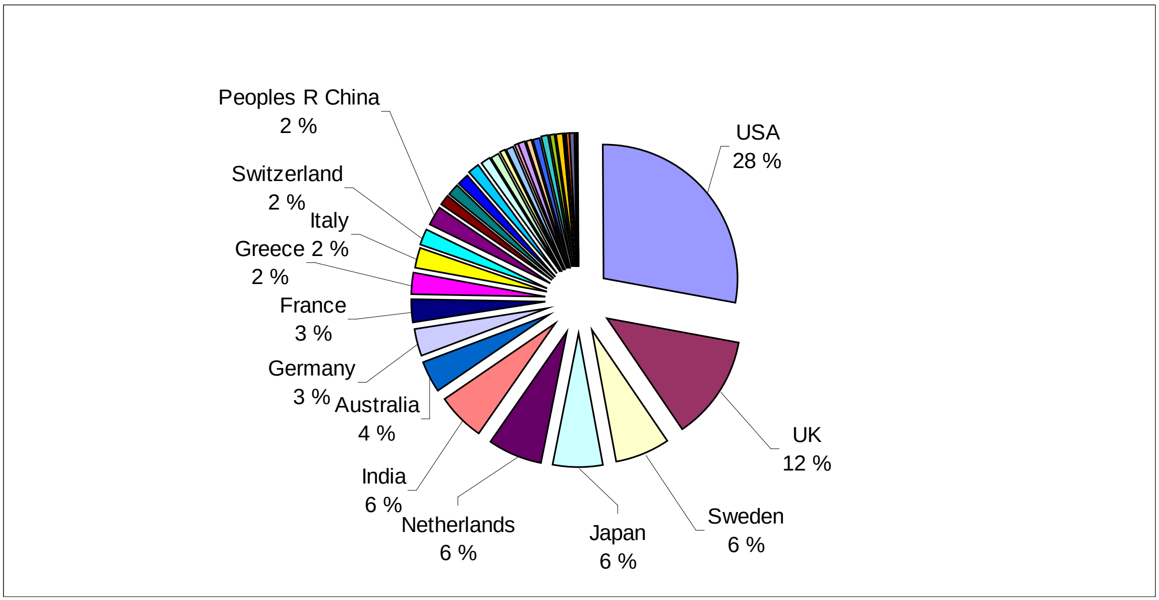
2.3.8 Solar photovoltaic

We identified 147 papers with relevance for solar photovoltaic energy. The journal with the highest number of papers was *Energy Policy* and the most visible social science groups in the sample were environmental studies and ecology and economic studies.

The international distribution is rather skewed as the following figure shows. 28 per cent of all papers were published by scientists from the USA, 12 per cent by scientists from UK, while Sweden, Japan, the Netherlands and India contributed with 6 per cent each.

The mean number of citation by all solar photovoltaic papers was 7.4, the median was 5. We identified all papers with at least 6 citations and in the next table the organisational affiliation of the authors is summarised. The most visible international research organisations were the University of California in Berkeley, USA, the Tokyo Institute of Technology in Japan, Chalmers in Sweden, Princeton University in USA and the University of Surrey in UK.

Figure 11: International distribution of publishing on solar photovoltaic. Based on weighted address shares. 1999-2008. N=147.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 20: Solar photovoltaics – most important international research organisations.

Sum of papers	Country	Organisation
3,7	USA	Univ Calif Berkeley
3,0	Japan	Tokyo Inst Technol
2,5	Sweden	Chalmers Univ Technol
2,5	USA	Princeton Univ
2,5	UK	Univ Surrey
2,0	USA	Denison Univ
2,0	USA	Natl Renewable Energy Lab
2,0	UK	Univ Cambridge
1,5	USA	Brookhaven Natl Lab
1,5	Peoples R China	Shanghai Jiao Tong Univ
1,5	Netherlands	Univ Utrecht
1,3	USA	Univ Michigan

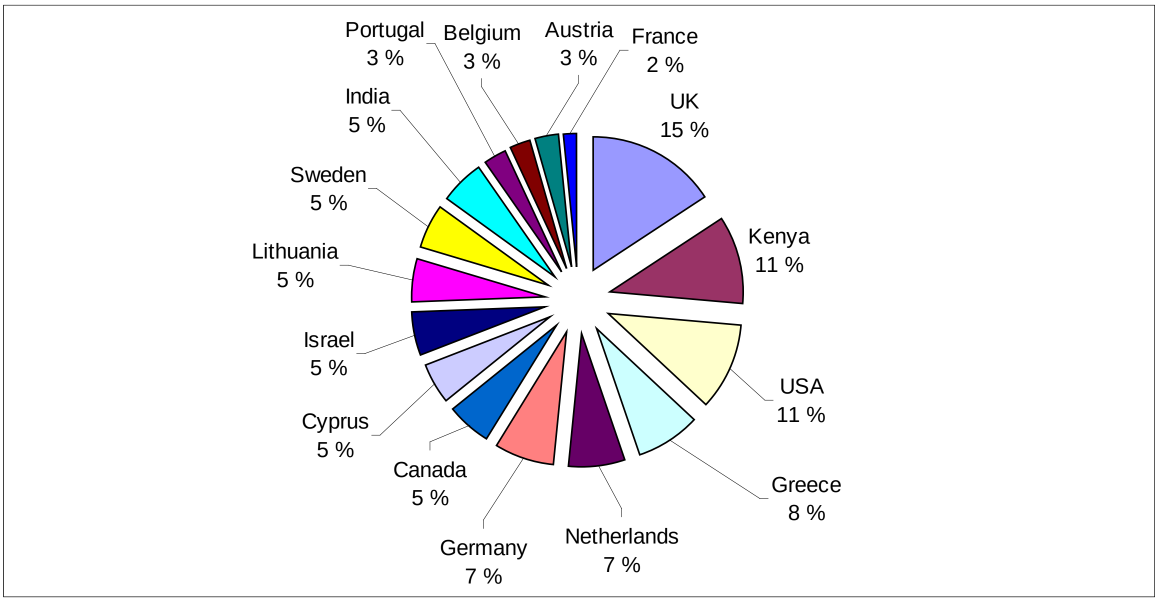
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

There were no Norwegian papers in the sample.

2.3.9 Solar thermal

Only 20 papers with relevance for solar thermal energy were identified. The journal with the highest number of papers was *Energy Policy* and the most visible social science groups in the sample were environmental studies and ecology.

Figure 12: International distribution of publishing on solar thermal. Based on weighted address shares. 1999-2008. N=20.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Which countries publish most on solar thermal? The distribution of the rather few papers is rather even as the following figure shows. This is the only topic where an African country, Kenya, could achieve a high share. Due to the low number of papers we cannot draw clear conclusions from the data.

The mean number of citation by all solar thermal papers was 4.9, the median was 3. We identified all papers with at least 4 citations and in the table the organisational affiliation of the authors is summarised.

Table 21: Solar thermal – most important international research organisations.

Sum of papers	Country	Organisation
2	Kenya	African Energy Res Policy Network
1	Sweden	Chalmers Univ Technol
1	Canada	Eco Innovate
1	India	Indian Inst Technol
1	USA	Univ Calif Berkeley

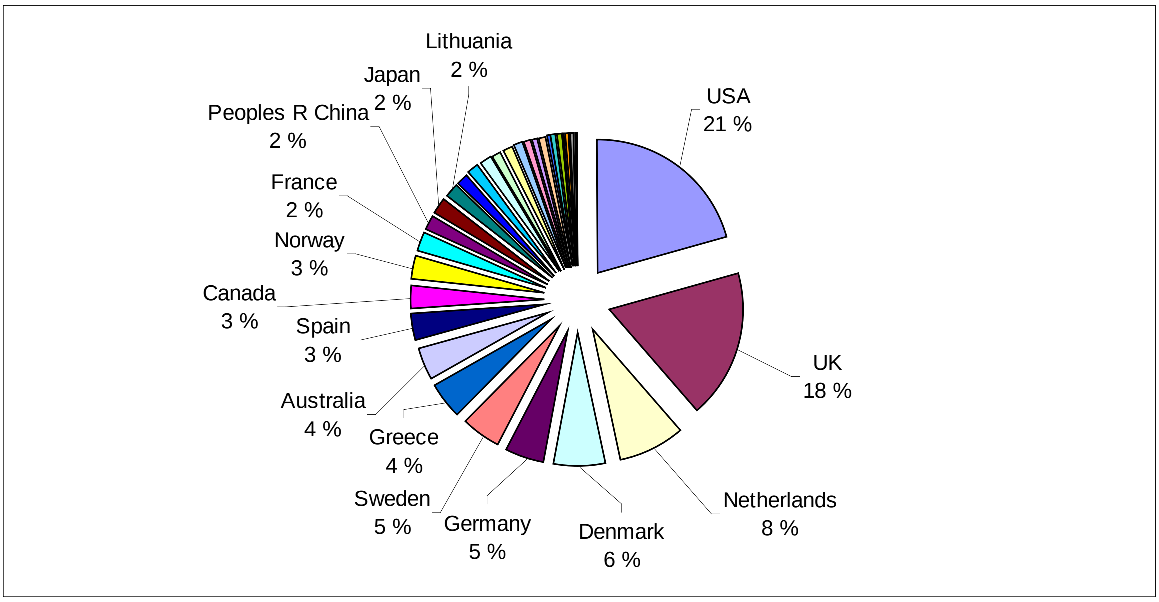
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

There were no Norwegian papers in the sample.

2.3.10 Wind

We identified 293 papers with relevance for wind energy. The journal with the highest number of papers was *Energy Policy* and the most visible social science groups in the sample were environmental studies and ecology. Some importance had also economic studies and political sciences.

Figure 13: International distribution of publishing on wind. Based on weighted address shares. 1999-2008. N=293.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The international distribution is rather skewed as the following figure shows. 21 per cent of all papers were published by scientists from the USA and 18 per cent by scientists from

UK, while scientists from the Netherlands had 8 per cent of the papers and Denmark published 6 per cent of the papers.

The mean number of citation by all solar photovoltaic papers was 7.4, the median was 4. We identified all papers with at least 6 citations and in the next table the organisational affiliation of the authors is summarised. The research organisations with the highest output were University of Utrecht in the Netherlands, the Technical University of Denmark, the TEI Piraeus in Greece, and University of Birmingham in Great Britain.

Table 22: Wind – most important international research organisations.

Sum of papers	Country	Organisation
6,5	Netherlands	Univ Utrecht
5,5	Denmark	Tech Univ Denmark & Riso Natl Lab
5,0	Greece	TEI Piraeus
3,5	UK	Univ Birmingham
3,0	USA	Carnegie Mellon Univ
2,2	USA	MIT
2,0	USA	Arizona State Univ
2,0	Sweden	Lulea Univ Technol
2,0	Netherlands	Univ Amsterdam
2,0	Spain	Univ Las Palmas Gran Canaria
2,0	UK	Univ London Imperial Coll Sci Technol & Med
2,0	USA	Univ Wisconsin
2,0	Finland	VTT Proc
2,0	USA	Univ Delaware
1,8	USA	Princeton Univ
1,5	Sweden	Chalmers Univ Technol
1,5	Sweden	Lund Univ
1,5	UK	Univ Glasgow
1,5	Germany	Univ Karlsruhe
1,5	UK	Univ Newcastle Upon Tyne
1,3	USA	Environm Def

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

There were many Norwegian research organisations involved in social science papers on wind energy, but none of them had a dominating position. Important to notice is also the contribution of companies in such papers, such as Statnett and Statkraft.

Table 23: Wind – the most important Norwegian research organisations.

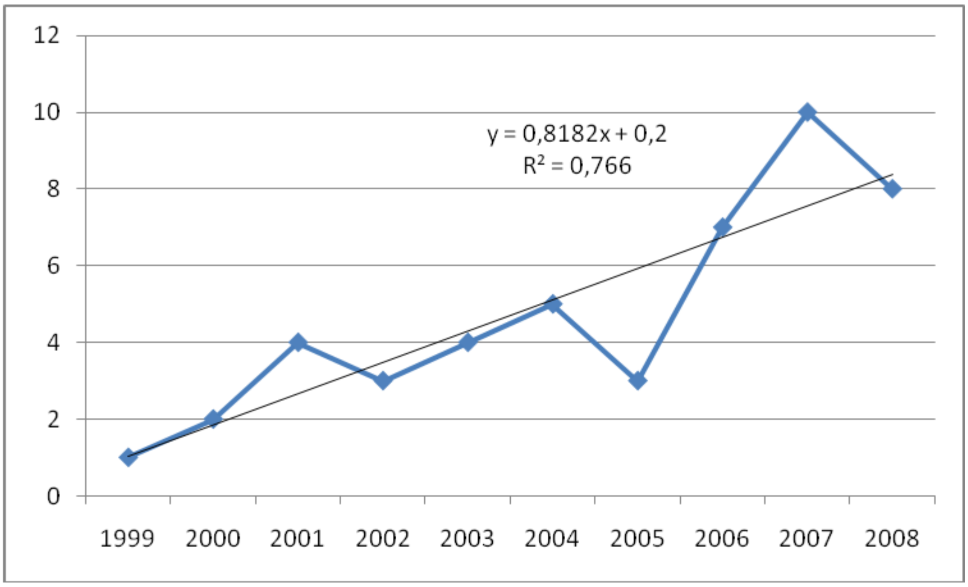
Sum of papers	Organisation	Department
1,5	UMB - Norwegian Univ Life Sci	Dept Econ & Resource Management
1,0	CICERO - Ctr Int Climate & Environm Res	
1,0	ECON Ctr Econ Anal	
1,0	Norwegian Univ Sci & Technol	
0,7	Univ Bergen	Dept Econ
0,5	Univ Bergen	Dept Geog
0,5	BI - Norwegian Sch Managment	
0,5	Econ Poyry	
0,3	NORAD	
0,3	Statnett	
0,3	Statkraft	
0,3	Univ Oslo	Dept Econ

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

2.4 Norwegian activities

There were 47 papers in the sample with at least one author linked to a Norwegian address. As shown in the graph below (figure 14) the number of papers has increased over time, with a steeper increase in recent years, following a decrease in 2005. A list of all of these Norwegian papers is provided in the Annex (8.2).

Figure 14: Number of papers with Norwegian addresses over time. N=47. 1999.-2008



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The most common journal for Norwegian publications is *Energy policy:* 44 percent of all Norwegian papers were published there. The main social science groups represented by these Norwegian publications are Environmental Studies and Ecology (29 papers) and Economics, Business and Management (18 papers). Five papers are found in the group Political science, Planning, Public Administration and International relations.

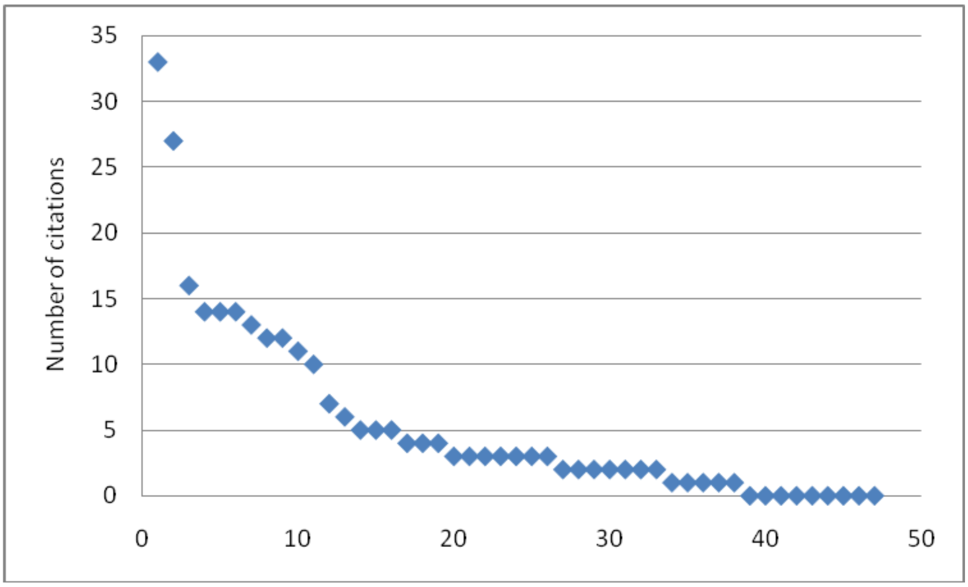
Table 24: The journals where Norwegian papers were published. N=47.

Journal title	1999-2003	2004-2008
ENERGY POLICY	6	16
ENERGY ECONOMICS	3	3
ENVIRONMENTAL & RESOURCE ECONOMICS	2	1
SCANDINAVIAN JOURNAL OF ECONOMICS	1	1
CLIMATE POLICY	0	1
ECOLOGICAL ECONOMICS	0	1
ECONOMIC MODELLING	1	0
ENERGY JOURNAL	0	1
ENVIRONMENT AND PLANNING C-GOVERNMENT AND POLICY	1	0
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	0	1
FOREST POLICY AND ECONOMICS	0	1
INTERNATIONAL JOURNAL OF URBAN AND REGIONAL RESEARCH	0	1
JOURNAL OF ECONOMIC PSYCHOLOGY	0	1
JOURNAL OF FOREST ECONOMICS	0	1
MARINE POLICY	0	1
REVUE D ECONOMIE POLITIQUE	0	1
SCIENTOMETRICS	0	1
URBAN STUDIES	0	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The Norwegian papers received 256 citations altogether, an average 5.4 citations per paper. However the numbers of citations are very unevenly distributed across the papers: nine papers received no citations, five papers received one citation and three papers received more than 25 citations (see figure 15). Most of the papers with no citations are recently published (2007–08), while the three highly cited papers were published in 2001, 2002 and 2004 respectively, and have collected citations over a longer period.

Figure 15: Number of citations for Norwegian papers. N=47. 1999-2008.



Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

The following table gives an overview of all Norwegian organisations involved in this sample of published papers. They represent a range of organisation types and industries. There are four firms in the sample, ABB Financial Services, Det Norske Veritas AS, Statkraft and Statnett. Among the universities, the NTNU is most visible (8 papers), followed by the University of Bergen (5 papers) and the University of Oslo (4 papers). However, there are several organisations affilated to the University of Oslo, such as the ProSus centre (1 paper) – which is however now a part of Sintef, and CICERO (4 papers). The Norwegian University of Life Sciences (UMB) produced 6 papers and the Norwegian School of Management 2 papers. The university colleges produced only one paper (Bodø University College). The Norwegian institute sector contributed with a considerable amount of papers, where Statistics Norway has a clear leadership with 8 papers, followed

Table 25: Norwegian organisations with at least one paper in the sample. N=47

Organisation name	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	*Total*
ABB Financial Serv			1								*1*
Bodo Univ Coll									1		*1*
Cent Bank Norway			1								*1*
CICERO				1	1			1		1	*4*
Det Norsk Veritas AS									1		*1*
ECON Ctr Econ Anal				1							*1*
Econ Poyry										1	*1*
Fdn Res Econ & Business Adm		1									*1*
Fridtjof Nansen Inst Polhogda									1		*1*
N Trondelag Res Inst				1			1				*2*
NIFU STEP								1	1		*2*
NORAD										1	*1*
Norwegian Competit Author								1			*1*
Norwegian Inst Int Affairs					1						*1*
Norwegian Sch Management					1	1					*2*
Norwegian Univ Life Sci						1		1	2	2	*6*
Norwegian Univ Sci & Technol				1		1		1	2	3	*8*
ProSus						1					*1*
Ragnar Frisch Ctr Econ Res			1								*1*
SNF						1					*1*
Statistics Norway	1		3		2		1			1	*8*
Statkraft										1	*1*
Statnett										1	*1*
Univ Bergen		1				1		2	1		*5*
Univ Oslo						1	1		1	1	*4*
Western Norway Res Inst							1				*1*
Total	*1*	*2*	*6*	*4*	*5*	*7*	*4*	*7*	*10*	*12*	*58*

Full counts have been used here. Because of co-authorship the sum of papers is higher than 47.
Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

by CICERO (4), and several institutes with one or two papers – Econ Poyri (the Norwegian branch of the Finnish consultancy), Fridtjof Nansen Institute, Nord-Trøndelag Research Institute, NIFU STEP, NUPI, Ragnar Frisch Centre, SNF and Western Norway Research Institute.

Based on these results, Norwegian social science research on energy appears to be somewhat underdeveloped and highly fragmented. Beside activities at the NTNU, Statistics Norway, the Norwegian University of Life Sciences and the University of Oslo (including CICERO) there are very limited publishing activities, resulting in few papers. This may be an indication of a lack of strategic funding in this field which will be studied further on in this report. On a more positive note, there seem to be an increase in papers published by Norwegian organisations, for 2007/2008, perhaps reflecting an increased focus or better funding developing within this area.

2.5 Concluding remarks

This chapter presents an analysis of social science papers on environmentally friendly energy based on the ISI Web of Science Social Science Citation Index. The study identified 2,459 relevant publications (period 1999 to 2008) published in 303 different journals. The most important journals identified are *Energy Policy*, *Energy Economics* and *Ecological Economics*. The publications are concentrated in three groups of social science disciplines: economics, business and management studies; environmental studies and ecology; and, to extent lesser extent, political sciences, including planning, public administration and international relations. Typical social science disciplines, such as sociology or anthropology, are almost invisible in the sample. It also emerged that many of the publications are published in journals which belong to a mixture of social science disciplines, indicating that the sample is dominated by multidisciplinary papers. This is especially the case for the papers belonging to environmental studies and ecology.

The analysis indicates that environmentally friendly energy has increased in importance within social science publishing. There is an increasing trend for all energy subjects, but the highest increase can be seen for energy use and bio-energy, while the other subjects have a more modest development. The energy subject area with the most publications overall is energy use, while carbon capture and storage (CCS) and wind technology are next in terms of numbers of papers.

The distribution of papers by country in the different energy subjects shows that while some countries are active in all energy subjects, such as the USA, Great Britain, the Netherlands, Sweden, Germany, Canada, Greece, Austria and France, other countries are more specialised on one or two selected energy fields, such as Japan, China, Australia and

Denmark among others. It is also important to note the high publication output of the Netherlands and Sweden.

Norwegian papers could be identified in seven out of ten energy subjects, with hydropower and wind as the main strongholds. Overall it can be concluded that environmentally friendly energy does not appear as a particularly high priority target in Norwegian social science. The research field is still relatively underdeveloped and highly fragmented. However, there is an increase in papers published by Norwegian organisations, for the last two years, reflecting an increased focus or better funding within this area. Outside the activities at the NTNU, Statistics Norway, the Norwegian University of Life Sciences and the University of Oslo (including CICERO), there are very limited activities, resulting in few papers. This may be an indication of a lack of strategic focus in this field. The sample of Norwegian papers is further examined in the chapter on Norwegian activities in the field (Chapter 6). Finally, a sample of 109 highly cited papers has been defined, including all papers with more than 25 citations. This sample is scrutinised in the chapter on the international literature (Chapter 4).

3 International social science research projects on new environmentally friendly technologies

3.1 Introduction

The chapter provides an overview of the position of social science research into environmentally friendly technologies within international research programmes. It focuses on a selected portfolio of projects, based around three important research funding bodies: the EU's 6th Framework Programme (FP6), Nordic Energy Research (NER) and the International Energy Agency (IEA). These research funding institutions have been chosen as a focus for this study as we expected Norwegian research actors to be particularly active within these contexts. We have approached these three research funders with three overall questions:

- To what extent do these actors support energy research projects based on social science research approaches or disciplines?
- If such research is present, what are the main disciplines of social science addressed by these projects?
- If such research is present, what are the main energy subjects covered by these projects?

3.2 The EU's sixth Framework Programme

The research and project activities that take place under all of the EU's framework programmes are potentially relevant for this project. Due to constraints of time and resources we have limited the study to two important EU programmes. Firstly, we have searched for projects within the 6th Framework Programme (FP6). Secondly, we have searched for energy projects in the European Commission's Socio-economic Sciences and Humanities (SSH) programme, which implements and disseminates results on EU research policies and activities that address changes facing the social, economic, political and cultural make-up of Europe.

3.2.1 Data sources and methods

The method used to map social science research projects on renewable energy issues within FP6 involved simple searches within the webpage CORDIS, the homepage of the FP6[4]. The website contains a 'find a project' section and simple search facility for projects, based on keywords (see table 25). FP6 projects are grouped by different types (based on EU criteria), and we have included all of these in our searches[5]. We conducted a series of

---

4 http://cordis.europa.eu/fp6/dc/idndex.cfm?fuseaction=UserSite.FP6HomePage

5 The types of project include Networks of Excellence, Integrated Projects, Specific Targeted Research Projects, Specific Targeted Innovation Projects, Coordination Action, Specific Support Action, SMEs co-operative Research Contracts, SMEs co-operative Research Projects, and a number of other project types. For all details see http://cordis.europa.eu/fp6/projects.htm#search

searches, each search providing a list of projects and project fact sheets containing the project's acronym and title, abstract, contact person and institution, project details (period, duration, status, costs and funding) and finally a list of project participants in terms of institutions (not persons).

The 'Find a project' search facility is not very sophisticated, and caused some methodological challenges in the search for social science renewable energy research within the FP6. Two key challenges were encountered in these searches. The projects are often duplicated, having been registered twice with slightly different information. Furthermore, information about the projects, in particular project abstracts, is often incomplete or missing a full elaboration of objectives. These limitations to the search outputs had implications for the accuracy of the searches and for how far a full overview of these projects can be established. It proved too time-consuming to go into the website for each project, to identify the objectives, research methods and the main findings of the projects, so this additional information was gathered for a limited number of cases only. Therefore, in most cases we have been only been able to describe and analyse information based on project titles, and (sometimes incomplete) abstracts.

The table below gives overview of the searches for projects in FP6 that have been done.

Table 26: Overview of search for renewable energy projects in FP6.

Keyword	Project hits	Projects with social science components	Comments
Energy system	179		Too broad
Energy use	188		Too broad
Renewable energy	486	Ca. 35	- very broad search, includes all technology areas in this table - includes water/environment and climate change related and transport research etc. - includes different interactive projects with relevance to sustainable policy and energy policy.
Biomass	52	17	many different projects with social science research components but none only social science research
Wind	35	14	many different projects with social science research components but none only social science research
CCS	23	4	
Solar photovoltaic	20	3	
Solar thermal	20	3	
Hydrogen	67	3	'Hydrogen' as key word seems to broad/ imprecise, gives many multi-technology project hits
Hydro energy/ Hydro power/ Hydropower	15/ 5/ 4	2	
Wave	17	1	
Geothermal	8		

The method used to search for energy projects within the European Commission's Socio-economic Sciences and Humanities (SSH) programme applied a simple search for the keyword 'energy' in the 'search project' feature on the SSH main website[6]. These searches yield a range of information: each hit retrieved text summarizing the project's background, objectives, work undertaken, and key outcomes/conclusions. Project details are also presented and in some cases there are links to final project reports.

These initial searches for energy projects in the SSH programme identifed ten projects, of which only two address the energy sector in one way or another. One project investigates how governance, infrastructure and lifestyle dynamics influence energy demand from the perspective of European post-carbon communities (this project looks at the cases of the Czech Republic, Germany, Hungary, The Netherlands and the UK). The second project investigates five themes related to tax and benefits systems and the growth potential of the EU, both in terms of scientific research and in terms of policy-orientated research. It includes one theme that considers the role of green taxes and emission trading in the energy sector.

3.2.2 Project activity areas

Projects within the FP6 are organised in 20 different thematic project activity areas[7]. Energy related projects can be found in about 10 of these 20 areas. While searches with the keywords 'energy', 'renewable' or 'sustainable' give hits, nearly all the projects featured are technical or technological energy projects. We could only find renewable energy projects with social science components or with social science objectives in three of these activity areas: 'Research for Policy Support', 'Joint Research Centre' and 'Marie Curie Actions'. The (small number of) relevant projects found in these areas typically were organisation of networks, so-called coordinated actions, specific support actions, and technology platforms. These projects seem to share a focus on on interaction and the dynamics around energy policy.

3.2.3 General findings: Social science research projects

The area with the most relevant activity on social science renewable energy in FP6 is called 'Sustainable development, global change and ecosystems'. We have therefore focused on this activity area, which includes 721 projects. Of these projects, 486 are listed when we search by the keyword 'renewable energy'. While we have not been able to go through each and every one of these projects in terms of detailed contents, an initial look at the search list makes it evident that most of these hits are not relevant to our study. The search term 'renewable energy' leads to very broad results, as we note in Table 27 (Chapter 6). The largest category within these search results is technical research projects, typically on one or several renewable energy technologies, but the results also relate to

---

6 For details see http://ec.europa.eu/research/social-sciences/projects/search_en.cfm

7 For details see http://cordis.europa.eu/fp6/projects.htm#search

other very broad environmental themes such as sustainable land based transport, marine transport, sustainable housing, agriculture, sustainable fresh water supplies and so on.

A number of these more technologically oriented projects have social science components. About 35 of the 486 projects have some social science components, amongst which we observed some common topics or features. Generally, these projects include components that address issues of economic, socio-economic, managerial, strategic or environmental concern, and therefore build a degree of social relevance or a more interactive perspective into the technical subject of the project. These common features seem to reflect the nature of energy debates: energy is a basic good in societies, energy consumption is a socially constructed process, and energy use is part of large, complex technological systems. However, the project components that we define as social science or dependent on social science often play only a minor part in the overall projects. Looking at abstracts and occasionally at project websites, it seems that the typical role of social science components relates to reflections on or recommendations for regulatory behaviour and policy practice. Social science issues are built into these projects in a number of ways: some projects include specific work packages that address relevant environmental impact concerns and go on to discuss regulatory and policy options; others include guidelines for best practice for the industry, policy makers and regulators; some projects take account of socio-economic impacts of different technologies on biodiversity and ecosystems; and, in other projects methods and tools based on social science approaches for integrated sustainability assessment are addressed.

Many of the projects that have social science components have a more processual character: they typically include workpackages and activities which aim to demonstrate a technology and/or processes, to establish a basis for the standardisation of that technology/process. In such projects, issues of management and implementation of technology are often important concerns, reflecting the complex and systemic character of the technology. Again, these features of the project seem to require a social science component, typically focused on management, planning or organisational issues. The background for this is the broad societal function and significance of energy technologies. They supply a product that is simple but of fundamental significance for human life.

There is another example of projects that have strong social science relevance. A small number of the projects are networking programmes and collaboration exercises. It may be networks of excellence and different coordinated actions within the different relevant technological domains; bio energy, wind energy etc. The project type Coordinated actions typically include components and activities such as organisation of conferences, meetings and workshops, exchange of personnel, the exchange and dissemination of good practices, and setting up common information systems and expert groups. Setting up secretariats for renewable energy technology platforms is an identified project illustrating this.

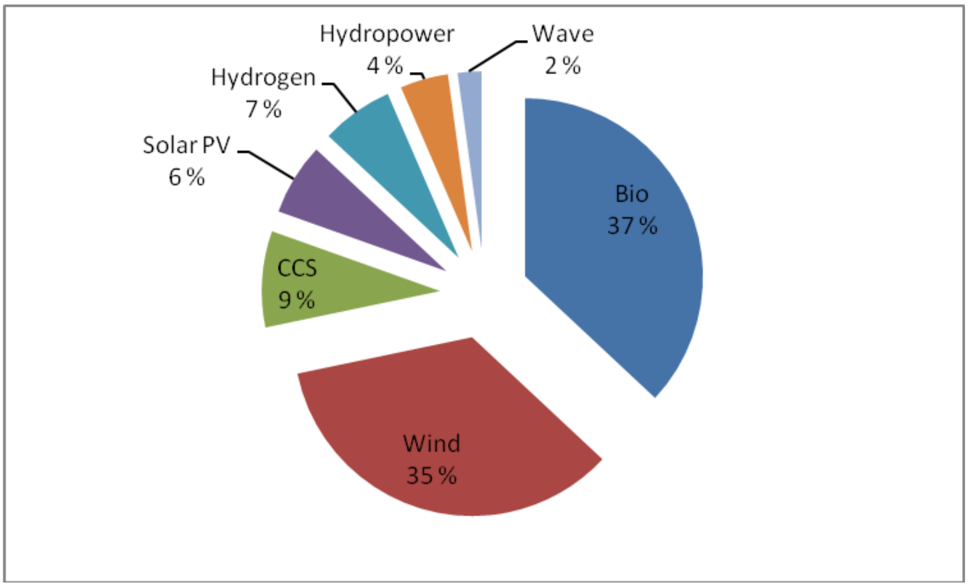
3.2.4 Technology specific keywords and projects

In addition to the search with the keywords ‘renewable energy’, we used specific searches for various technologies.

When using technology specific keywords in the search engine on the Cordis FP6 website, we found that some of the hits overlapped with results from the more general term ‘renewable energy’. This is due to many of the projects addressing renewable energy feature also specific technology themes or examples (for example wind energy).

The distribution of FP6 projects by renewable energy technology is summarised in Figure 16 and reveals the dominating position of bio-energy and wind.

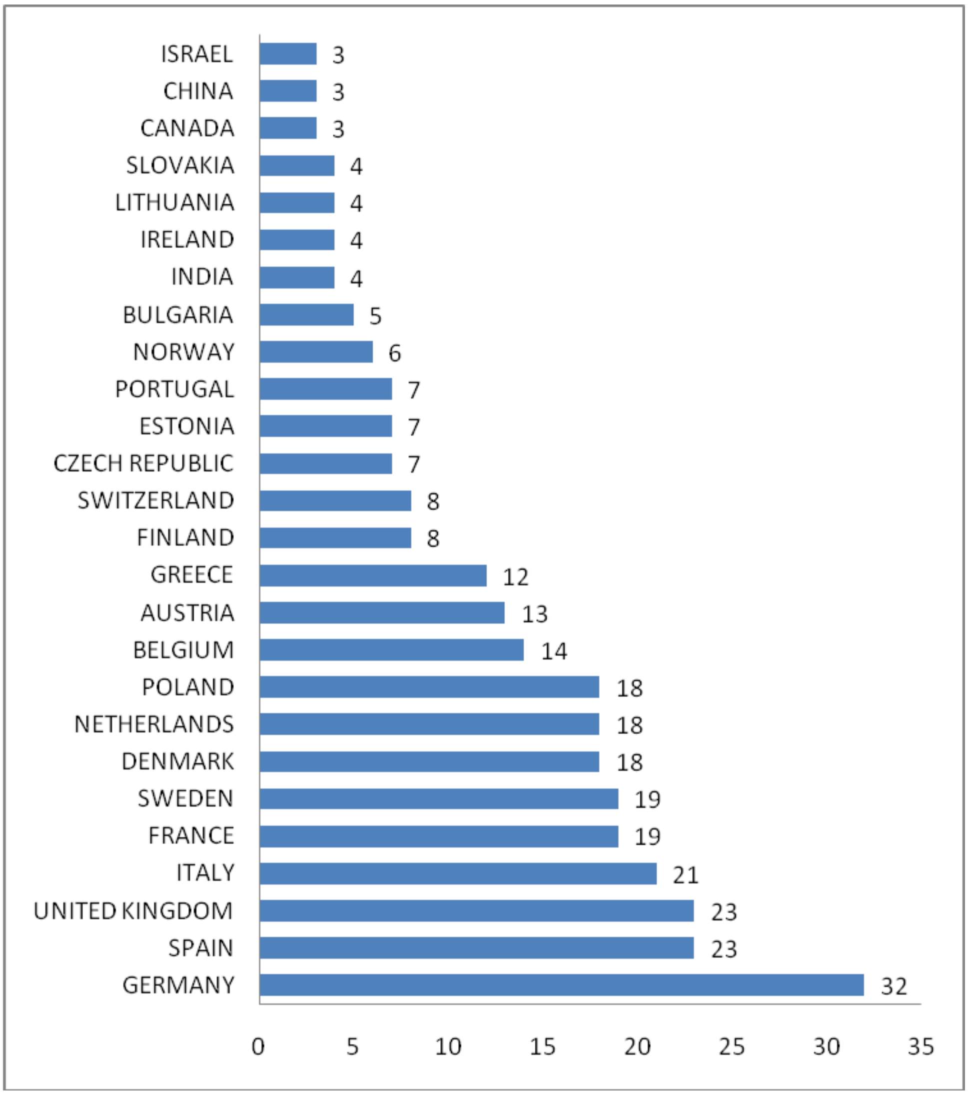
Figure 16: Distribution of FP6 projects with social science relevance by renewable energy technology. N=46.



Source: CORDIS

Figure 17 shows the distribution of the 46 identified projects across countries. Germany as the most active country has participants in 32 of the 46 projects.

Figure 17: Countries with at least three FP6 projects on environmentally friendly energy with social science relevance. N=46.



Source: CORDIS

Energy system and energy use

Searching for projects using the key words 'energy system' and 'energy use' generates 179 and 188 hits, respectively. Our project focuses on research into new, environmentally friendly energy. Browsing the search done by means of the keywords 'energy system' and 'energy use' makes it evident that the hit lists include very many different projects. There are a lot of projects that address issues far beyond the focus of the theme social science research front on new renewable energy. Eventually the heterogeneity in terms of topics covered is too great, and we have therefore excluded them from further investigation.

We have, however, identified a couple of key projects that are focused on the more specific issue of sustainable energy systems and energy use. These projects address the societal costs of a transition to sustainable energy systems and energy use. We discuss the objectives and findings of these projects in more detail in chapter five (see 5.3.4), along with a more general discussion of key crosscutting issues in the research we have mapped.

Wind energy

The search for research projects on wind energy is based on the keyword 'wind'. The search gives 35 hits, of which 21 projects are assessed to be not relevant as they do not include any social science component. Of the remaining 14 projects, one is about several renewable energy technologies, while the other 13 are about wind energy only. The projects cover a range of themes and issues. An important theme amongst these projects is technology demonstration: they are typically organised around the aim of exploring the cost effectiveness of wind energy projects, in particular geographical environments. Related to this theme of demonstration are design tools for optimisation of wind farm topology and operation, and strategic and operative management of wind farms. These projects typically aim at planning and forecasting the impact or outputs from wind power or offshore wind and wave resource prediction. One other project in this group looks at the organisation of a secretariat for a wind energy technology platform.

Wind power and security of supply are also overall concerns. In light of this, the integration of large-scale wind generation into electricity grids is subject to considerable research. A hot topic in wind energy papers is research that identifies and investigates the likely impact of introducing a large number of wind power plants into the electric power systems within Europe. In order to successfully take such a step, there is need for advanced management tools for such technology, as well as for the further development of technical and regulatory solutions and standardisation guidelines. This research seeks to contribute to the establishment of codes, standards and regulations related to the construction and operation of wind energy plants, in line with public opinion. The impact of wind energy on society and the environment – its wider social acceptance – is therefore an important issue.

Related to security of supply in wind energy, is the challenge of planning for energy production based on the combination of several energy sources. A common project theme is dissemination practices, in terms of the necessary conditions to trade energy between wind power, combined heat and power (CHP) and refrigerated warehouses (balancing). The aim of such dissemination is the increased competitiveness of wind power, and the spread of knowledge about short term solutions for combination of different energy sources. Such solutions depend on having appropriate tools and strategic analysis available to support decision making, including coordination mechanisms between grid operators, power plant operators, power exchanges and so on.

Bio-energy

Initial searches for research projects on bio-energy were based on the keywords 'bio-energy' or 'bio energy', but these keywords retrieved no hits. A search using the keyword 'biomass' generates 52 hits. Our assessment from browsing through titles and abstracts of those 52 projects is that 17 have social science research components. Except for the project initiatives related to the establishment of a technology platform and a network of excellence, there is not a single, pure socio-economic research project. These projects are all of a technical character; typically have a socio-economic component, such as an assessment of market implications, a demonstration component, a monitoring element, a lifecycle assessment or an environmental assessment.Of these 17 projects, six focus on various issues related to bio-fuel production and use. Another seven projects are grouped around the theme of co-firing biomass and fossil fuels for electricity production. The remaining four projects address a broad range of issues on market dynamics and the possibilities for implementing biomass into the existing energy mix in different contexts.

Hydropower

The low status and visibility of research projects on hydropower within the FP6 seems to reflect the marginal hydropower production within the European Union. A search with the keyword ‘hydro energy’ generates 15 hits, and variations of this keyword, such as ‘hydro power’ or ‘hydropower’ generate five and four hits, respectively. These searches lead to research projects which are mainly about hydrogen and fuel cell technology. Only two of these projects are about hydropower specifically. The first one is called SHAPES, and addresses facilitating and strengthening co-operation between EU small Hydropower (SHP) actors and research and market actors. This project is about networking, but does not involve a strong social science component. The second project is a technological project called HYDROGENIE. This project looks at the development and field testing of a compact HTS (hydropower turbine systems), a hydro power generator which offers reduced investment costs, lower environmental impacts and strongly improved performance, and therefore aims to reduce the hydroenergy cost per KWh.

Hydrogen

The search for projects about hydrogen technology was performed with ‘hydrogen’ as the keyword. The search generates a list of 67 projects, but this list comprises a very wide range of projects. Many of the projects address several of renewable energy technologies instead of focusing on hydrogen technology. By browsing titles and abstracts we were able to identify three projects that address hydrogen specifically and have social science components. The first one addresses the common concerns in the EU about improving research co-operation on fuel cells and hydrogen, in particular to include countries outside of the EU. The work packages within this project are designed to identify relevant research institutions and enrol them into the EU research community, with the overall aim of improving entrepreneurial skills and wider diffusion of the relevant technologies. The second project aims to harmonise standards and regulations for sustainable hydrogen and fuel cell technology. This involves mapping the impact of relevant standards and regulations on a global level, and then formulating guidelines for the introduction of adequate bodies to solve the problems identified. The third project aims to develop and implement the European Hydrogen and Fuel Cell Technology Platform Secretariat, which has an overall role of accelerating the realization of a sustainable hydrogen society.

Carbon capture and storage (CCS)

The search for projects based on the keywords for ‘CO_2 capture and storage’ generates 23 projects, but only four of these are assessed as including social science components and themes. The common theme in these projects is the facilitation of interfaces between technology and society. The social science components of these projects are typically related to monitoring and verification of technological solutions, risk assessments, confidence building and other issues that may contribute to public acceptance and political momentum behind CCS, if researched thoroughly and disseminated well. Common for all these projects is a substantial degree of scepticism and uncertainty related to CCS, in particular regarding the feasibility of safe storage.

As part of the concerns about increased public acceptance and political intention, these projects also consider the role of international cooperation, and the need to establish stronger international relations on CCS, both within the increasing European domain and with the rest of the world. The international dimension is important both in the domain of research and knowledge generation, and in the policy domain.

One of the CCS projects identified looks exclusively at the secretariat of the CCS technology platform (TP), taking a service-oriented advisory role to the existing and emerging activities within this TP.

Wave energy

Searches of EU FP6 projects using the keyword ‘wave’ generate 17 hits, but only one of these projects seems to have a social science component. It relates to co-ordinated action on ocean energy and one of the main concerns of the project is to disseminate information about ocean energy, thereby contributing to public awareness and acceptance. Ocean energy research and industrial opportunities currently lack focus, and the project’s abstract argues there is a need for a more united effort from the developers and research community, to present principles and results in a more coordinated manner and built public support. The main deliverables in this project are workshop proceedings and expert evaluation reports from five workshops conducted during the project. The last of these five workshops has more of a social science aspect: it looks at environmental economics, development policy and the promotion of opportunities.

Solar photovoltaic and solar thermal

Using searches for ‘solar photovoltaic’ and ‘solar thermal’ generates hits on the same 20 projects. Only three of these projects have social science components. One such relevant project is about establishing a science base on photovoltaic performance, for increased market transparency and customer confidence. This project feeds directly into ongoing standardisation processes around solar photovoltaic technology. The other two projects look at the co-ordination of efforts for interaction and synergy between researchers in this field, not least in establishing communication channels between academic groups, SMEs and industrials.

Geothermal

Searches using the keyword 'geothermal' generate 8 hits, of which two projects have social science components. One of these projects is about establishing a geothermal innovative network, in which evaluations of the socio-economic and environmental impacts of geothermal energy are included as activities. The other project is found when using several of our energy keywords: the RESTMAC project is about creating markets for renewable energy technologies, it is part of an EU renewable energy sources (RES) technology marketing campaign.

3.3 Nordic Energy Research

Norway participates in the Nordic cooperation framework for energy research. For this reason we have mapped the main activities and studies within the social sciences supported by the Nordic institution Nordic Energy Research (NER). Since the mid 1980s Nordic energy research is organised through a common Nordic platform. NER is the funding institution for energy research under the Nordic Council of Ministers and administers a portfolio of projects on energy research. NER also has an advisory role for the Nordic Council of Ministers and the Nordic energy and research authorities. The aim is for NER to give concrete advice on improvement potentials in the framework conditions for research, development and innovation in new energy technologies and environmentally friendly energy systems. It is important to note that the five Nordic agencies responsible for funding energy research are members of the Board of NER. The Norwegian Research Council is the board member agency for Norway.

For the purpose of this report we have selected social science studies that are relevant to the energy sector and have been supported by the NER during the last five years. Only studies and reports which have been published on the website of the NER have been included. In total we have selected 33 studies which cover various energy technology fields. Among these 33 projects are seven policy studies under the thematic area 'Policy studies for strengthening the Nordic Research and Innovation Area in energy' (NORIA-energy), initiated in 2007. These studies focus on energy innovation systems and renewable power production. The studies are expected to contribute suggestions on how to improve Nordic research and development in energy. These seven policy studies are:

- Russian energy research and innovation – prospects for co-operation on renewable and energy efficiency (NUPI, Norway)
- Patterns of need integration and co-operation in Nordic energy innovation systems (Risø National Laboratory/DTU, Denmark)
- Competitive policies in the Nordic Energy Research and Innovation Area (eNERGIA), (NIFU STEP, Norway)

- Nordic Opportunities for Collaboration with China in Energy Research and Innovation (NIAS-Nordic Institute of Asian Studies, Denmark)
- Industrial development and export opportunities for Nordic energy Industry and other companies in the energy field – a research project within Nordic Energy Perspectives (Elforsk, Sweden)
- How to bring renewable energies down their learning curves (Lunds Universitet, Sweden)
- Governance and Research of Nordic Energy System Transition (VTT, Finland).

To date the results of five of the studies have been reported. Overall these NORIA policy studies describe and analyse the framework conditions for innovation systems related to energy production in the Nordic countries. The technology areas that receive most attention are solar photovoltaics, wind energy, bioenergy, hydrogen and fuel cells, which are also the areas where more industrial and scientific efforts are underway. A couple of studies also include an analysis of the potential use and framework conditions for carbon capture and storage (CCS) (see Klitkou et al. 2008 and Torvanger 2007). Research cooperation patterns are also investigated (Borup et al. 2008) and two of the studies investigate the opportunities for Nordic cooperation with China (Delman, Jørgen & Chen Yong, 2008) or Russia (Øverland and Kjærnet, 2009), in the area of energy research and development.

Over recent years a relatively large number of Nordic studies concerning bio-energy have been supported by the NER. The results of these studies are relevant for mapping and understanding the consequences of an expanding Nordic bioenergy market. Several of these studies concern the potential for sustainable production of biomass and bio-energy, imports of biomass to the Nordic region, policies and measures related to the development and use of biomass resources and the bio-energy value chain amongst other issues. Methodologically, both qualitative and quantitative approaches are evident. Amongst the most visible organisations in the Nordic bio-energy project is the Finnish consultancy Econ Pöyry. Other important organisations that have been identified are: the Ministry of Agriculture and Forestry (Finland), Agriculture (Sweden), Swedish Forestry Agency (Sweden), Swentec (Sweden), Forest & Landscape (Denmark), Royal Veterinary, and Agricultural University (Denmark), Swedish Bioenergy Association (Sweden), VTT (Finland), Forest Owners Association of Lithuania (Lithuania), Finnish Forest Research Institute (Finland), Ministry of Agriculture Republic of Latvia (Latvia), Estonian Agricultural University (Estonia), Swedish Association of Pellet Producers (Sweden).

Out of the 33 studies selected, six involve Norwegian participation. Amongst these, no organisation stands out particularly as more active than the others; neither has it been possible to distinguish particular organisations' strengths with regard to subject or technology field. The Norwegian organisations linked to the selected studies are: BI - Norwegian School of Management (2 studies), the Institute for Energy Technology (2 studies), CICERO, NIFU STEP, NIRAS AS and SINTEF (all with one study).

A report by Klitkou et al. (2008) concludes that a high share of the policy projects that address the political and economic need for changes to the existing energy system are supported by NER. This conclusion is based on the examination of the NER's project portfolio between 2003 and 2010 (Klitkou et al. 2008, report 26). The analysis indicated that a large group of these projects are social science and policy oriented (the analysis did not include the NORIA policy projects, mentioned above). These types of projects were grouped under the heading "general", which also included subjects such as Impacts of Climate Change on Energy, Climate and Energy Systems and Nordic Energy, Environmental Constraints and Integration. NER funding for these types of projects amounted to NOK 34.3 million, making social science studies the third largest subject field after the more technology-oriented fields of bio-fuels (NOK 37 million) and hydrogen (NOK 37.9million). The total budget of NER project portfolio between 2003 and 2010 was NOK 280.5 million, of which 70 percent came from NER funding.

3.4 International Energy Agency

In this section we explore the social science research activities of the International Energy Agency (IEA). We present an overview of their activities based on their relevant publications and reports. The IEA is an autonomous body which was established in 1974 under the framework of the Organisation for Economic Co-operation and Development (OECD), to implement an international energy programme.

The methodology used for the selection of IEA studies is based on a scan of publications and reports produced under the IEA's Implementing Agreements. These agreements are at the core of IEA's International Energy Technology Co-operation Programme[8]. For the purpose of this study, papers and reports published under the *Technology agreement for renewable energy technologies* have been under scrutiny.

The agreement has well-defined tasks. 76 studies have been selected by going through each task under the agreement, and identifying all reports with social science relevance.

Here we present an overview of the most common research approaches used within the selected technology fields. As far as possible each paper has been classified into different social science groups. The pre-defined distribution of journals into specific social sciences fields was used (see Chapter 2). Where this information is missing the publication has been classified based on keywords and formulations included in the particular reports, often summarised in abstracts.

[8] The programme is carried out among twenty-six of the OECD's thirty member countries. The Implementing Agreements focus on technologies for fossil fuels, renewable energies, efficient energy end-use and fusion power.

The majority of the social science studies supported by the *Technology agreement for renewable energy technologies* are related to the bio-energy field. In total 53 references on *bio-energy* out of 76 IEA studies have been identified. Social science research on bioenergy is carried out under three Tasks. The Task on *Socio-economic drivers in implementing bio-energy projects* has the specific aim to:

> ...achieve a better understanding of the social and economic drivers and impacts of establishing bioenergy markets at the local, regional, national and international level, to synthesise and transfer to stakeholders critical knowledge and new information, and to improve the assessment of the socioeconomic impacts of biomass production and utilisation in order to increase the uptake of bioenergy as well as providing better guidance to policy makers. (see http://www.task29.net/).

Overall, this research comprises studies on public attitudes and benefits of bio-energy (be they environmental, social or economic), suggestions of strategies for local governments to undertake the introduction of bio-energy, the assessment of socio-economic impacts of biomass production and utilisation as well as on guidelines for policy makers and socio-economic modelling. In total 11 studies have been identified under this particular task.

A second IEA task area is entitled *Sustainable International Bioenergy Trade –Securing Supply and Demand*. In total 26 studies have been identified under this Task. Typically, the studies undertaken in this task area are of socio-economic character and address the stated aims:

- to improve the understanding of biomass and bioenergy markets and trade;
- to analyse the possibilities to develop biomass resources and exploit biomass production potentials in a sustainable way, including supply chains and required logistics;
- to perform coherent analyses of biomass markets and trade by modelling and scenario analysis;
- to evaluate the political, social, economic and ecological impact of biomass production and trade, and develop frameworks to secure the sustainability of biomass resources and utilisation;
- to provide a significant and ongoing contribution to market parties, policy makers, international bodies, as well as NGO's by providing high quality information on these topics (http://www.bioenergytrade.org/).

A series of annual country reports are carried out under this IEA task area which explore the framework conditions for bio-energy on the national level.

The third and last IEA task area which includes relevant social science research on bio-energy is entitled *Commercialising 1st and 2nd Generation Liquid Biofuels from Biomass*. The 15 studies selected within this task touch upon issues such as: north-south linkages in biofuel development, sustainability, research gaps, market barrier perspectives, policy options to support biofuels and issues around standardisation of biodiesel.

The countries and organisations which are most active in terms of these three selected bioenergy tasks are the Energy Institute Hrvoje Pozar in Croatia, Climate Change Solutions in Canada, Lappeenranta University of Technology in Finland, the University of Life Sciences in Norway, the Copernicus Institute at the University of Utrecht in the Netherlands and Thames Valley Energy Ltd. in the United Kingdom.

The three selected studies belonging to the *IEA geothermal energy agreement/sustainable geothermal utilisation*, explore the sustainability of geothermal usage and the possible contribution of geothermal energy to mitigation of climate change. The studies have been classified under the scientific field “Environmental studies”. The most visible countries and organisations in this context are the United Nations University Geothermal Training Programme (Iceland) and GFZ Potsdam (Germany) Enel S.p.A. (Italy), National Institute of Advanced Industrial Science and Technology (Japan).

The Implementing Agreements *Ocean Energy Systems* and the *IEA PVPS Task 8 - Study on Very Large- Scale Photovoltaic Generation systems* support predominately technology oriented research. For wave energy we have nevertheless, classified three of the studies on as belonging to the multidisciplinary sciences. The research combines technology assessments with policy relevant discussions. A first report reassesses the status of ocean energy RD&D in 2006 and examines policies that impact on development, as well as services and facilities which support RD&D, and the barriers to progress; a second provides an overview of the available wave data appropriate for assessing and characterizing the wave energy resource with the purpose of informing about policy options; the third focuses its attention on identifying (in comparison to wind energy) any potential differences and opportunities associated with integrating wave and tidal current energy plants into electrical grids. It also discusses how the experience gained from the wind energy industry could be used to mitigate any future grid integration challenges associated with large-scale implementation of ocean energy technologies. The main organisations responsible for the studies are Powertech Labs Inc (Canada), Department of Renewable Energies (Portugal) and Sustainable Energy Ireland (Ireland).

With regard to IEA photovoltaics research one report have been classified within the subject of *Environmental studies.* Here the authors examine and evaluate the potential of very large-scale photovoltaic power generation in desert regions. Socio-economic, financial, technical and environmental aspects are investigated in parallel, which in general seems to be a typical approach for social science studies of renewable energy systems. The main authors of the report are employed at the Tokyo Institute of Technology (Japan) and Mizuho Information & Research Institute (Japan).

The Agreement called “Renewable energy technology development” includes several subtasks focusing on socio-economic aspects of renewable energies. Examples of these are studies with the aim:

- to develop a policy instrument design to reduce financing costs in RE technology projects;
- to assess economic values of various externalities - air emissions, system integration, security of supply, employment;
- to study barriers, challenges and opportunities for the deployment of renewable energy;
- to provide policy makers and other stakeholders with concrete means of supporting sustainable bioenergy deployment;
- to assist policy makers and project developers in a better understanding of the specifics of offshore renewable energy and to give them practical guidelines in how to foster their deployment;
- to provide an overview of options and a policy framework needed for the transformation of the road transport sector in order to meet the challenges of reduction of GHG emissions and independence of oil through large-scale deployment of sustainable and effective renewable energy (RE) technologies (http://www.iea-retd.org/).

Some of the participating organisations are: Ecofys International BV (the Netherlands), IPA Energy + Water Economics (UK), COWI (Denmark), SGA Energy (Canada), Ea Energy Analyses (Denmark), Center for Resource Solutions (USA).

A substantial number of studies have been carried out under the technology agreement for wind energy which investigates *social acceptances of wind energy projects*. Here we find studies which use several different types of approaches. To mention a few, there are papers using case studies to investigating public attitudes towards wind energy development, such as "not in my backyard" effects, wind power policy in landscape planning, etc. We also find a study which summarises existing social research on the acceptance of renewable energy technologies, and "provides a novel classification of personal, psychological and contextual factors which combined shape public acceptance". The organisations which are found to be active in this context are: the Architecture Research Centre at the University of Manchester in the UK, Lund University in Sweden and the Land Use Policy Centre in France.

A quite limited number of studies have been identified for IEA projects with Norwegian participation. In only seven out of the 76 studies selected there where Norwegian organisations involved. Of these five are about bioenergy and two about hydrogen. The organisations are: the Norwegian Forest Research Institute, the Norwegian University of Life Sciences (3), Energidata AS, Transportøkonomisk institutt, Norwegian Research Council (2), Institute for Energy Technology (2) and Norsk Hydro.

3.5 Concluding remarks

Norway participates in several international arenas supporting energy research. In our study we have concentrated on three international organisations in particular: the EU's 6th

Framework Programme (FP6), Nordic Energy Research and the International Energy Agency. Although these organizations largely fund technologically oriented energy research, social science-oriented studies are being produced to some extent. The conclusions below are based on the identification and analysis of relevant projects and studies, amongst these three international funding organisations.

Within the research taking place under EU FP6 there are hardly any projects with a pure social science orientation. Social science elements are addressed within more technology oriented projects. The majority of these projects include reflections and recommendations for regulatory behaviour and policy practice, and the assessment of socio-economic impacts of the deployment of renewable technologies is also a common theme. Issues of management and implementation of energy technology are also focused on. Social science components are also found in projects with a more organisational character, typically in projects with strong cooperative features, for example operation of a technology platform or networking programmes.

When analysed by energy subject, a few recurrent themes can be noticed. With regard to the social science dimension in wind energy projects typically the social acceptance for wind energy is investigated. This is the case for projects both under FP6 and the IEA.

Research into the socio-economic aspects of bio-energy is found to be more frequently supported compared to other energy subject fields. Typical issues covered are socio-economic drivers and impacts of introducing bioenergy markets, guidelines and recommendations to policymakers, public attitudes towards bioenergy and biomass markets and trade. In fact the largest number of social science studies supported by the IEA implementing agreement for renewable energies are related to the bioenergy field. Bioenergy research is also frequently supported at the Nordic level, through NER. Both quantitative and qualitative approaches are used. Typically case studies are used. There are also studies describing national bioenergy market and framework conditions.

For CCS only a few studies were found to cover social science aspects of the technology. These were supported under FP6 and by NER. These are typically studies looking at public acceptance and political intentions of CCS and possibilities for international cooperation. Some Nordic projects have focused on the national framework conditions for CCS and research and innovation capacity in terms of patents and scientific publishing.

For solar photovoltaics the same conclusion can be drawn, as only a few projects with a social science component could be identified. The EU projects are more of an organisational character as aiming at improved coordination efforts and interaction between researchers and creating networks between research groups. At the Nordic level some of the NORIA studies include PV in their analysis of renewable energies in the Nordic countries.

As indicated by IEA photovoltaics research socio-economic, financial, technical and environmental aspects are investigated in parallel, which in general seems to be a typical approach for social science studies on renewable energy systems. For the other technological fields, geothermal, hydropower and wave energy only a minor number of studies with social science relevance were found.

4 Analysis of highly cited publications

This chapter describes and reviews the state of the art in social science research on environmentally friendly energy by analysing highly cited articles. Assuming that highly cited articles are significant markers of the state of the art, we examined the ways these articles have targeted the thematic field of energy. A range of different categories to sort and group the relevant research publications and studies were developed and applied. We initially identified 14 broad social science groupings; then went on to define 11 energy related subjects, which were also used to cluster and organise key words for publication searches. In an in-depth, qualitative analysis of the 109 highly cited articles, we morevoer sought to identify patterns in terms of thematic areas, common research approaches, recurring research questions, methods used and key findings or conclusions.

4.1 Methods and data

A sample of 109 highly cited articles was defined by including all articles with more than 25 citations each in the period 1999–2008 (for further details see Table 6). These selected papers constitute an empirical basis for the study. The matrix summarising the thematic issues, the objectives, the applied methods and the main findings and conclusions of these articles, is available on demand.

The energy subject key words

The highly cited articles were grouped around 11 energy subjects (see section 2.1.2). As many articles are related to several keywords, the total sum adds up to a higher number than the number of the actual articles (see 2.1.2, Table 6). A close reading gave about the same distribution of the keywords, but also inidates that the boundaries between the subjects *energy use*, *energy system* and *renewable energy production* are blurred, and the energy subject *renewable energy production* was in practice difficult to distinguish from the other categories. Still the category is kept here, but will be defined by the different, specific forms of technologies used to enable sustainable and renewable production of energy.

The papers analysed in this section are categorised according to their *major* energy subject. In about half of the 109 articles the main energy subjects are *energy use* and *energy system*. In the other half important subjects are: to *capture and store carbon (CCS),* further various technologies for renewable energy production, their development and the societal implementations. The prevalent energy subject is *wind technology*, but also energy subjects like *bio-energy*, *hydrogen* and *photovoltaic* are represented in the sample.

The social science disciplines

The publications identified in this report were mainly concentrated within three groups of social sciences:

- economics, including business and management studies;
- environmental studies and ecology; and,
- political sciences, including planning, public administration and international relations.

In addition to these leading groups, interdisciplinary fields such as multidisciplinary sciences and interdisciplinary social sciences featured strongly. Social science studies in relation to specific sectors like agriculture and forestry or transportation were also prominent (see 2.1.1, Table 1).

A close read of the highly cited articles confirmed this overall picture of disciplinary representation given in the bibliometric study of all 2,459 articles. The group of economics is a central contributor to the research on sustainable energy, but within this, it may be useful to draw a distinction between socio-economics on one hand and business and management studies on the other hand, as their general approach to the issue of sustainable energy varies considerably.

The group environmental studies and ecology seems to have a somewhat lower representation among the highly cited articles than in the overall view (see 2.1.1, Table 1). One reason for this may be that some of papers relating to environment and ecology have been re-categorised as economics, giving weight to the main approaches, theories and methods they apply.

It is also important to note that a established, multidisciplinary field – social sciences studies on technology and society (STS-studies) – seems to be weakly represented in the systematizing of social scientific journals by ISI (cf. table 1).

The most important journals

The noteworthy journals in the field are listed in 2.2, Table 3. *Energy Policy* ranks as the most important journals. This conclusion is reinforced by looking at the highly cited articles: *Energy Policy* published a majority of these articles, (44 of 109 publications); hence *Energy Policy* was the most important scientific journal in this area for the years 1997–2008, in terms of number of papers, as well as number of highly cited papers.

4.2 Main findings

4.2.1 Energy use

The energy subject *energy use* is the main topic in about 40 of the 109 highly cited publications. A closer look at the publications within this subject reveals a range of research question, but that a majority of the papers (about 28 of 39) examine various aspects of the causal relations between economic growth/transition and energy consumption or energy demand. In general, these articles are written by economists who apply standard econometric methods and theories from an economic perspective to the subject of energy. Some of these authors also offer a historical perspective, using longitudinal data and analysing time series. Through a close reading of the articles in this group, including the references given in the text, one gets a clear sense of an ongoing international scientific dispute (at least amongst economists) about whether economic development should take precedence over energy consumption, or whether energy itself is a stimulus for economic development. Some of the main questions addressed in this debate are about the direction of causality between energy consumption and economic variables such as Gross National Product (GNP), Gross Domestic Product (GDP), income and energy prices.

The remaining ten articles with *energy use* include a variety of topics, research questions, theories and methods, and are not clearly defined to one discipline. The group includes general overviews on the environmental impact of energy consumption, as well as more specialized studies on the energy supply, potential savings and transformations in different sectors like agriculture, in transportation and in commercial firms. In addition we find a couple of sociological and anthropological studies that deals with pro-environmental behaviour contra factual energy use in the households.

4.2.2 Energy system

The subject *energy system* is represented by approximately 20–25 articles of 109. The group includes articles that examine how innovations and technologies can address key energy and environmental challenges to create and implement a society with environmental, sustainable energy. Also represented are papers about policies to reach this goal. The publications in the group of energy system often seems to have an interdisciplinary approach; several studies tend to be set in a combination of economic, political, social and natural resource criteria. The multidisciplinary field of environmental studies and ecology is represented, as well as the discipline of political science and to some extent economics. This energy subject embraces articles with topics such as the theoretical development of the concept of ecological footprints, estimations of the cost of the climate changes in monetary terms, the linkages between climate changes and sustainable development in developing countries.

4.2.3 Carbon capture and storage

The energy subject *Carbon capture and storage (CCS)* is represented by about 20 of 109 articles. The publications seem to belong to the discipline of economics and/or social sciences for specific societal sectors: agriculture, silviculture, transportation and architecture. The papers dealing with this subject can roughly be divided in two sets: first, articles that aim to develop analytical tools in order to understand the specific forces driving the global, environmental changes through a high level of atmospheric carbon concentration. The second set is specialized studies often directed towards specific sectors: transportation, architecture, agriculture and forestry. The possibilities and monetary costs of carbon sequestration in the forests and in the soil as means to reduce the concentration of carbon in the atmosphere are the main research questions handled. In the sector of transportation, articles about the rebound effect were important. In the field of urban studies, a highly cited paper dealt with how one could to reduce carbon dioxide and other greenhouse gases when constructing multi-storey buildings.

4.2.4 Renewable energy production – various technologies

Various technologies for environmentally friendly, low carbon energy were identified as main energy subjects for this study, such as: *bio energy*, *geothermal power*, *hydrogen*, *hydropower*, *photovoltaic*, *solar thermal power* and *wind energy* (see 2.1.2). In the sample of the 109 publications with a high rate of citations, around 30 articles deal with the above listed technologies. Among them the subject *wind energy* is, with about 10–15 articles, the technology most frequently referred to. In articles dealing with *wind energy*, the authors often examine how technologies are successfully or unsuccessfully implemented in different countries in order to establish an infrastructure for supply of energy from renewable energy resources. But unlike the above mentioned subject group, energy system, the highly cited articles in this category are to a lesser extent interdisciplinary. Given the two focal points, investigations of policies and the establishment of commercial markets, theories and methods from economics and political science often are the disciplinary points of departure. A research question is why Germany, Denmark and the Netherlands in the 1980s and 1990s became leading countries in the adoptions and spread of the wind energy. We also find the USA and the United Kingdom as cases in the studies.

The remaining 10–15 articles cover other technologies: *bioenergy*, *hydropower*, *photo-voltaic* and *hydrogen.* The energy sources *geothermal power* and *solar thermal power* are not represented at all among the highly cited papers, nor is wave energy.

4.3 Concluding remarks

In general the highly cited articles on renewable energy seem to be marked by one or more of these features:

- The article introduces a new theme; it is a pioneer work in the field.
- The author(s) investigates a particular case in an established field.
- The author(s) develops a genuinely new theory.
- The author(s) applies already know theories or methodology in a new way or in a new field.
- The article formulates a review, overview and/or synthesis of the hitherto scholarly development of a scientific field.
- The scientific article(s) is/are interpreted as an (official) political statement.

The highly cited papers comprise both defined disciplinary based studies and explorative, multidisplinary approaches. Economics is the single dominant discipline. In addition a range of disciplines contributes, including also multidisciplinary fields.

The disciplinary approaches are partly in concordance with the different energy subjects. *Energy use* and *energy system* represent two thematic fields at the core of the scientific publishing on renewable energy. In particular the subject *energy use* seems to be dominated by economists applying established econometric methods on a new area, in other words: renewable energy defined as energy use has become a theme of research in economics. Several of the publications address relations between economic development and energy consumption often using China as a case, where as other articles contribute to knowledge on environmental impact, energy use and potential for saving in industries and energy use in households.

The issue *energy system* more often has an interdisciplinary approach than the previous discussed energy subject, the same goes for *Carbon capture and storage (CCS)*. Studies tend to be set in a combined context of economic, political, social and natural factors. Regarding CCS, issues dealing with specific societal sectors issues are prevalent. The emerging discipline of environmental studies and ecology are represented, along with political science and to some extent also economics. The highly cited articles have in common a focus on how innovation and technology can deal with the environmental challenges and a more sustainable energy supply. Possibly some of the results of research were inspired by the multidisciplinary field, social sciences studies on technology and society (STS-studies). Alas this field of knowledge is weakly represented in the labelling of the social sciences journals. Relatively few articles had a principal focus on the single technologies, including their implementations and significance for renewable energy production. *Wind energy* is most studied, often as case in order to examine how technologies are implemented in the energy system.

5 Central topics in the international discourse

In the following section we will discuss selected issues or topics identified as frequently addressed in the international discourse. These have been identified from our main sources, including the highly cited articles, the international activities and from selected books and reports. These topics are explored by themes, including: *foresight studies, public acceptance, environmental impact assessment, the innovation system approach and energy system transformation* and *sustainable energy systems and use.*

5.1 Foresight studies

Foresight studies have been a popular method in public policy sectors to explore and understand the complexities of system dynamics. It has been applied to different focal areas, including energy provision based on environmentally friendly energy technologies. A useful explanation of the foresight concept can be found in Voß et.al:

> Foresight is about anticipating possible future developments in a focal area. It differs from forecasting, however, because it recognizes the impossibility of predicting the future due to complex dynamics that are involved in bringing it about. Foresight conceptualized the future as open, not determined by natural necessities, but contingent and influenced by human action (Voß, Truffer et al. 2006).

In this sense, foresight can be used as an approach to produce orientation or direction rather than predictions. The literature also refers to foresight as a "scenario approach" (Berkhout and Hertin 2002; Gallopín 2002). This approach is frequently used by national governments and international organisations, to present decision makers with alternative development paths and thereby preventing lock-in effects to particular power production choices. This benefit is described by McDowall & Eames:

> Scenarios, roadmaps and similar foresight methods can play an important role in the development of shared visions of the future: creating powerful expectations of the potential of emerging technologies and mobilising resources necessary for their realization (McDowell and Eames 2006).

Foresight studies have for several decades been used in the Norwegian policy context, not least to portray future possibilities and scenarios regarding the Norwegian public sector (Øverland 2000). Since 2002, the RCN has supported foresight projects which focus on a range of technological fields such as ICT, biotechnology, advanced materials and energy systems. Foresight studies related to the energy field was also used as a central element for the process which led to *Energi21,* Norway's collective R&D strategy for the energy sector initiated in 2008.

In this section we give a brief description of foresight work conducted by the IEA and also look closer at some of the studies using scenario and foresight modelling identified among the highly cited articles presented in the previous section.

Energy and environment scenarios have been developed by a variety of organisations, amongst whom the International Panel on Climate Change (IPCC) and the company Shell are frequently cited. Since 2001 the IEA has produced bi-annual publications about energy technology perspectives and in 2003 the IEA published a volume exploring possible futures for energy and the environment up to 2050. The latter illustrates how different types of scenarios, be they explorative and normative, can be used. The IEA describes the uses of these different kinds of future scenarios, noting that while “exploratory scenarios are designed to explore several plausible future configurations of the world”, they see normative scenarios as more policy oriented, prescriptive and “designed on the basis of a set of desirable features that the future world should possess according to the agent elaborating the scenario” (IEA 2003). The IEA report also features the so-called *business-as-usual scenario,* which takes an approach closer to forecasting. Three other explorative scenarios in the IEA report are titled *Clean but not sparkling*, *Dynamic but careless*, and *Bright skies* and it also features a more normative scenario, titled *Sustainable vision*. Considering that new energy technologies take a long time to develop, and even longer to reach their full scale market development, such scenarios of various future outcomes might help strategic decision making.

The first two scenarios (*Clean but not sparkling* and *Dynamic but careless)* portray a quite negative picture, assuming that the future will be characterised by either: strong concern for the global environment amongst the public and policymakers, but accompanied by a slow rate of technological change or, on the other hand, by dynamic technological change but relatively limited policy intervention. The third scenario (*Bright skies*) is characterised by a situation in which both rapid technological change and strong engagement amongst the public and policymakers emerge alongside one another. Finally, in the more prescriptive or normative scenario (*Sustainable vision*) it is possible to discern the policies that the IEA believe are needed, to realise an ideal future, essentially what the IEA think should be done with respect to climate change mitigation, energy security and diversification, and energy access. This last scenario envisages a diversified power production system, where the share of energy from renewable sources (including hydro, wind, solar PV, solar thermal, geothermal and others) continues to increase, climbing from 3.6 percent (2000 levels) to 18.9 percent in 2050. However, this scenario accepts that the world would need to rely on many different types of energy technologies, including, nuclear power and fossil fuel based technologies, for power generation. This scenario also considers carbon capture and storage technologies as an attractive option, in the short and medium term, if they become available on a large scale (IEA 2003).

As indicated earlier in this section, forecast approaches are usually undertaken by actors with a particular interest or perspective on energy issues, be they governments, industrialists or academics. We now focus our attention on studies which take an academic viewpoint. In our sample of highly cited articles we identified a few studies dealing with foresight modelling, including the following:

- Riahi, K., & Roehrl, R. A. (2000). Greenhouse gas emissions in a dynamics-as-usual scenario of economic and energy development. Technological Forecasting and Social Change, 63(2-3), 175-205.
- Gritsevskyi, A., & Nakicenovic, N. (2000). Modeling uncertainty of induced technological change. Energy Policy, 28(13), 907-921.
- Brown, M. A., Levine, M. D., Short, W., & Koomey, J. G. (2001). Scenarios for a clean energy future. Energy Policy, 29(14), 1179-1196.
- Ferng, J. J. (2002). Toward a scenario analysis framework for energy footprints. Ecological Economics, 40(1), 53-69.
- Azar, C., Lindgren, K., & Andersson, B. A. (2003). Global energy scenarios meeting stringent CO_2 constraints - cost-effective fuel choices in the transportation sector. Energy Policy, 31(10), 961-976.
- Junginger, M., Faaij, A., & Turkenburg, W. C. (2005). Global experience curves for wind farms. Energy Policy, 33(2), 133-150.
- Crompton, P., & Wu, Y. R. (2005). Energy consumption in China: past trends and future directions. Energy Economics, 27(1), 195-208.
- McDowall, W., & Eames, M. (2006). Forecasts, scenarios, visions, back casts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature. Energy Policy, 34(11), 1236-1250.

As can be seen from the article titles, scenario building is applied to a wide range of subjects and technological fields. A closer look at the methodologies of these studies reveals how different scenario models are being used. A frequent method in these studies is the system-engineering model MESSAGE, developed by the International Institute for Applied Systems Analysis (IIASA), and also used by the IEA. The MESSAGE model is used to describe green house gas emission scenarios (Riahi and Roehrl 2000), in modelling uncertainty of induced technological change (Gritsevskyi and Nakicenovic 2000), in scenarios for energy efficient and clean energy technology (Brown, Levine et al. 2001), in scenarios of the ecological and energy footprints (Ferng 2002), and to describe particular energy technology forecasts, such as the forecasting of technological development of wind turbines (Junginger, Faaij et al. 2005). The Bayesian vector autoregressive methodology is also used, in an article which analyses the future demand for energy and structural changes in China (Crompton and Wu 2005).

Supported by the EU FP7, the research area "Socio-economic development trajectories" and the ongoing *Pathways for carbon transitions* (PACT) project explores how a post-carbon society might look like, and how to reach it within the next 50 years. Emerging concerns related to energy demand, infrastructure, renewable energies and urbanisation are elements that these projects focus on. These projects will investigate the role of social forces, actors and stakeholders in the transition toward this post-carbon concept. The ultimate objective of the PACT project is to complement these analytical components with an attempt to quantify scenarios of post-carbon societies, at the world level.[9]

In summary, scenario-building that explores the future development possibilities, in terms of environmentally friendly energy, has become an attractive tool to deal with the inherent uncertainties facing policy makers, business actors and academics. It has become a widely applied method to explore issues of climate change mitigation and to portray future possibilities for new energy technologies.

5.2 Public acceptance

Another recurrent topic identified in this analysis, is public involvement and acceptance of new energy technologies.

As a great deal of research show, these concerns are increasingly discussed in connection with new energy technologies. However, defining terms such as "public", "social" or "societal acceptance" is not a straightforward exercise. Different aspects and phenomena are linked to these concepts. Social acceptance (or resistance to) a technology is considered to be an important element in any innovation processes. In other words, it is assumed that society has a stake in, and some influence over, the development and introduction of a new technology or product. In this way societal actors (be they consumer organisations, environmental groups or others) can be seen as stakeholders, who influence public opinion, governments and firms (Deuten, Rip et al. 1997).

Different methods are applied to investigate public acceptance of new energy technologies. Some studies examine public acceptance in terms of public opinion surveys, others focus on acceptance amongst specific social groups or by a broad spectrum of actors. The latter approach is the starting point for Brohmann *et al.*, who defines "societal acceptance more broadly to include the views and actions of the expert and policy community, as well as of social interest groups, NGOs, technology users, local residents and the general public" (Brohmann, Feenstra et al. 2007). Their report was written for the EU-funded project Create Acceptance, supported by the European Commission under FP6. The project's objective was to contribute to the implementation of new and emerging sustainable energy technologies, by assessing optimal conditions for the implementation of these new technologies, in terms of socio-economic aspects, consumer preferences and citizen needs (Acceptance 2007). The project has delivered important insights into public acceptance of new energy technologies and is a good starting point for anyone interested in investigating these issues further (the reference list of the final project report gives a good overview of state-of-the-art literature and case studies on the subject). A main outcome of the Create Acceptance project is the ESTEEM tool (Engage stakeholders through a systematic toolbox to manage new energy projects). ESTEEM has been developed for projects

9 http://www.pact-carbon-transition.org/index.html

managers involved in new energy projects, who wish to improve the societal acceptance of their project by building participation amongst stakeholders (Raven, Jolivet et al. 2009).

The IEA also supports research into public acceptance through the Implementing Agreement for wind energy, which (among others topics) investigates social acceptance of wind energy projects (see task 28 in this IEA implementing agreement)[10]. In this area of the IEA's work, we find studies which use several different approaches. A great deal of research makes use of case studies to investigate public attitudes towards wind energy development, such as 'not in my backyard' effects (Nimby), wind power policy in landscape planning, and so on. Another study summarises existing social research on the acceptance of renewable energy technologies, and provides a novel classification of personal, psychological and contextual factors, which the paper argues combine to shape public acceptance (Devine-Wright 2007).

Amongst the list of highly cited articles a number of studies focusing on public acceptance of sustainable energy were found. A few interesting examples are summarised here. The issue of public acceptance is addresses by Bell et al (2005). Looking specifically at wind farm siting decisions in the UK, they explore issues of 'gaps' that can influence acceptance and the 'not in my backyard' (Nimby) syndrome. This paper distinguishes between two kinds of 'gaps' which shape attitudes to wind farm sites: the 'social gap' that stands between high public support for wind energy as expressed in opinion surveys, and low success rates of planning applications for wind power developments; and the "individual gap" which exists when an individual has a positive attitude to wind power in general, but actively opposes a particular wind power development. Understanding such gaps in attitudes is an important step for policymakers involved in wind farm planning (Bell, Gray et al. 2005). These conclusions also seem to be supported by a large number of other researchers (Toke 2005). A study examining general attitudes towards wind power among Swedish electricity consumers found that, although the public generally expresses a positive attitude towards wind power, experience shows that specific wind power projects often face resistance from the local population (Ek 2005).

As can be seen from the discussion above, several studies have considered public acceptance in terms of wind energy development. However, other environmental energy technologies have also been subject to similar analysis. Examples include studies on public acceptance of carbon capture and storage (Itaoka, Saito et al. 2004), wave energy (Hansen, K. Hammarlund et al. 2003), solar energy (Faiers and Neame 2006) and bioenergy (Roracher, Bogner et al. 2004).

---

[10] http://www.socialacceptance.ch/

5.3 Environmental impact assessment

The interaction between technology and the environment has received increasing attention from scholars and policy makers alike over the last decade. Concerns about energy utilisation and its environmental impacts drive policy makers and civil society to search for alternative energy sources, where renewable energy technologies are found to be effective solutions for sustainable energy development and environmental pollution prevention. Nevertheless, the deployment of new environmentally friendly energy technologies still has impacts in terms of resource utilisation, biodiversity, air quality and sustainable development at large.

An important and frequently cited article in this area concentrates on the environmental impacts of electricity generation systems, based on life-cycle assessments (LCAs) (Gagnon, Belanger et al. 2002). As the authors explain:

> A life-cycle assessment is an environmental assessment of all of the steps involved in creating a product. Its goal is to give an all inclusive picture of the environmental impacts of products, by taking into account “upstream” and “downstream” impacts. In the power sector, the assessment should include extraction, processing and transportation of fuels, building of power plants, production of electricity and waste disposal (Gagnon, Belanger et al. 2002).

Interestingly, the results from comparing different power options show that hydropower and wind power both have excellent performance. Several other articles in the highly cited selection apply impacts assessment analysis to explore the interaction between technology and the environment. An article by York et al (2003), published in Ecological Economics, is frequently cited for their assessment and refinement of the analytical tools STIRPAT; IPAT and ImPACT. The concept of ecological elasticity (EE), is important in this field, and is defined as the proportional change in environmental impacts due to a change in any driving force (mathematically, ecological elasticity is the same measure as elasticity in economics) (York, Rosa et al. 2003). While not going into great detail about these measures, it is important to point out the frequent use of these models by researchers and the areas they are commonly applied to. Common approaches involve the estimations of ecological footprints (Haberl, Erb et al. 2001; Wiedmann, Lenzen et al. 2007), climate change impacts (Tol 2002; Tol 2002) and the impacts of large deployment or installation of various technologies such as wind energy(Alvarez-Farizo and Hanley 2002).

One of the bio-energy tasks of the IEA is to evaluate the political, social, economic and ecological impact of biomass production and trade. In response, studies have been undertaken that seek to improve the knowledge about the socio-economic impacts of biomass production and utilisation. Different methodological approaches are used and various common analytical models and theories are applied to specific empirical cases. An example in this area is the study by Dornburg *et al.* (2008) which provides a comprehensive assessment of global biomass potential estimates, focusing on the various factors affecting these potentials, such as food supplies, water use, biodiversity, energy demands and agro-economics. In addition, a number of other studies analysing greenhouse gas balances of bio-energy are presented and discussed. These analysis lead to policy relevant recommendations for sustainable biomass use in the future including R&D needs (Dornburg and al 2008).

5.4 The innovation system approach and energy system transformation

The development of environmentally friendly energy technologies and the transition to a low-carbon economy have been analysed with the help of two major theoretical frameworks: the innovation system approach and the transition management approach. Both theoretical frameworks have been further developed through studies on environmentally friendly energy.

The innovation system approach has been developed at different levels of analysis (Carlsson, Jacobsson et al. 2002), such as the *national* level, on national systems of innovation (Nelson 1993), at *sectoral* level, on sectoral innovation systems (Malerba 2004), at *regional* level, on regional innovation systems (Cooke, Heidenreich et al. 2004), and at the level of a specific *technology* on technological innovation systems (Carlsson and Stànkiewicz 1991; Carlsson 1997; Jacobsson and Bergek 2004; Jacobsson, Sandén et al. 2004; Hekkert, Suurs et al. 2007; Bergek, Hekkert et al. 2008; Negro, Hekkert et al. 2008). The sectoral innovation system approach has been applied in the Europe Innova project SYSTEMATIC: Sectoral Innovation System Analysis in EU25. In this project, the energy sector was one of eleven industry sectors studied.

The use of a technology specific approach to innovation systems, offers a number of advantages. It is more dynamic, reduces the very complex national innovation system approach and it is not confined to national borders. This technology specific approach has been demonstrated in a number of empirical studies, two of which are amongst the highly cited papers identified in this study (Jacobsson and Bergek 2004; Jacobsson and Lauber 2006). These two articles by Jacobsson et al. on the *transformation of the energy sector*, are based on a technological innovation system model, have received a great deal of attention amongst academics (Jacobsson and Bergek 2004; Jacobsson and Lauber 2006). The purpose of the first paper was to contribute to the policy debate, and the management of transforming the energy sector (Jacobsson and Bergek 2004). The study focused on cases of development and diffusion of renewable energy technologies in Germany, Sweden and the Netherlands. The life cycle model of industry was enlarged in this study, to include the formation and growth of new technological systems, and relevant inducements and blocking mechanisms were identified. Through this analysis, a set of challenges was identified for policy makers attempting to influence a transformation of the energy sector. The transition from a first to a second phase is not easy venture. The Dutch wind turbine and the Swedish solar energy, while initially successful systems, show that further growth can be very difficult to achieve, while Germany had a successful second phase. The reasons seem to be related to investment in the first period. The second paper looks at the need for a rapid transition to a low carbon economy (Jacobsson and Lauber 2006). The rate of diffusion of new technologies, such as those for the generation of electricity from renewable energy sources, is a central issue. This second article explores the reasons for the particularly rapid spread of two such technologies in Germany, wind turbines and solar cells. It traces this rapid diffusion to key policy instruments employed and to political processes which led to the adoption of these instruments. The analysis demonstrates how the regulatory framework formed in a 'battle over institutions' where the German parliament, informed and supported by an increasingly strong advocacy coalition, backed policies that supported renewable electricity, against more reluctant governments and opposition from nuclear and coal interests. This study also demonstrates that this example of a major political and environmental achievement carries a modest price, when total costs to society (both subsidies to coal and the negative external economies of coal) are considered (Jacobsson and Lauber 2006).

In the early stages of emergence of a new technology innovation system, the number of actors, relevant institutions and networks is small, which reduces the complexity even further (Negro, Hekkert et al. 2008). To capture the dynamics of new technological innovation systems, key activities have been identified and the concept of "functions of innovation systems" has been developed and applied to renewable energy technology systems (Johnson and Jacobsson 2003; Hekkert, Suurs et al. 2007; Bergek, Hekkert et al. 2008; Suurs and Hekkert 2009). As defined in Hekkert et al. (another of the highly cited papers), the approach "focuses on the most important processes that need to take place in the innovation systems to lead successfully to technology development and diffusion". The seven functions defined by Hekkert et al. (Hekkert, Suurs et al. 2007) are:

1. Entrepreneurial activities
2. Knowledge development
3. Knowledge diffusion through networks
4. Guidance of the search
5. Market formation
6. Resource mobilisation
7. Creation of legitimacy/counteract resistance to change

This framework has been applied on onshore wind technology and solar photovoltaic technology (Jacobsson and Johnson 2000; Jacobsson and Bergek 2004; Brandt and Svendsen 2006; Hekkert, Suurs et al. 2007; Negro, Hekkert et al. 2008). Cicero has worked recently along the same line with CCS, as a publication from Cicero, co-authored with researchers from Utrecht University, shows (Alphen, Ruijvena et al. 2009).

The transition to a low-carbon economy was addressed by the *multi-level perspective* (Geels 2002; Geels 2004; Geels 2004; Geels and Schot 2007) and the *transition management approach* by Kemp et al. (Kemp and Loorbach 2006; Kemp, Loorbach et al. 2007).

The multilevel framework for the analysis of technological transitions distinguishes processes taking place at three different levels: macro, meso and micro (Geels 2004). The macro level is defined as the landscape level, which “refers to aspects of the wider exogenous environment”. Landscapes cannot be changed by actors as they include factors such as “material environments, shared cultural beliefs, symbols and values”. Landscapes are also described in the literature as a:

> ..set of heterogeneous factors, such as oil process, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems (Geels 2002).

However, landscapes that undergo change can exert pressure and destabilise technological regimes at the meso-level. Technological regimes have been defined in the literature by various scholars. Rip and Kemp (Rip and Kemp 1998) define technical regimes as the rule-set embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures. All of these features are also found embedded in institutions and infrastructures. Subsequently, Geels proposed the addition of more social aspects, in contrast to the engineering-oriented definition Rip and Kemp had set out, and therefore introduced the concept of socio-technical regimes. The socio-technical regime can be understood as the “deep structure or grammar of socio-technical systems and are carried out by social groups” (Geels 2004).

Regime shifts involve changes in technologies and technical artefacts, as well as in user practices, policies, markets, industrial structures and supporting infrastructures (Geels 2002). Niches represent the micro-level of the framework and are defined as “protected spaces or incubation rooms, in which new technologies or socio-technical practices emerge and develop” (Markard and Truffer 2008). Niches do not necessarily have to host purely new technologies, but can also host technologies that have existed for some time and are established in a stable niche environment. Both regimes and niches are influenced by changes in the landscape. Difficulties in breaking or replacing an existing regime are compounded by stabilising factors represented by institutions, organisations, economic and cultural factors. As claimed by Geels (2004):

> Radical novelties may have a “miss-match” with the existing regime and do not easily break through. Nevertheless, niches are crucial for system innovations, because they provide the seeds for change (Geels 2004).

The success or failure of a niche technology may depend on its capacity to avoid bottlenecks in the existing regime. Thus, the relationship between the regime and the niche is crucial for the eventual breakthrough or decline of such new, niche technologies. The strategic niche management approach has been used in several studies, among others in studying Danish wind energy (Smith 2006) and green biorefineries in Austria (Späth, Rohracher et al. 2006). The technological transition framework has inspired recommendations for policy intervention and broader governance issues by elaborating concepts such as strategic niche management or transition management (Markard and Truffer 2008). The concept of transition management has been adopted by Dutch policy makers working towards more sustainability (Kemp and Loorbach 2006). Transition management is a form of reflexive governance, addressing five strategy elements: knowledge integration, anticipation of long-term systemic effects, adaptivity of strategies and institutions, iterative participatory goal formulation, and interactive strategy development (Voß and Kemp 2006: p. 17ff.). The transition management approach has been used for analysing Dutch policy for biomass and biofuels (Kemp and Loorbach 2006: p. 123ff.).

Very few attempts to merge both approaches – the TIS approach and the multi-level approach – exist (Geels, Hekkert et al. 2008; Markard and Truffer 2008), despite the fact that this combination may offer analytical benefits. Markard and Truffer explore the conceptual commonalities of these two approaches and propose that it is "the concept of technological innovation systems that allows integrating the multi-level framework and the innovation system concept for the study of emerging, far reaching novelties" (Markard and Truffer 2008). However, such a combined framework has not yet been developed. Markard and Truffer argue that a number of empirical test cases would be required to demonstrate its relative advantage, compared both approaches being used independently.

5.5 Sustainable energy use and energy system

The concepts of energy systems and energy use represent core topics in research on renewable energy. The reason for this is straightforward: energy production is characterised by complex, systemic technologies. Energy use and consumption depends on distribution in the energy system. Change in energy use implies energy system transformation, as discussed in the paragraphs above. According to the analysis of the highly cited papers energy use and energy system are, respectively, topics in 40 and 20-25 out of 109 highly cited papers. The majority of papers within the topic *energy use* address links between economic development and energy consumption or demand. Other common topics include environmental impact, energy saving in industry branches and energy use in households. Highly cited papers with the topic energy system focus on how innovation and technology can address environmental challenges in society. Interdisciplinary approaches, combining perspectives from economic, political and social science groups and the multidisciplinary field of environmental studies, have also strong presences among these papers. Climate change and sustainable development represent the overall concern in these papers.

The search for research in FP6 on energy system and energy use identified a large number of very varied projects. If we try to identify the overall topics that could be described as the most common focus in these projects, these would be issues around costs and efficiency and issues around policy options for the transition towards more sustainable energy systems and energy use. The funding institution Nordic Energy Research works with the explicit objective to support research that provides advice on improvement potentials in the framework conditions for research, development and innovation in new energy technologies and environmentally friendly energy systems. The focus for the NER is therefore on policy studies that strengthen research and innovation, but the audience for these studies is above all policy makers, who can make a difference in developing research and innovation policy for the complex energy systems in question.

We have found a number of books that also address the topics energy system and energy use. A common subject in these books is the ambition to contribute to understanding opportunities and obstacles to sustainable development in advanced societies by means of new energy systems and changed patterns of energy use. Coming at this broad theme from the field of political science, Lafferty and Ruud (2008) shed light on how path dependency of dominant energy systems, in a whole range of different European countries, influence the promotion of electricity production from renewable energy sources (RES-E). The book takes up the issue of how conflicting interests, within nation states in particular, support conservatism in the policy systems and bureaucracies that need to make decisions if renewable energy is to be supported according to overall policy targets.

Utilising an approach that analyses the interplay of technological, institutional, market and management factors in the dynamics of energy systems, the book *Innovation for a Low Carbon Economy* (Foxon, Köhler et al. 2008) applies the multi-disciplinary and inter-disciplinary approach, which provides a high degree of relevance to the empirical material that is needed to support the final aim of contributing to the promotion of policies and strategic management for low carbon innovation.

Another social science approach uses a more normative framework, by prescribing a stricter managerial hand (governance) in guiding the required transition towards sustainable development. The book *Reflexive Governance* (Voß, Bauknecht et al. 2006) argues that transition towards sustainable approaches is about the organisation of processes rather than about particular outcomes. This approach rests on the conviction that a vision of sustainable development needs to be followed up by shaping wider societal development, in terms of concepts, practices and institutions by which that societal development is governed.

Reflecting more state-of-the-art innovation policy from the OECD Innovation Strategy (OECD: Inovation and Growth, 2007), the book *Ny Energi og Innovation i Danmark* (Borup, Dannemand Andersen et al. 2009) provides a number of renewable energy technology system analyses in the Danish context. In addition to providing insight into the actors, networks and framework conditions that each technological system embodies, the book’s output is specific innovation policy recommendations. It argues that improved Danish framework conditions need technology-specific policies, exploitation of the interactive features of the innovation system, strengthened public-private cooperation, and coordination of energy policy and innovation policy.

5.6 Concluding remarks

The particular policy relevance of social science energy research is made clear when we group the research by topics or issues addressed. The topics *foresight studies, public acceptance, environmental impact assessment, the innovation system approach and energy system transformation* and *sustainable energy systems and use*, have all been identified as frequently addressed in the literature and within the frameworks of research sponsored by international organisations. Several illustrative examples have been discussed in this chapter. They are used as starting point for the analysis of various aspects related to energy. Policy recommendations are frequently addressed.

As described above, a great number of studies have been undertaken on these topics, including those by Norwegian researchers. Foresight studies have proved attractive as they can support policymakers in situations with high levels of uncertainty. Scenario building has increasingly been used in the intersection with issues of climate change mitigation to portray future possibilities for new energy technologies. Environmental impact assessments are used to measure the effects these technologies have on society when they are produced and deployed. The results from the impact analysis are important knowledge on the sustainability of supporting different technology options. In these analyses, life cycle assessments are a commonly used approach.

In order to understand the complexities and the dynamics of technology innovation systems, interesting theoretical approaches have been developed by a number of Dutch researchers. The transition management approach addresses the interactions between different levels that imply that niches and technological regimes can be analysed in terms of changing landscapes. The approach allows for reflexive governance, focused on knowledge integration, anticipation of long-term systemic effects, adaptivity of strategies and institutions and iterative strategy development. The innovation systems approach is useful to understand the role of actors, networks and framework conditions that technological systems typically embody.

Finally we have seen great deal of research on energy systems and energy use. Several papers within the subject energy use address relations between economic development, energy consumption and demand. Interestingly, these papers are generally based on large, interdisciplinary and multidisciplinary projects, combining economic, political and social sciences with environmental studies. As has been illustrated in more detail in this report, these studies provide useful insights into the opportunities and obstacles to sustainable development, by means of new energy systems and changed patterns of energy use.

6 Norwegian research projects and publishing

This chapter analyses Norwegian social science research on environmentally friendly energy and its standing in an international context. We first present an analysis of the Norwegian participation in international research projects, especially under the EUFP6, the IEA Implementation agreements and Nordic Energy Research. In addition, the two main research programmes in the Research Council of Norway relevant for environmentally friendly energy, RENERGI and CLIMIT are mapped. The main topics of Norwegian publishing in scientific journals and selected other sources are also explored. Finally, we give an overview of the main Norwegian research organisations in this area and their fields of research.

6.1 Participation in international research projects

During the investigation of social science research on energy within FP6 we identified 47 projects with a focus on a specific technology. Amongst these projects, six involved Norwegian participation, including one wind project, one project on bio-energy, three projects on CCS, and one project on hydrogen. The most visible Norwegian participants in these projects are all from the industrial domain, being the three companies Statoilhydro, Statoil and Hydro. In the domain of research institutions the largest commercial research foundation in Scandinavia, SINTEF, is the most active participant in this area, with different departments active in technology areas such as bio-energy and CCS. Please consult the table below for further details.

Table 27: Norwegian participants in energy technology specific FP6 projects.

Wind	Bio-energy	CCS	CCS	CCS	Hydrogen
METEOROLOGISK INSTITUTT	SINTEF - THE FOUNDATION FOR SCIENTIFIC AND INDUSTRIAL RESEARCH	STATOILHYDRO ASA	STATOILHYDRO ASA	SINTEF PETROLEUMS-FORSKNING AS	NORSK HYDRO ASA
E-CO TECH AS	SVARTLAMOEN BOLIGSTIFTELSE	SINTEF ENERGI-FORSKNING A/S	SINTEF PETROLEUMS-FORSKNING AS	STATOIL ASA	
SWECO GROENER AS	TRONDHEIM OG OMEGN BOLIGBYGGELAG		SINTEF ENERGIFORSKNING A/S	WESTERNGECO A/S	
	HEIMDAL GRUPPEN AS		SINTEF - STIFTELSEN FOR INDUSTRIELL OG TEKNISK FORSKNING VED NORGES TEKNISKE HOEGSKOLE AS	DET NORSKE VERITAS AS	
	TRONDHEIM ENERGIVERK AS		NORGES TEKNISK – NATUR-VITENSKAPELIGE UNIVERSITET		
	TRONDHEIM KOMMUNE				
	COWI AS				

Table 28: International research projects with Norwegian participation. NER and IEA.

Agency	Thematic area	Technology field	Participants	Year
NER	Policy studies for strengthening the Nordic Research and Innovation Area in energy (NORIA-energy)	Solar photovoltaics, wind energy, 2nd generation biofuels, Carbon capture and storage	NIFU STEP (Norway)	2008
NER	Policy studies for strengthening the Nordic Research and Innovation Area in energy (NORIA-energy)	Bio-energy, hydrogen technology & fuel cells, solar cells, and wind energy	Technical University of Denmark (Denmark), Chalmers University of Technology (Sweden), BI Norwegian School of Management (Norway)	2008
NER		Carbon Capture and Storage	CICERO (Norway), SINTEF (Norway)	2007
NER		Renewable energy sources, hydrogen	Institute for Energy Technology (Norway)	2008
NER	Energy planning and system studies	Energy systems	Econ (Denmark), Institute for Energy Technology (Norway) Nordic Energy Research (Norden), NIRAS AS (Norway)	2004
NER	Nordic Working Group for Renewable Energy	Renewable energy sources	GreenStreem Nerwork Plc (Northern European Consultancy), Norwegian School of Management (Norway)	2008
IEA	Socio-Economic Drivers in Implementing Bio-energy Projects	Bio-energy	Energy Institute Hrvoje Pozar (Croatia), Tipperary Institute (Ireland), Norwegian Forest Research Institute (Norway), Sustainable Europe Research Institute (Austria), Centre for Energy Policy and Economics (Austria), Swiss Federal Institute of Technology (Switzerland), City of Växjö, Planning Department (Sweden), TV Energy Ltd (UK), Natural Resources Canada, Canadian Forest Service (Canada) Biomass Research Group, AIST (Japan)	2004
IEA	Sustainable International Bio-energy Trade - Securing Supply and Demand	Bio-energy	Norwegian University of Life Sciences (Norway),	2009
IEA	Sustainable International Bio-energy Trade - Securing Supply and Demand	Bio-energy	Climate Change Solutions, (Canada)Vienna University of Technology (Austria), European Bioenergy Services - EBES AG (Austria), Norwegian University of Life Sciences (Norway)	
IEA	Sustainable International Bio-energy Trade - Securing Supply and Demand	Bio-energy	Norwegian University of Life Sciences (Norway), Copernicus Institute, Utrecht University (the Netherlands)	2007
IEA	Sustainable International Bio-energy Trade - Securing Supply and Demand	Bio-energy	Energidata AS (Norway) Transportøkonomisk institutt (Norway), KEMA Consulting (the Netherlands)	2005
IEA	Hydrogen	Hydrogen	Research Council of Norway, (Norway), Norsk Hydro, (Norway), Institute for Energy Technology(Norway),	
IEA	Hydrogen	Hydrogen	IEA HIA Task 17 Operating Agent, Research Council of Norway (Norway), Institute for Energy Technology (Norway)	

Out of the 33 studies within Nordic Energy Research's portfolio, six involve Norwegian participation. However, amongst these projects there is no single organisation particularly active or visible; neither has it been possible to identify particular areas of strength or focus in terms of subject or technology field. The Norwegian organisations are: BI - Norwegian School of Management (with 2 papers), the Institute for Energy Technology (2), CICERO, NIFU STEP, NIRAS AS and SINTEF. However, one of the most visible organisations active in Nordic bio-energy projects is the Finnish consultancy Econ Pöyry, which has also a Norwegian branch.

A quite low number of IEA projects involve Norwegian participation. Out of the selected 76 studies only seven had Norwegian organisations involved. Of these, five studies address bio-energy and two address hydrogen. The organisations involved here are the Norwegian Forest Research Institute, the Norwegian University of Life Sciences (three studies), Energidata AS, the Transportøkonomisk institutt, the Norwegian Research Council (two studies), the Institute for Energy Technology (two studies) and Norsk Hydro.

The participation of Norwegian research organisations is summarised in Table 28. The involvement is fairly limited compared with other Nordic countries or other comparable countries. However, recently there has been more activity in this area which may indicate a shift towards more international collaboration on these issues involving Norwegian organisations.

6.2 Social science research projects on energy funded by the Research Council of Norway

Social science research projects on energy and the framework condition for the deployment of environmentally friendly energy are key priorities in the Norwegian energy strategy, Energi21. In particular, such research is addressed by the RENERGI programme under the Research Council of Norway and to some extent by the CLIMIT programme.

6.2.1 RENERGI – social science energy projects

RENERGI is a national research programme under the Research Council of Norway that aims at the development of knowledge and solutions supporting environmentally friendly, economically efficient and rational governance and administration of Norway’s energy resources. The aims of the programme include ensuring a high degree of security of energy supply and internationally competitive industrial development of the energy sector.

The RENERGI research programme was based on the merger of four social science research programmes on energy taking place under the Research Council of Norway: *Energi og samfunn*, *SAMRAM*, *SAMMEN* og *SAMSTEMT*. However, social science research forms only a relatively small part of the RENERGI programme. Technological research remains by far the biggest area, reflecting the relative dominance of technical research over social science research in Norway, and indeed in general in western countries. Over the last few years RENERGI has increased its funding for social science research: the annual funding of social science projects was around 20 million NOK during 2005–2008, but increased to 50 million NOK in 2009, and will reach about 65 million NOK in 2010 (Unander 2010).

A summary of the role and importance of social science energy research within the RENERGI programme is provided in an ECON-report from 2006 (ECON 2006). The focus of the report is on the uses and benefits of energy-related social science research. ECON discusses three hypotheses about the benefits of such research:

- It contributes to increased productivity through organisational, institutional and regulatory knowledge and also by contributing to new services and employment.
- It informs public discussions about priorities in society, by providing more information about the consequences of different options and about the relationships between different options.
- It contributes to a qualitatively better life through increased knowledge about issues that are important to our lives.

The main thematic issues addressed by RENERGI in terms of social science research are:

- *Energy markets*, including the development of models, effective market design, demand and consumer behaviour.
- *Energy policy and policy measures*, including the regulation of effective energy markets, the effects of different policy measures and interactions between different policy measures.
- *Analyses at the national and international level*, of international energy policy and its implications for the Norwegian energy policy, model development and analysis of societal costs of energy and climate policy and of public acceptance regarding policy measures and deployment of new energy technologies (see Unander 2010).

The focus of this report is primarily empirical, analysing the issues addressed by RENERGI social science research projects on renewable and environmentally friendly energy technologies. The data source is a project catalogue providing an overview of 68 projects under the label social science in the RENERGI programme. We have excluded two of these projects organised internally within the Research Council of Norway and eight projects that started in 2009 or launch in 2010. In total the project portfolio under investigation features 58 projects that started between 2000 and 2008.

The projects address various issues, but *climate policy* is one of the concepts that occur most frequently in the project titles. Focusing on issues related to climate change, policy studies outnumber technology specific studies. Of the 66 social science projects, only one or two focus specifically on one of the new energy technologies. Sustainable policy and climate policy are frequently addressed, often in studies that seek to establish how policy measures can be effectively designed and contribute to fulfilling policy objectives. The impact of climate change on the Nordic and Norwegian context is also a recurring topic. Several projects assess or study the Kyoto agreement and its Norwegian implementation. The project portfolio demonstrates the breadth of policy domains that relate to sustainable development, including environmental policy, energy policy, economic policy, market policy or market regulation and innovation policy. A couple of the projects also address important questions regarding the kinds of policy instruments that are needed to regulate emissions from energy use. This illustrates a situation where policy makers need to do more than establish policy instruments to stimulate the use of new renewable energy. Policy makers also need to look at economic incentives, regulation and the conditions that change energy consumption and discourage emission intensive behaviour.

Table 29: RENERGI funding of social science projects, started between 2000 and 2008.

	Started in									
Organisation / unit	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	***Total***
CICERO - Center for International Climate and Environmental Research Oslo	2	1		2	3		1		1	*10*
Statistics Norway (SSB)	1	2			2	1		1	2	*9*
Ragnar Frisch Centre for Economic Research	1	3			2		2			*8*
SNF - Institute for Research in Economics and Business Administration	1	3					1	1	1	*7*
BI - Norwegian School of Management			1	1	1		1			*4*
Institute for energy technology		1				1		1		*3*
NTNU, Department of Interdisciplinary Studies of Culture		1						1	1	*3*
Econ Pöyry AS			1				2			*3*
Energi Norge AS			1			1				*2*
Fridtjof Nansen Institute					1			1		*2*
University of Oslo, Department of Public and International Law			1				1			*2*
NTNU, Department of Industrial Economics and Technology Management								1		*1*
SINTEF Technology and Society				1						*1*
UMB, Department of Ecology and Natural Resource Management									1	*1*
UMB, Department of Economics and Resource Management		1								*1*
University of Oslo, ProSus Centre for Development and the Environment		1								*1*
Total	*5*	*13*	*4*	*4*	*9*	*3*	*8*	*6*	*6*	*58*

Source: RENERGI

Many projects focus on *energy markets* and integration of new renewable energy. The degree of interest in energy markets may be explained by the steps taken in Norway and the Nordic region that have liberalized energy markets, and the implementation of new renewable energy production into these markets. These changes may imply a demand for studies on these issues, to evaluate and explain the success of the common Nordic market.

Topics such as *environmental impact assessment* and *public acceptance of new energy technologies* are also present in several of the projects. It is interesting to observe that projects about research and development (R&D) and the significance of R&D for deployment of sustainable energy technologies, are topics that are almost absent in the project portfolio. The project portfolio is generally market-oriented and focused on how to support, develop and prepare more renewable energy for introduction in the relatively well-functioning Nordic energy market.

We have mapped the most frequently occurring project participants in the project portfolio. Table 29 provides the overview. The four most active research institutions in the RENERGI-programme are the Center for International Climate and Environmental Research Oslo (CICERO), Statistics Norway (SSB), the Ragnar Frisch Centre for Economic Research and the Institute for Research in Economics and Business Administration (SNF). These organisations are involved in ten, nine, eight and seven projects, respectively. For further details, see the table. The table also shows that thirteen of the projects were started in 2001. The annual average number of project startups is 6.5.

6.2.2 Social science research in CLIMIT

The research programme on power generation with carbon capture and storage (CLIMIT) focuses on natural gas power technology with CO_2 management. The programme is administered jointly by the Research Council of Norway and Gassnova, the state owned centre for gas power Technology. CLIMIT is a technologically oriented research programme. There is no focus on social science research in the mandate of the programme. However, the nature of complex and large scale technologies such as *CO_2* capture and storage (CCS) makes economic, environmental and social factors crucial to their implementation. There is a certain 'grey area' in technological research related to climate mitigation technologies and energy technologies, which involves an overlap between more technical and social topics, that decision makers and the public need information about. CLIMIT has financed a small number of projects and project components oriented towards economic or cost aspects, environmental aspects, and public awareness/acceptance aspects of CCS. The primary objective of the CLIMIT programme is:

> To commercialise power generation from fossil fuels with CO_2 management through research, development and demonstration.

The mandate of CLIMIT addresses technology development activities that facilitate the commercialization of *CO_2* capture and storage. Their activities aim to reduce costs across the whole value chain, and to promotecompetition by increasing the number of technologies and suppliers. The CLIMIT programme is therefore clearly technologically oriented. More specific CLIMIT objectives, both in the short term and in the long term, identify technological challenges. The need for social science research is not mentioned. The mandate, as defined in their work programme for 2006-2009, does however state three essential factors that are crucial to facilitate deployment of CCS. It is essential to:

- address health, safety and environmental (HSE) factors in all aspects of CO2 capture, transport and storage;
- promote the safety and acceptance of geological storage (including monitoring, improvement and closure of facilities); and,

- disseminate adequate, accurate information to enable the general public and decision-makers to gain a sound understanding of the technology.

The last point addresses dissemination processes. The general public and decision makers need to know about the technology, its costs and its consequences. The need for knowledge about the social consequences of CCS, in particular in terms of cost, entails some social science research. Even though the CLIMIT work programme is largely addressing technical research topics and challenges, and social science research on climate mitigation technologies is supposed to be financed by the research programme RENERGI, CLIMIT does have a track record of financing a few social science research projects. These projects address economic conditions, public awareness or acceptance and other conditions that need to be present in order for CCS technology to be implemented. Environmental impact assessment is also a research topic that is crucial as part of the knowledge base and in terms of decision support, for the public in general and decision makers in particular.

6.3 Publications with Norwegian authors

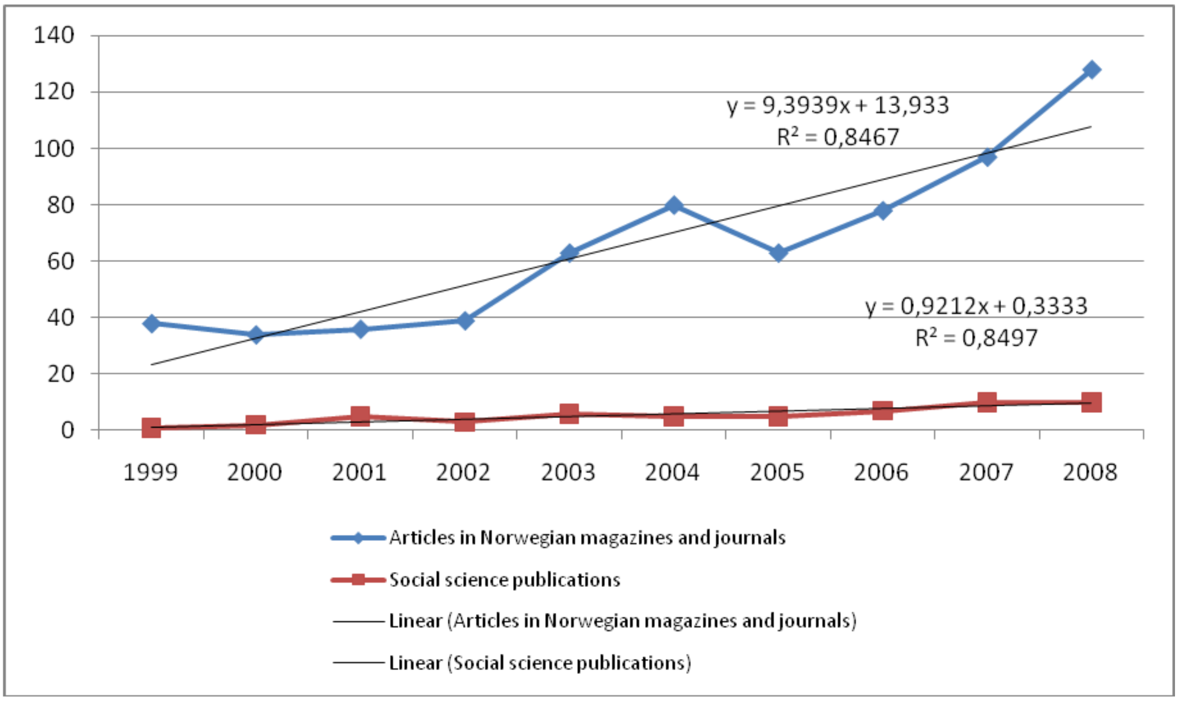
In this section we map Norwegian social science publications, concentrating on publications in international scientific journals (see the list of Norwegian papers in the Annex 8.2).[11] Research reports are not included in the analysis. Altogether, 56 publications are mapped.

The energy subject has received more attention from the Norwegian public over the last ten years. This trend is revealed when screening Norwegian articles in Norwegian journals and magazines. For that purpose we used the database Norart and applied the Norwegian keywords. In total 656 articles relevant articles have been identified, in Norwegian or another Scandinavian language (Figure 18). However, most of them are not found in scientific journals but magazines, and only a small number of them contain social science research by Norwegian authors: four articles in *Økonomisk forum* (four articles), and one in each of *Tidsskrift for samfunnsforskning* (Kasa 2003), *Sosiologisk tidsskrift* (Solli 2003), *Norsk økonomisk tidsskrift* (Amundsen 2005) and *Magma* (Anker-Nilssen 2006). These are also analysed in this chapter. However, the majority of the articles found were published in industry or technology magazines, such as *Teknisk ukeblad*, *Elektro* or *Norsk VVS* (Table 30) and are not analysed further. Nevertheless, the publishing output of magazine articles shows a high public interest in this topic, and the interest has increased significantly over recent years. Over the same period, the overall number of social science research publications has not increased likewise. This may indicate a gap between the public or wider interest in these issues, and the interest within the social sciences.

---

[11] Three of these papers are highly cited papers (Vorkinn and Riese 2001; Ibenholt 2002; Jumbe 2004). The paper of Vorkinn & Riese was not identified as Norwegian in the bibliometric study since there was no author address registered in ISI, but the analysis of highly cited papers revealed that this is a Norwegian paper as well. We also added recently published book (Lafferty and Ruud 2008), a relevant journal article not covered by ISI (Tjernshaugen 2008), an article not identified by the bibliometric study (Golombek and Hoel 2008) and an article published in an anthology (Midttun and Koefoed 2005).

Figure 18: Publishing on environmentally friendly energy in Norwegian journals and magazines (N_a=656) and social science publications (N_s=54).



Source: Norart / NIFU STEP

Table 30: Number of articles in most prominent Norwegian magazines. 1999–2008.

Magazine / Journal title	Number of articles
Teknisk ukeblad	106
Elektro	91
Norsk VVS	60
Miljøstrategi	44
Cicerone	30
Norsk skogbruk	27
Norsk energi	22
Økonomisk rapport	22
Elektro energiteknikk	15
Illustrert vitenskap	13
Natur & miljø	13
Norsk landbruk	13
Byggeindustrien	12
Skogeieren	10

Source: Norart

The following discussion summarises the main issues covered by the Norwegian social science publications. The publications are grouped thematically, starting with the energy market and energy use, followed by emission of carbon dioxide and carbon capture and storage, and energy innovation systems. We then move on to summarise publications on bio-fuels, hydropower and wind energy. Finally, we focus on international studies.

The energy market

The *deregulation of the power market* is a central topic in several articles. This can be explained by long-standing experience of the deregulated Norwegian power market and the Nordic Pool, but also the strong position of economic studies in Norway in general. Critics, who identify the dominance of these kinds of studies, demand that such market analysis be balanced by more policy analysis (Ruud 2010).

Mork studied the experience of deregulation of power markets, by analysing the Nordic energy market (Mork 2001). The author concludes the following issues as central in explaining the success of the deregulation of the Nordic energy market: the Nordic pool model, the price index, standard contracts and the large share of hydropower. Mork claims that deregulation will improve efficiency in energy generation, will allow more transparency and, accordingly, will improve consumer choices. However, such deregulation has to be coupled with environmental policy to prevent increased energy consumption. Sunnevag highlights the importance of voluntary agreements as central instruments in environmental policies (Sunnevag 2000), and points out that they should be designed as incentive based agreements.

Meyer and Koefoed analyse implications of the Danish energy reform after 2001 and the problems and uncertainties connected to the introduction of green certificates, compared with feed-in-tariffs (Meyer and Koefoed 2003). The impact of a green certificate market on energy prices is also explored in two articles by Amundsen (Amundsen 2005; Amundsen, Baldursson et al. 2006). Olsen, Amundsen and Donslund focus on the bridging function of Western Denmark between the Nordic power market, Nord Pool, which is characterised by a high share of hydropower and the power market in Northern Germany, which is dominated by thermal power plants (Olsen, Amundsen et al. 2006).

According to an article by Anker-Nielsen, increasing energy demand and a liberalisation of the energy market have led to increased energy prices and uneven distribution of energy (Anker-Nilssen 2006). Skaar studied the ambiguous price effects of an acquisition in a hydropower system with temporary bottlenecks (Skaar and Sorgard 2006).

Bye et al. analysed the deregulated Nordic and the North German energy markets by applying a market model (Bye, Bruvoll et al. 2008). They simulated the effects of inflow shortage scenarios in these combined hydropower and thermal capacities, and the analysis concludes that the security of supply is not endangered. Rosnes studied the impact of climate policies on the operation of a thermal power plant in Western Denmark (Rosnes 2008), and suggests that the technological know-how of industry practitioners should be combined with policy analysis, and that an expansion of wind power capacity should be considered in the context of the particular energy system.

Energy use

Studies on *residential energy use* and how to achieve reduced *energy consumption* in private households are another target area (Aune 2007). Several studies analysed the growth of residential energy consumption in Norway (Nesbakken 1999; Vaage 2000; Halvorsen and Larsen 2001; Nesbakken 2001; Unander, Ettestol et al. 2004). Nesbakken revealed that the price sensitivity in residential energy consumption is higher for high-income households than in low-income households (Nesbakken 1999), and that household characteristics have a significant impact on the choice of heating equipment and the level of energy consumption (Nesbakken 2001). Vaage developed an econometric model based on micro data gathered in the Norwegian Energy Surveys (Vaage 2000). Vaage highlights the high degree of heterogeneity between households, and that appliance choice and energy demand are significantly influenced by energy prices. Halvorsen and Larsen explained the growth of residential energy consumption in terms of an increased number of households, a higher number of electric household appliances, increased house area and increased household incomes (Halvorsen and Larsen 2001). Unander et al. compared the development of residential energy use in Norway in the period 1973–1999 with Denmark and Sweden (Unander, Ettestol et al. 2004). They point out that Norway initially had a lower per capita income level and the rapid income growth during this period was the main reason for enlarged house area and increased energy use. Residential energy saving was more common in Denmark and Sweden until 1990, but Unander et al. claim that after 1990 this became more of a focus in Norway than in Denmark and Sweden.

Holden and Norland point out three main challenges in reducing energy use in compact cities: higher rates of leisure-related air transport, less access to gardens nearby and poor energy standards for housing in cities (Holden and Norland 2005). Ornetzeder et al. studied the car-free housing model in Vienna, Austria (Ornetzeder, Hertwich et al. 2008). They concluded that households in the car-free settlement have a higher income, more sustainable lifestyles with a lower environmental impact in ground transport and energy use, but higher emissions because of greater use of air transport.

Nyrud, Roos and Sande studied consumer perceptions of residential bio-energy heating in Oslo (Nyrud, Roos et al. 2008). They concluded that marketing campaigns for the implementation of renewable energy in residential households should also consider the users' perceptions of such equipment, as well as their environmental concerns.

Emission of carbon dioxide and carbon capture and storage (CCS)

There are several relevant Norwegian articles on *carbon dioxide emissions*. The possible impacts of reduced Norwegian sales of natural gas on European emissions of carbon dioxide have been analysed by Berg et al., who concluded that such a reduction would only have a minor impact, as the consumption of natural gas would be replaced by consumption of coal and oil (Berg, Boug et al. 2001).

Bruvoll and Medin investigated the origins of changes in emissions into the air over the period 1980 to 1996 (Bruvoll and Medin 2003). They concluded that policies can counteract increased emissions by supporting environmentally friendly energy research, directly reducing emissions though policy actions, introducing incentives for lower energy use and replacing fossil energy sources with environmentally friendly energy sources.
Faehn and Holmoy explored the effects of the liberalisation of global trade on polluting emissions in Norway, with the help of two scenarios (Faehn and Holmoy 2003). They conclude that trade liberalisation will lead to slightly increased GDP, but also to increases in polluting consumption and solid waste. They predict that this will favour heavy-polluting industry, increased hydropower prices and a substitution of renewable energy with more polluting energy sources.

Kasa analysed climate policy positions and strategies related to emission intensive industries and the deployment of natural gas in five Norwegian industrial municipalities (Kasa 2003). Golombek and Hoel study considers the relationship between endogenous technology development and tradable emission quotas (Golombek and Hoel 2008).

Three articles address *carbon capture and storage* (Severud 2007; Shackley, Waterman et al. 2007; Tjernshaugen 2008). Severud studied Norway's experience with carbon storage, but concludes that there will be no international carbon storage agreement in the near future. Shackley et al. conducted a survey on perceptions of possible risks of carbon capture and storage amongst European stakeholders, including representatives from industry, governments, parliaments, NGOs and researchers (Shackley, Waterman et al. 2007). The survey identifies a range of perceived risks and points out two particular risks connected with CCS: the risk that CCS may lead to the additional use of fossil fuels and the risk that CCS may detract from investments in renewable energy. Tjernshaugen studied the political commitment to CCS based on an assessment of governmental budgets for RD&D in CCS (Tjernshaugen 2008). He concludes that countries with high incomes from petroleum production may be leaders in promoting CCS.

Energy innovation systems

Midtun and Koefoed compared the dynamics of innovation systems by analysing the institutional framing and commercial development of six cases: wind power and bio-fuels in Denmark, combined heat and power and bio-fuels in Finland and in Sweden (Midttun and Koefoed 2005). Finon, Johnsen and Midtun studied the challenges for energy capacity expansion, under a deregulated market economy, for the Nordic region (Finon, Johnsen et al. 2004). They suggest that these challenges are different depending on the scale of the technological systems: large-scale technical systems require some coordinated governance while small-scale and decentralised technical solutions may function well in a competitive market.

An article by Soli discusses the contribution of science and technology studies to economic practice, through a study of the discourse around wind technology development in Norway (Solli 2003).

Lafferty and Ruud edited a book on the implementation of the EU RES Directive, its impact on the dominant energy systems in each country and discuss the importance of path dependency and path creation (Lafferty and Ruud 2008). This comparative study covers Austria, Denmark, Ireland, the Netherlands, Norway, Spain and Sweden, and makes use of not just economic theory but, more substantially, ideas from political science.
The importance of a systemic approach in innovation policy is addressed by several papers. Godoe & Nygaard explored the case of technological innovation in hydrogen and fuel cells in Norway, in the period 1990-2002, and identified the system failure of innovation policy (Godoe and Nygaard 2006). Technological innovation in hydrogen and fuel cells in Norway was also studied by Klitkou et al. in a bibliometric analysis of techno-science networks based on cooperation information stemming from publishing, patent and project data (Klitkou, Nygaard et al. 2007).

Public acceptance of renewable energy

Public acceptance of renewable energy features in a study by Navrud and Bråten on consumer preferences for wind power, hydropower and gas in Norway (Navrud and Bråten 2007). They conducted an experiment to identify preferences amongst Norwegians, and conclude that large wind farms are preferred by Norwegians to further deployment of hydropower, domestic gas power plants or the import of electricity from foreign coal-fired power plants; however, the NIMBY-effect is also expected to be an obstacle in building more wind farms. Vorkinn and Riese analysed local attitudes towards hydropower in Skjåk, a rural community in Norway (Vorkinn and Riese 2001). Attitudes towards a proposed major hydropower development, which will cause major environmental impacts, were examined in relation to socio-demographic variables and place attachment. The study concluded that place attachment explained more of the variances in attitudes than socio-demographic variables.

Bio-fuels and the forestry sector

Several articles address the importance of the forestry sector for the production of bio-fuels in Norway. The articles highlight that the different interests of timber production, bio-fuel production and carbon sequestration have to be balanced (Bjornstad and Skonhoft 2002). The economic supply curve for forest-based bio-fuels has been estimated for the Norwegian North-Trondelag County (Bjornstad 2005). Tromborg et al. describe how different policy instruments may affect the deployment of forest-based bio-fuels in Norway (Tromborg, Bolkesjo et al. 2007). The instruments studied were subsidies for district heating installations, deposit grants for replacing oil-based heating installations with bio-energy based systems and feed-in tariffs for energy production in district heating, based on bio-energy. They applied a regionalised equilibrium model including three competing industry sectors, forestry, forest industry and the bio-energy sector, and concluded by setting out medium-term projections for bio-energy use under different policy regimes.

Hydropower

Few social science articles on hydropower have been identified. Bockman et al. analysed the relationship between production size, investment costs and price limits for small hydropower projects (Bockman, Fleten et al. 2008). Kjaerland applied the real option theory in a study of hydropower investment opportunities in Norway (Kjaerland 2007).

Wind energy

The further development and deployment of wind energy technology is addressed by several articles. These articles often have a comparative perspective, mainly comparing Denmark and Norway, and examining the role of the different sets of policy instruments in each country (Ibenholt 2002; Buen 2006). Ibenholt's study compared the learning curves for wind power in three countries: Denmark, Germany and the United Kingdom. She concludes that utilisation differs between countries, due to different aerodynamic conditions and to differing policies. Policies that enhance competition can probably result in large cost reductions, but may hamper diffusion of wind power. The use of price systems that guarantee wind turbine owners a certain price for each kWh generated, as in Germany and Denmark, have created stable market conditions, and thereby increased the capacity installed, although costs are not much reduced. The crowding-out of hydropower and network congestions induced by increased wind energy utilisation in Norway has been addressed by a collaborative paper authored by experts from the University of Oslo, NORAD, Statnett and Statkraft (Forsund, Singh et al. 2008).

International studies

Beside the quite common approach in these studies, of comparing Norway with other Nordic or Western European countries, there are also several studies targeting other international regions.

There are a number of studies on the conditions, barriers and future developments of environmentally friendly energy in the *People's Republic of China*. Gan analysed the barriers and perspectives of a more environmentally friendly *transport sector*, concluding that there is a need for economic incentives to support emission reduction, more energy efficiency, improvement of the public transport system and the development of new technologies (Gan 2003). Gan & Yu also studied the deployment of *bio-energy* in China (Gan and Yu 2008) and point out that biomass burning is currently overemphasised in China and the potential for household-based deployment of bio-energy should be more of a focus in policy. Liu, Gan and Zhang explored the economics of *wind power* deployment in China, considering the major constraints for further wind technology development and obstacles in current policies (Liu, Gan et al. 2002). Another topic relevant for China is the dependence on heavily polluting coal resources. Glomsrod & Wei addressed this topic by suggesting the introduction of *coal washing* as a viable strategy to reduce particle emissions (Glomsrod and Wei 2005).

Two studies address energy and environment issues in developing countries. Jumbe examined co-integration and causality between electricity consumption, overall GDP, agricultural-GDP and non-agricultural-GDP in *Malawi* (Jumbe 2004). The results show causality running one-way, from non-agricultural-GDP to electricity consumption, suggesting that a permanent rise in GDP may cause a permanent growth in electricity consumption. An article by Upadhyay, Solberg and Sankhayan analysed land-use changes, forest/soil degradation and carbon sequestration in the *Himalaya region* (Upadhyay, Solberg et al. 2006). The authors reviewed and synthesised existing models and present a dynamic conceptual modelling framework, which captures both socio-economic behaviour and bio-physical processes, and combines these with geographical information systems and remote sensing techniques. Such a model may help policy makers to support sustainable agriculture and forestry.

Two articles address the development of the *U.S.-energy system*. Maribu et al. Looks at the diffusion of distributed energy resource technologies in the U.S. commercial building sector (Maribu, Firestone et al. 2007). Menz & Vachon analysed the contribution of state-level policies to wind power development in several U.S. states (Menz and Vachon 2006). They analysed several factors, including renewable portfolio standards, fuel generation disclosure rules, mandatory green power options and retail choice options for customers. Renewable portfolio standards and green power options are found to have a positive impact on wind power development, while retail choice options have a negative impact.

6.4 The most important Norwegian research organisations in this field

In the following section we list the main Norwegian research organisations active in the field of social science research on environmentally friendly energy. We distinguish between universities, institutions affilatated with a university, other higher education institutions and research institutes. For universities, the main departments active in this field are identified. There are also several companies active in this area, with one publication each, but they are not listed here. The summary is based on the publication output analysed in the previous section, and on participation in international and national research projects. However, as the number of publications and projects listed is limited, it is difficult to detect clear specialisation patterns.

The University of Bergen

At the University of Bergen we have identified three departments active in these topics: the Department of Economics, the Department of Geography and the Department of

Information Science and Media Studies, the first being the most active one. The Department of Economics has specialised in studies on Green Certificate markets, the European power market and Norwegian households' energy demand.

The University of Oslo

At the University of Oslo there are three units that are particularly active: the Department of Economics, ProSus (the Centre for Development and the Environment) and the *Department of Public and International Law*. The *Department of Economics* has worked on the effects of investing in wind power, on utilisation of existing hydropower and on energy efficiency and energy use, while *ProSus* has also worked on energy efficiency and energy use, but also ran a long, comparative project on the implementation of the EU RES Directive in different European countries. ProSus received funding from RENERGI to investigate green consumers and green producers. Since 2009 the ProSus team is part of SINTEF Energy. The Department of Public and International Law also received funding from RENERGI on the Kyoto agreement and the interaction between international and national rules.

CICERO – the Center for International Climate and Environmental Research Oslo

CICERO – affiliated with the University of Oslo – has a strong specialisation on climate policy and has also been involved in several publications in our sample addressing governmental policy for carbon capture and storage and policy regimes for promoting renewable energy. Several publications on the People's Republic of China by Chinese authors but with CICERO's author address indicate that CICERO has been successful in attracting research fellows and researchers from the People's Republic of China. CICERO also receives the main bulk of its funding from RENERGI for social science projects and for the publication of CICERONE (ended in 2007), one of the magazines identified as very active in the field.

The NTNU –the Norwegian University of Science and Technology

At the NTNU we identified quite a large number of departments engaged in social science studies on energy: the Department of Industrial Economics and Technology Management, the Department of Interdisciplinary Studies of Culture, the Department of Electric Power Engineering, the Department of Production and Quality Engineering and the Department of Energy and Process Engineering. The first three are the most relevant. The *Department of Industrial Economics and Technology Management* has worked on forestry-based bio-fuels and on investment timing for small hydropower projects. The *Department of Interdisciplinary Studies of Culture* has published on private energy consumption, Danish and Norwegian wind industry and the influence of science and technology studies on the discourse around wind energy development in Norway. This department has also been funded for several projects by RENERGI, including those investigating the role of economics in energy policy and energy use and recently on the implementation and commercialization of new energy technologies. The *Department of Electric Power Engineering* has analysed distributed energy resources market diffusion models and residential energy use in Denmark, Sweden and Norway.

The Norwegian University of Life Sciences

At the Norwegian University of Life Sciences almost all activities in the field are concentrated in one department, the *Department of Ecology and Natural Resource Management*. Their publication output indicates a specialisation on forest-based bio-fuels and residential use of bio-energy, consumer preferences for renewable energy in Norway and the impacts of climate policies. However, amongst their publications there are two on relevant problems in developing countries – on Malawi and the Himalaya region – which indicate the university's focus on development studies. The university has also been active in three IEA projects on sustainable international bio-energy trade. A further project on the development of second generation bio-fuels has recently received funding from RENERGI.

BI – the Norwegian School of Management

BI's publication output indicates a specialisation in power markets, energy policy and energy innovation systems in the Nordic region. This is consistent with their participation in a NER policy study, on strengthening the Nordic Research and Innovation Area in terms of energy, and their participation in the Nordic Working Group for Renewable Energy. BI has also received ongoing RENERGI funding for research projects on the power market, regulation of energy utilities, and residential energy demand.

Statistics Norway

Statistics Norway is one of the most active research organisations in this field in Norway, both in terms of publications and research projects funded by RENERGI. They demonstrate a strong specialisation on residential energy consumption, air pollution, emission trading, environmental policy and the deregulated power markets.

Other research institutes

There are several research institutes with just one or two research publications in the sample. They are listed alphabetically below. A specialisation pattern cannot be deducted for these organisations, due to the small number of papers.

- The Eastern Norway Research Institute, with a paper on environmental concerns and place attachment for a hydropower project in Norway.
- Econ Pöyry, the Norwegian branch of the Finnish consultancy, with a paper on learning curves for wind power and a paper on the impact of climate policies on the operation of a thermal power plant. Econ Pöyry has also received funding from RENERGI several times, for work on burden allocation and climate policies.

- The Fridtjof Nansen Institute Polhøgda, with a paper on Norway's experience of carbon dioxide storage. They have also had several projects funded by RENERGI on the EU's Emissions Trading Scheme and climate policy.
- The Institute for Energy Technology has no social science publication output on environmentally friendly energy, but has participated in several IEA projects on hydrogen, in a NER project on energy planning and system studies and a NER project on hydrogen. The institute also received RENERGI funding for studies on energy trade and climate policy and Norwegian energy technology innovation and diffusion in a global technology market, among others.
- The Norwegian Institute for Studies in Innovation, Research and Education (NIFU STEP), with two papers on innovation systems and techno-science networks in fuel cells and hydrogen in Norway, and a NER policy study about strengthening the Nordic Research and Innovation Area in energy.
- The Norwegian Forest Research Institute has no social science publications in our sample, but has participated in an IEA project on bio-energy.
- The Norwegian Institute of International Affairs (NUPI), with a paper on air pollution and environmental policy and a NER policy study on collaboration with Russia.
- The Ragnar Frisch Centre for Economic Research has published on energy and environmental economics, and especially on the economics of climate policy and energy use. They have received funding from RENERGI for several projects.
- SINTEF has no publications in our sample, but has participated in several FP6 projects on CCS and bio-energy, and an NER project on CCS. The transition of the ProSus team to SINTEF Energy may also indicate a shift in their interest in this area.
- Trøndelag Forskning og Utvikling, with two papers on forestry-based bio-fuels.
- Vestlandsforsking, with a paper on challenges for energy use in compact cities.

6.5 Concluding remarks

In Norwegian social science, the research on energy is dominated by two types of studies: *economic studies*, especially studies on the energy market and energy consumption, and *climate policy* and *environmental policy studies*. Other social science studies are still fairly underdeveloped. Issues such as new, emerging energy technologies, the significance of R&D for deployment of sustainable energy technologies and the energy innovation system are less widely addressed in the Norwegian context. The high level of energy market research can be explained by special conditions in Norway for economists wishing to study a functioning, deregulated power market. However, such analysis should be complimented and developed by taking different types of policy analysis into account, as the debate on different approaches to energy market analyses at the Energiuka 2010 shows.

There are many Norwegian research organisations working on energy issues, but this research seems to be rather fragmented. Beside the activities at the NTNU, Statistics Norway, the Norwegian University of Life Sciences and the University of Oslo (including

CICERO) activities are generally more limited and result in few publications for many of the research units identified. This may indicate of a lack of strategic focus in this field. At the national funding level, however, this does not seem to be a problem, as this area has received increased attention.

Norwegian participation in international research projects is limited compared to other Nordic countries. However, the increasing participation in Nordic and European projects by several Norwegian research organisations may indicate a shift towards a stronger focus on social science research on environmentally friendly energy.

Interestingly, there are signs of increased attention amongst technological research institutes, such as SINTEF Energy and the Institute for Energy Technology, in social science issues. This shift is in line with increased public interest in environmentally friendly energy.

7 Final conclusions

This analysis indicates that energy, and environmental friendly energy especially, has increased in importance within social science publishing and also in terms of Norwegian participation in national and international research projects. This heightened research interest reflects a stronger focus on environmentally friendly energy in general, in an international context and nationally. The requirements of deploying new energy technologies, reducing energy consumption and building effective and socially sustainable energy markets have to be addressed by politicians, but are also quite visible in international public debate. Social science studies actively contribute to such debate.

This report has addressed the following research questions:

- How have social science disciplines targeted environmentally friendly energy as an empirical field of research?
- Which problems have been addressed, which methods have been applied, and which main results have been accomplished?
- Which Norwegian research environments have worked in this field, and what is their main focus?

Environmentally friendly energy as a target in social science research

When viewed in terms of the portfolio of international and Norwegian projects and publications on environmentally friendly energy within the social sciences, the activity is concentrated in three social science disciplines: economics, business and management studies; environmental studies and ecology; and, to some extent, political sciences including planning, public administration and international relations. Such contributions are often multidisciplinary as many publications are found in multidisciplinary journals and some of the social science groups are multidisciplinary themselves, such as environmental studies and ecology. The subject seems to require a multidisciplinary approach to be understood properly.

In this study we have examined the international and the national social science discourse on environmental friendly energy and identified key areas covered by this discourse. The energy subject area with the most publications is energy use, followed by carbon capture and storage (CCS) and wind technology. There is an upwards trend in publishing for all energy subjects, but the highest increase can be seen in energy use and bio-energy, while the other subjects show a more modest development.

Environmentally friendly energy, energy use, energy systems and energy markets are issues which have attracted increased attention worldwide, but the international distribution of publications is quite skewed. However, the dominant position of the U.S. papers is not as marked in this field as it is in the social sciences overall. The Netherlands and Sweden have both achieved quite a high share of papers, compared to their average share of social science articles. Some countries have research groups active across all energy subjects, such as the USA, the United Kingdom, the Netherlands, Sweden, Germany, Canada, Greece, Austria and France. Other countries are more specialised in selected energy fields, such as Japan, China, Australia and Denmark among others.

Research questions that have been addressed, methods and main results

In this study we concentrated on project funding from three international organisations: the EU's 6th Framework Programme (FP6), Nordic Energy Research and the International Energy Agency. Although these organisations largely fund technological oriented energy research, the social science aspects are also being addressed to some extent.

Under the FP6 not many projects have a "pure" social science orientation. Social science research more often features as a component in more technology oriented projects. The majority of these social science projects include reflections on, or recommendations for, regulatory behaviour and policy practice. A typical theme of these papers is the assessment of socio-economic impacts of the deployment of renewable technologies. Issues of management of the implementation of these technologies are also common focuses. Social science components can be found in projects with a more organisational character; these can often be characterised as projects with strong cooperative features, for example those on the operation of a technology platform or networking programmes.

When we analyse social science research by technological field, a few recurrent themes can be found. In wind energy projects with a social science dimension the social acceptance for wind energy is often investigated. This tendency applies to projects under FP6 and the IEA.

Research into the socio-economic aspects of bio-energy is more frequently supported when compared to other energy subject fields. Issues most frequently covered include socio-economic drivers and impacts of introducing bio-energy markets, guidelines and recommendations to policymakers, public attitudes towards bio-energy and biomass markets and trade. In fact, the largest number of social science studies supported by the IEA implementing agreement for renewable energies relate to the bio-energy field. Bio-energy research is also frequently supported at the Nordic level, through NER. Both quantitative and qualitative approaches are used in these studies: case studies are widely used, as are studies describing national bio-energy markets and framework conditions.

Nordic Energy Research works with the explicit objective to support research that provides advice on improvement potentials in the framework conditions for research, development and innovation in new energy technologies and environmentally friendly energy systems. Their focus is on policy studies that strengthen research and innovation, but their audience is primarily policy makers, who can make a difference in developing research and innovation policy for the complex energy systems in question. Nordic Energy Research has funded quite a few policy studies that aim to strengthen the Nordic Research and Innovation Area's work on energy.

The particular policy relevance of social science energy research is clearly demonstrated by grouping the research identified in this study by topic or the issues it addresses. The topics most frequently adopted in the scholarly literature and within research sponsored by international organisations are *foresight studies, public acceptance, environmental impact assessment, the innovation system approach and energy system transformation* and *sustainable energy systems and use*.

As described above, a great number of studies have been conducted on these topics overall, and they constiute a particular focus for Norwegian researchers. Foresight studies are attractive as they can support policymakers in situations with high levels of uncertainty. Scenario building has increasingly been used in the intersection with issues of climate change mitigation to portray future possibilities for new energy technologies. Environmental impact assessments are used to measure the effects these new technologies can have on society when they are produced and deployed. The results from such impact analyses provide important knowledge on the sustainability of different technology options. In such cases, life cycle assessment is a commonly used approach.

The concepts of energy systems and energy use represent core topics in research on energy. The reason is obvious: energy production is characterised by complex, systemic technologies and energy use and consumption depends on distribution in the energy system. Changes in energy use imply transformations in the energy system. According to the analysis of the 109 highly cited papers (cf. chapter 4), energy use features as a topic in 40 papers and energy systems feature in 20–25 papers. The majority of papers within the topic *energy use* address the relationships between economic development and energy consumption or demand. Other common topics include environmental impact, energy saving in industry branches and energy use in households. Highly cited papers within the topic *energy system* focus on how innovation and technology can be used to deal with environmental challenges in society.

Interdisciplinary approaches combining economic, political and social sciences, and the multidisciplinary field of environmental studies, are also present in many of the energy papers. Climate change and sustainable development are the overall concerns amongst the highly cited articles.

Norwegian focus and research units in the field

We conclude that the research field in Norway is dominated by two types of studies: *economic studies*, especially studies on the energy market and energy consumption and research on *climate policy* and *environmental policy studies*. The high interest in energy market research, in Norway and in an international context, is possibly explained by the special conditions for Norwegian economists, in terms of studying a functioning, deregulated power market. Thus we find the research perspective should be broadened to take different types of policy analysis into account. Other social science studies still seem rather underdeveloped. New emerging energy technologies and the energy innovation system are addressed less in the Norwegian context than in the rest of the sample.

Several research organisations study energy issues, but Norwegian research seems to be rather fragmented in this area. Outside the activities at the NTNU, Statistics Norway, the Norwegian University of Life Sciences and the University of Oslo (including CICERO) the activities going on in other organisations seem to be more limited, and to result in few publications. This may indicate a lack of a strategic focus in this field. This does not seem to be explained by the volume of national funding, however, which does not seem to be a hindrance and where environmental friendly energy has received increasing attention, especially over the last two years following the new energy strategy, Energi21. Increased funding by the RENERGI programme will presumably lead to an increased publishing output.

The participation in Nordic and European projects by several Norwegian research organisations may also indicate a shift towards greater interest in, and a clearer focus in, social science research on environmentally friendly energy. Another promising step is the increased attention on social science issues amongst technological research institutes, such as SINTEF and the Institute for Energy Technology. Their increased awareness is in line with the increased public attention being paid to environmentally friendly energy.

8 Appendix

8.1 Most important journals and social science groups by energy subject

Table 31: Bio-energy - the most important journals. N=210.

Journal full title	Number of papers
ENERGY POLICY	127
REVIEW OF AGRICULTURAL ECONOMICS	7
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS	6
CLIMATE POLICY	4
ECOLOGICAL ECONOMICS	4
ENVIRONMENTAL & RESOURCE ECONOMICS	4
FORBES	4
NATURAL RESOURCES FORUM	4
ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES	3
JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS	3
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	3
TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	3

Source: Thomson Reuters ISI Web of Science, Social Science Citation Index, NIFU STEP

Table 32: Bio-energy - the most important social science group. N=210.

Social Science Group	Number of papers
Environmental Studies and Ecology	163
Economics, Business and Management	51
Agriculture and Forestry	30
Political science, Planning, Public administration and International relations	17
Transportation	8
Geography and Area studies	3
Multidisciplinary Sciences	3
Information Science & Library Science and Communication	2
Sociology and Anthropology	2
Law	1
Social Issues	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 33: CCS – the most important journals. N=322.

Journal full title	Number of papers
ECOLOGICAL ECONOMICS	80
CLIMATE POLICY	62
ENERGY POLICY	50
CANADIAN JOURNAL OF AGRICULTURAL ECONOMICS-REVUE CANADIENNE D AGROECONOMIE	22
ENERGY JOURNAL	22
GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS	20
LANDSCAPE AND URBAN PLANNING	18
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS	16
LAND ECONOMICS	16
ENERGY ECONOMICS	15
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	12
ENVIRONMENTAL & RESOURCE ECONOMICS	10
FOREST POLICY AND ECONOMICS	9
REGIONAL ENVIRONMENTAL CHANGE	8
RESOURCE AND ENERGY ECONOMICS	8
JOURNAL OF ENVIRONMENTAL MANAGEMENT	7
AGRICULTURE ECOSYSTEMS & ENVIRONMENT	6
AUSTRALIAN JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	6
JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	6
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	6
CANADIAN JOURNAL OF FOREST RESEARCH-REVUE CANADIENNE DE RECHERCHE FORESTIERE	5
AGRICULTURAL ECONOMICS	4
ENVIRONMENT AND DEVELOPMENT ECONOMICS	4
GLOBAL ENVIRONMENTAL POLITICS	4
POLICY SCIENCES	4
PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	4
SOCIETY & NATURAL RESOURCES	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 34: CCS – the most important social science groups. N=322.

Social Science Group	Number of papers
Environmental Studies and Ecology	214
Economics, Business and Management	131
Agriculture and Forestry	58
Political science, Planning, Public administration and International relations	46
Geography and Area studies	22
Multidisciplinary Sciences	10
Urban studies and Architecture	10
Law	2
Social Sciences, Interdisciplinary	2
Social Sciences, Mathematical Methods and Computer sciences	2
Sociology and Anthropology	2
Social Issues	1
Transportation	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 35: Energy system – the most important journals. N=274.

Journal full title	Number of papers
ENERGY POLICY	166
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	22
ENERGY JOURNAL	22
CLIMATE POLICY	18
ENERGY ECONOMICS	15
ECOLOGICAL ECONOMICS	12
INTERNATIONAL JOURNAL OF URBAN AND REGIONAL RESEARCH	6
FUTURES	4
POLICY SCIENCES	4
SPACE POLICY	4
GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS	4
ENVIRONMENTAL POLITICS	4
GLOBAL ENVIRONMENTAL POLITICS	4
JOURNAL OF WORLD TRADE	3
INTERNATIONAL JOURNAL OF GEOGRAPHICAL INFORMATION SCIENCE	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 36: Energy system – the most important social science groups. N=274.

Social Science Group	Number of papers
Environmental Studies and Ecology	214
Economics, Business and Management	58
Political science, Planning, Public administration and International relations	37
Geography and Area studies	7
Social Sciences, Interdisciplinary	5
Urban studies and Architecture	4
Multidisciplinary Sciences	3
Agriculture and Forestry	2
Law	2
Social Sciences, Mathematical Methods and Computer sciences	2
Transportation	2
Information Science & Library Science and Communication	1
Sociology and Anthropology	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 37: Energy use – the most important journals. N=1,222.

Journal full title	Number of papers
ENERGY POLICY	557
ECOLOGICAL ECONOMICS	138
ENERGY ECONOMICS	121
ENERGY JOURNAL	72
ENVIRONMENTAL & RESOURCE ECONOMICS	46
TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	46
CLIMATE POLICY	38
RESOURCE AND ENERGY ECONOMICS	32
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	30
FUTURES	18
LANDSCAPE AND URBAN PLANNING	15

OPEN HOUSE INTERNATIONAL	14
TOURISM MANAGEMENT	14
ENVIRONMENT AND PLANNING A	12
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	10
HOUSING STUDIES	10
ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES	10
JOURNAL OF POLICY MODELING	9
SOCIETY & NATURAL RESOURCES	9
URBAN STUDIES	8
JOURNAL OF THE AMERICAN PLANNING ASSOCIATION	8
HOUSING POLICY DEBATE	8
EURASIAN GEOGRAPHY AND ECONOMICS	8
ENVIRONMENT AND PLANNING B-PLANNING & DESIGN	7
JOURNAL OF ENVIRONMENTAL MANAGEMENT	7
TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE	7
ENVIRONMENTAL SCIENCE & TECHNOLOGY	6
LAND ECONOMICS	6
POLICY SCIENCES	6
POPULATION AND ENVIRONMENT	6
ENVIRONMENT AND PLANNING C-GOVERNMENT AND POLICY	6
URBAN GEOGRAPHY	6
WORLD DEVELOPMENT	6
JOURNAL OF ARCHITECTURAL AND PLANNING RESEARCH	6
ENVIRONMENTAL POLITICS	6
ENVIRONMENT AND BEHAVIOR	5
TRANSPORT REVIEWS	5
JOURNAL OF ENVIRONMENTAL PSYCHOLOGY	5
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS	4
RESEARCH POLICY	4
AGRICULTURE ECOSYSTEMS & ENVIRONMENT	4
AGRICULTURAL ECONOMICS	4
IDS BULLETIN-INSTITUTE OF DEVELOPMENT STUDIES	4
TRANSPORTATION QUARTERLY	4
HUMAN ECOLOGY	4
AGRICULTURE AND HUMAN VALUES	4
GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS	4
JOURNAL OF TRANSPORT GEOGRAPHY	4
SUSTAINABLE DEVELOPMENT	4
PACIFIC FOCUS	4
ENVIRONMENT AND DEVELOPMENT ECONOMICS	4
INTERNATIONAL JOURNAL OF SUSTAINABLE TRANSPORTATION	4
SURVIVAL	3
REGIONAL SCIENCE AND URBAN ECONOMICS	3
HABITAT INTERNATIONAL	3
SOCIAL SCIENCE & MEDICINE	3
JOURNAL OF URBAN PLANNING AND DEVELOPMENT-ASCE	3
JOURNAL OF REGULATORY ECONOMICS	3
CHINA & WORLD ECONOMY	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 38: Energy use – the most important social science groups. N=1,222.

Social Science Group	Number of papers
Environmental Studies and Ecology	872
Economics, Business and Management	404
Political science, Planning, Public administration and International relations	98
Transportation	48
Urban studies and Architecture	44
Geography and Area studies	38
Agriculture and Forestry	14
Sociology and Anthropology	12
Social Sciences, Interdisciplinary	11
Social Sciences, Mathematical Methods and Computer sciences	10
Multidisciplinary Sciences	9
Law	4
Information Science & Library Science and Communication	2
Social Issues	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 39: Hydrogen – the most important journals. N=93.

Journal full title	Number of papers
ENERGY POLICY	53
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	14
TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	8
TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	6
ECOLOGICAL ECONOMICS	4

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 40: Hydrogen – the most important social science groups. N=93.

Social Science Group	Number of papers
Environmental Studies and Ecology	66
Economics, Business and Management	19
Transportation	9
Political science, Planning, Public administration and International relations	8
Geography and Area studies	3
Multidisciplinary Sciences	3
Information Science & Library Science and Communication	2
Agriculture and Forestry	1
Social Sciences, Interdisciplinary	1
Sociology and Anthropology	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 41: Hydropower – the most important journals. N=135.

Journal full title	Number of papers
ENERGY POLICY	67
ECOLOGICAL ECONOMICS	10
LAND ECONOMICS	8
NATURAL RESOURCES JOURNAL	4
ENERGY ECONOMICS	4
POLITICAL GEOGRAPHY	4
CONTEMPORARY ECONOMIC POLICY	4
CLIMATE POLICY	4
LANDSCAPE AND URBAN PLANNING	3
ENVIRONMENTAL IMPACT ASSESSMENT REVIEW	3
HABITAT INTERNATIONAL	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 42: Hydropower – the most important social science groups. N=135.

Social Science Group	Number of papers
Environmental Studies and Ecology	95
Economics, Business and Management	35
Political science, Planning, Public administration and International relations	14
Geography and Area studies	8
Law	4
Social Sciences, Mathematical Methods and Computer sciences	3
Social Sciences, Interdisciplinary	2
Sociology and Anthropology	2
Urban studies and Architecture	2
Agriculture and Forestry	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 43: Renewable energy production in general – the most important journals. N=225.

Journal full title	Number of papers
ENERGY POLICY	127
ECOLOGICAL ECONOMICS	18
ENERGY JOURNAL	12
ENVIRONMENTAL & RESOURCE ECONOMICS	8
CLIMATE POLICY	8
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	6
ENERGY ECONOMICS	6
EURASIAN GEOGRAPHY AND ECONOMICS	6
FUTURES	4
NATURAL RESOURCES JOURNAL	4
LANDSCAPE AND URBAN PLANNING	3
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 44: Renewable energy production in general – the most important social science groups. N=225.

Social Science Group	Number of papers
Environmental Studies and Ecology	171
Economics, Business and Management	63
Political science, Planning, Public administration and International relations	15
Geography and Area studies	9
Agriculture and Forestry	3
Law	3
Social Sciences, Mathematical Methods and Computer sciences	3
Sociology and Anthropology	3
Urban studies and Architecture	3
Transportation	2
Information Science & Library Science and Communication	1
Multidisciplinary Sciences	1
Social Issues	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 45: Solar photovoltaic – the most important journals. N=147.

Journal full title	Number of papers
ENERGY POLICY	96
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	16
ENERGY JOURNAL	10
FUTURES	6
FORBES	4
TECHNOVATION	4
OPEN HOUSE INTERNATIONAL	4
TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	4
ENERGY ECONOMICS	3
INTERNATIONAL JOURNAL OF GEOGRAPHICAL INFORMATION SCIENCE	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 46: Solar photovoltaic – the most important social science groups. N=147.

Social Science Group	Number of papers
Environmental Studies and Ecology	108
Economics, Business and Management	37
Political science, Planning, Public administration and International relations	15
Information Science & Library Science and Communication	4
Geography and Area studies	3
Multidisciplinary Sciences	3
Urban studies and Architecture	3
Social Sciences, Interdisciplinary	1
Social Sciences, Mathematical Methods and Computer sciences	1
Transportation	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 47: Solar thermal – the most important journals. N=20.

Journal full title	Number of papers
ENERGY POLICY	16
OPEN HOUSE INTERNATIONAL	6

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 48: Solar thermal – the most important social science groups. N=20.

Social Science Group	Number of papers
Environmental Studies and Ecology	19
Urban studies and Architecture	3
Geography and Area studies	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 49: Wind – the most important journals. N=293.

Journal full title	Number of papers
ENERGY POLICY	168
ECOLOGICAL ECONOMICS	16
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	10
ENERGY ECONOMICS	9
ENERGY JOURNAL	8
TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	8
MARINE POLICY	6
ENVIRONMENTAL POLITICS	6
CLIMATE POLICY	6
FORBES	5
FUTURES	4
ENVIRONMENT AND PLANNING C-GOVERNMENT AND POLICY	4
IDS BULLETIN-INSTITUTE OF DEVELOPMENT STUDIES	4
ENVIRONMENTAL & RESOURCE ECONOMICS	4
GLOBAL ENVIRONMENTAL POLITICS	4
LANDSCAPE AND URBAN PLANNING	3
INTERNATIONAL JOURNAL OF URBAN AND REGIONAL RESEARCH	3
SOCIETY & NATURAL RESOURCES	3

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

Table 50: Wind – the most important social science groups. N=293.

Social Science Group	Number of papers
Environmental Studies and Ecology	212
Economics, Business and Management	63
Political science, Planning, Public administration and International relations	35
Geography and Area studies	16
Multidisciplinary Sciences	4
Urban studies and Architecture	4
Law	3
Social Issues	3
Sociology and Anthropology	3
Social Sciences, Mathematical Methods and Computer sciences	2
Transportation	2
Agriculture and Forestry	1
Information Science & Library Science and Communication	1
Social Sciences, Interdisciplinary	1

Source: ISI Web of Science / Journal Performance Indicator / NIFU STEP

8.2 List of Norwegian articles

Amundsen, E. S., Baldursson, F. M., & Mortensen, J. B. (2006). Price volatility and banking in Green Certificate markets. *Environmental & Resource Economics, 35*(4), 259-287.

Aune, M. (2007). Energy comes home. *Energy Policy, 35*(11), 5457-5465.

Berg, E., Boug, P., & Kverndokk, S. (2001). Norwegian gas sales and the impacts on European CO_2 emissions. *Energy Economics, 23*(4), 427-456.

Bjornstad, E., & Skonhoft, A. (2002). Wood fuel or carbon sink? Aspects of forestry in the climate question. *Environmental & Resource Economics, 23*(4), 447-465.

Bjornstad, E. (2005). An engineering economics approach to the estimation of forest fuel supply in North-Trondelag county, Norway. *Journal of Forest Economics,* 10(4), 161-188.

Bockman, T., Fleten, S. E., Juliussen, E., Langhammer, H. J., & Revdal, I. (2008). Investment timing and optimal capacity choice for small hydropower projects. *European Journal of Operational Research, 190*(1), 255-267.

Bruvoll, A., & Medin, H. (2003). Factors behind the environmental Kuznets curve - A decomposition of the changes in air pollution. *Environmental & Resource Economics, 24*(1), 27-48.

Buen, J. (2006). Danish and Norwegian wind industry: The relationship between policy instruments, innovation and diffusion. *Energy Policy, 34*(18), 3887-3897.

Bye, T., Bruvoll, A., & Aune, F. R. (2008). Inflow shortages in deregulated power markets - Reasons for concern? *Energy Economics, 30*(4), 1693-1711.

Faehn, T., & Holmoy, E. (2003). Trade liberalisation and effects on pollutive emissions to air and deposits of solid waste. A general equilibrium assessment for Norway. *Economic Modelling, 20*(4), 703-727.

Finon, D., Johnsen, T. A., & Midttun, A. (2004). Challenges when electricity markets face the investment phase. *Energy Policy, 32*(12), 1355-1362.

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

Gan, L. (2003). Globalization of the automobile industry in China: dynamics and barriers in greening of the road transportation. *Energy Policy, 31*(6), 537-551.

Gan, L., & Yu, J. (2008). Bioenergy transition in rural China: Policy options and co-benefits. *Energy Policy, 36*(2), 531-540.

Glomsrod, S., & Wei, T. Y. (2005). Coal cleaning: a viable strategy for reduced carbon emissions and improved environment in China? *Energy Policy, 33*(4), 525-542.

Godoe, H., & Nygaard, S. (2006). System failure, innovation policy and patents: Fuel cells and related hydrogen technology in Norway 1990-2002. *Energy Policy, 34*(13), 1697-1708.

Golombek, R. and M. Hoel (2008). Endogenous technology and tradable emission quotas. *Resource and Energy Economics,* 30(2): 197-208.

Grepperud, S., & Rasmussen, I. (2004). A general equilibrium assessment of rebound effects. *Energy Economics, 26*(2), 261-282.

Halvorsen, B., & Larsen, B. M. (2001). Norwegian residential electricity demand - a microeconomic assessment of the growth from 1976 to 1993. *Energy Policy, 29*(3), 227-236.

Holden, E., & Norland, I. T. (2005). Three challenges for the compact city as a sustainable urban form: Household consumption of energy and transport in eight residential areas in the greater Oslo region. *Urban Studies, 42*(12), 2145-2166.

Ibenholt, K. (2002). Explaining learning curves for wind power. *Energy Policy, 30*(13), 1181-1189.

Jumbe, C. B. L. (2004). Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi. *Energy Economics, 26*(1), 61-68.

Kjaerland, F. (2007). A real option analysis of investments in hydropower The case of Norway. *Energy Policy, 35*(11), 5901-5908.

Klitkou, A., Nygaard, S., & Meyer, M. (2007). Tracking techno-science networks: A case study of fuel cells and related hydrogen technology R&D in Norway. *Scientometrics, 70*(2), 491-518.

Lindkvist, K. B., & Antelo, A. P. (2007). Restructuring a peripheral coastal community: The case of a Galician fishing town. *International Journal of Urban and Regional Research, 31*(2), 368-383.

Liu, W. Q., Gan, L., & Zhang, X. L. (2002). Cost-competitive incentives for wind energy development in China: institutional dynamics and policy changes. *Energy Policy, 30*(9), 753-765.

Maribu, K. M., Firestone, R. M., Marnayb, C., & Siddiqui, A. S. (2007). Distributed energy resources market diffusion model. *Energy Policy, 35*(9), 4471-4484.

Menz, F. C., & Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy Policy, 34*(14), 1786-1796.

Meyer, N. I., & Koefoed, A. L. (2003). Danish energy reform: policy implications for renewables. *Energy Policy, 31*(7), 597-607.

Mork, E. (2001). Emergence of financial markets for electricity: a European perspective. *Energy Policy, 29*(1), 7-15.

Moxnes, E. (2004). Estimating customer utility of energy efficiency standards for refrigerators. *Journal of Economic Psychology, 25*(6), 707-724.

Navrud, S., & Braten, K. G. (2007). Consumers' preferences for green and brown electricity: A choice modelling approach. *Revue D Economie Politique, 117*(5), 795-811.

Nesbakken, R. (1999). Price sensitivity of residential energy consumption in Norway. *Energy Economics, 21*(6), 493-515.

Nesbakken, R. (2001). Energy consumption for space heating: A discrete-continuous approach. *Scandinavian Journal of Economics, 103*(1), 165-184.

Nyrud, A. Q., Roos, A., & Sande, J. B. (2008). Residential bioenergy heating: A study of consumer perceptions of improved woodstoves. *Energy Policy, 36*(8), 3169-3176.

Olsen, O. J., Amundsen, E. S., & Donslund, B. (2006). How to play the game as the bridge between two European power markets - the case of Western Denmark. *Energy Policy, 34*(17), 3293-3304.

Ornetzeder, M., Hertwich, E. G., Hubacek, K., Korytarova, K., & Haas, W. (2008). The environmental effect of car-free housing: A case in Vienna. *Ecological Economics, 65*(3), 516-530.

Rosnes, O. (2008). The impact of climate policies on the operation of a thermal power plant. *Energy Journal, 29*(2), 1-22.

Severud, I. A. (2007). Norway's experience of carbon dioxide storage: A basis for pursuing international commitments? *Climate Policy, 7*(1), 13-28.

Shackley, S., Waterman, H., Godfroij, P., Reiner, D., Anderson, J., Draxlbauer, K., et al. (2007). Stakeholder perceptions of CO_2 capture and storage in Europe: Results from a survey. *Energy Policy, 35*(10), 5091-5108.

Skaar, J., & Sorgard, L. (2006). Temporary bottlenecks, hydropower and acquisitions. *Scandinavian Journal of Economics, 108*(3), 481-497.

Sunnevag, K. (2000). Voluntary agreements and the incentives for innovation. *Environment and Planning C-Government and Policy, 18*(5), 555-573.

Tromborg, E., Bolkesjo, T. F., & Solberg, B. (2007). Impacts of policy means for increased use of forest-based bioenergy in Norway - A spatial partial equilibrium analysis. *Energy Policy, 35*(12), 5980-5990.

Unander, F., Ettestol, I., Ting, M., & Schipper, L. (2004). Residential energy use: an international perspective on long-term trends in Denmark, Norway and Sweden. *Energy Policy, 32*(12), 1395-1404.

Upadhyay, T. P., Solberg, B., & Sankhayan, P. L. (2006). Use of models to analyse land-use changes, forest/soil degradation and carbon sequestration with special reference to Himalayan region: A review and analysis. *Forest Policy and Economics, 9*(4), 349-371.

Utne, I. B. (2008). Are the smallest fishing vessels the most sustainable? trade-off analysis of sustainability attributes. *Marine Policy, 32*(3), 465-474.

Vaage, K. (2000). Heating technology and energy use: a discrete/continuous choice approach to Norwegian household energy demand. *Energy Economics, 22*(6), 649-666.

Vorkinn, M., & Riese, H. (2001). Environmental concern in a local context - The significance of place attachment. *Environment and Behavior, 33*(2), 249–263.

Wei, T. Y. (2007). Impact of energy efficiency gains on output and energy use with Cobb-Douglas production function. *Energy Policy, 35*(4), 2023-2030.

References

Create Acceptance, C. (2007). Factors influencing the societal acceptance of new energy technologies:Meta-analysis of recent European projects. Executive Summary of Work Package 2 of the Create Acceptance Project.

Alphen, K. v., J. v. Ruijvena, et al. (2009). "The performance of the Norwegian carbon dioxide, capture and storage innovation system." Energy Policy **37**(1): 43-55.

Alvarez-Farizo, B. and N. Hanley (2002). "Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms. An example from Spain." Energy Policy **30**(2): 107-116.

Amundsen, E. S. (2005). "Omsettelige grønne sertifikater under autarki og handel." Norsk økonomisk tidsskrift **119**(1): 1-15.

Amundsen, E. S., F. M. Baldursson, et al. (2006). "Price volatility and banking in Green Certificate markets." Environmental & Resource Economics **35**(4): 259-287.

Anker-Nilssen, P. (2006). "Energibruk og energipriser - et fordelingsproblem." Magma **9**(5/6): [93]-103 : port.

Aune, M. (2007). "Energy comes home." Energy Policy **35**(11): 5457-5465.

Bell, D., T. Gray, et al. (2005). "The 'social gap' in wind farm siting decisions: Explanations and policy responses. ." Environmental Politics **14**(4): 460-477.

Berg, E., P. Boug, et al. (2001). "Norwegian gas sales and the impacts on European CO2 emissions." Energy Economics **23**(4): 427-456.

Bergek, A., M. Hekkert, et al. (2008). Functions in innovation systems: A framework for analysing energy system dynamics and identifying goals for system-building activities by entrepreneurs and policymakers. Innovation for a low carbon economy: economic, institutional and management approaches. T. J. Foxon, J. Köhler and C. Oughton. Cheltemham, UK, Edward Elgar**:** 79-111.

Berkhout, F. and J. Hertin (2002). "Foresight, future scenarios. Developing, and applying a participative strategic planning tool." Greener Management International **37**: 37-52.

Bjornstad, E. (2005). "An engineering economics approach to the estimation of forest fuel supply in North-Trondelag county, Norway." Journal of Forest Economics **10**(4): 161-188.

Bjornstad, E. and A. Skonhoft (2002). "Wood fuel or carbon sink? Aspects of forestry in the climate question." Environmental & Resource Economics **23**(4): 447-465.

Bockman, T., S. E. Fleten, et al. (2008). "Investment timing and optimal capacity choice for small hydropower projects." European Journal of Operational Research **190**(1): 255-267.

Borup, M., P. Dannemand Andersen, et al. (2009). Ny energi og innovation i Danmark. København, Jurist- og Økonomforbundets Forlag.

Brandt, U. S. and G. T. Svendsen (2006). "Climate change negotiations and first-mover advantages: the case of the wind turbine industry." Energy Policy **34**(10): 1175-1184.

Brohmann, B., Y. Feenstra, et al. (2007). "Factors Influencing New, Renewable and Energy Efficient Technologies: Meta-Analysis of Recent European Projects. ." Paper for the 11th

European Rondtable on Sustainable Consumption and Production, June 20-22, Basel, Switzerland.

Brown, M. A., M. D. Levine, et al. (2001). "Scenarios for a clean energy future." Energy Policy **29**(14): 1179-1196.

Bruvoll, A. and H. Medin (2003). "Factors behind the environmental Kuznets curve - A decomposition of the changes in air pollution." Environmental & Resource Economics **24**(1): 27-48.

Buen, J. (2006). "Danish and Norwegian wind industry: The relationship between policy instruments, innovation and diffusion." Energy Policy **34**(18): 3887-3897.

Bye, T., A. Bruvoll, et al. (2008). "Inflow shortages in deregulated power markets - Reasons for concern?" Energy Economics **30**(4): 1693-1711.

Carlsson, B., Ed. (1997). Technological systems and industrial dynamics. Economics of science, technology and innovation. Boston, Dordrecht, London, Kluwer Academic Publishers.

Carlsson, B., S. Jacobsson, et al. (2002). "Innovation systems: analytical and methodological issues." Research Policy **31**(2): 233–245.

Carlsson, B. and R. Stànkiewicz (1991). "On the nature, function, and composition of technological systems." Journal of Evolutionary Economics **1**(2): 93-118.

Cooke, P., M. Heidenreich, et al., Eds. (2004). Regional innovation systems: the role of governance in a globalized world. London, Routledge.

Crompton, P. and Y. R. Wu (2005). "Forecasts, scenarios, visions, back casts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature." Energy Policy **27**(1): 195-208.

Deuten, J. J., A. Rip, et al. (1997). "Societal embedding and product creation management." Technology Analysis & Strategic Management **9**(2): 131-148.

Devine-Wright, P. (2007). Reconsidering public acceptance of renewable energy technologies: a critical review Taking Climate Change Seriously: A low carbon future for the electricity sector. Grubb, Jamas and Pollitt.

Dornburg, V. and e. al (2008). "Biomass Assessment: Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy – Main Report ".

ECON, Ed. (2006). Nytten av samfunnsfaglig forskning i RENERGI. ECON-notat. Oslo, ECON Analyse.

Ek, K. (2005). "Public and private attitudes towards "green" electricity: the case of Swedish wind power." Energy Policy **33**(13): 1677-1689.

Faehn, T. and E. Holmoy (2003). "Trade liberalisation and effects on pollutive emissions to air and deposits of solid waste. A general equilibrium assessment for Norway." Economic Modelling **20**(4): 703-727.

Faiers, A. and C. Neame (2006). "Consumer attitudes towards domestic solar power systems." Energy Policy **34**(14): 1797-1806.

Ferng, J. J. (2002). "Toward a scenario analysis framework for energy footprints." Ecological Economics **40**(1): 53-69.

Finon, D., T. A. Johnsen, et al. (2004). "Challenges when electricity markets face the investment phase." Energy Policy **32**(12): 1355-1362.

Forsund, F. R., B. Singh, et al. (2008). "Phasing in wind-power in Norway: Network congestion and crowding-out of hydropower." Energy Policy **36**(9): 3514-3520.

Foxon, T. J., J. Köhler, et al. (2008). Innovation for a low carbon economy: economic, institutional and management approaches. Cheltenham, Edward Elgar.

Gagnon, L., C. Belanger, et al. (2002). "Life-cycle assessment of electricity generation options: The status of research in year 2001." Energy Policy **30**(14): 1267-1278.

Gallopín, G. C. (2002). Planning for resilience: scenarios, surprises, and branch points. Panarchy. Understanding Transformations in Human and Natural Systems. L. H. Gunderson and C. S. Holling. Washington, DC, Island Press**:** 361-94.

Gan, L. (2003). "Globalization of the automobile industry in China: dynamics and barriers in greening of the road transportation." Energy Policy **31**(6): 537-551.

Gan, L. and J. Yu (2008). "Bioenergy transition in rural China: Policy options and co-benefits." Energy Policy **36**(2): 531-540.

Geels, F. W. (2002). "Technological transitions as evolutionary reconfiguration processes: a multilevel perspective and a case study." Research Policy **31**(8-9): 1257-1274.

Geels, F. W. (2004). "From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change fom sociology and institutional theory." Research Policy **33**(6-7): 897-920.

Geels, F. W. (2004). "From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory." Research Policy **33**(6-7): 897-920.

Geels, F. W., M. P. Hekkert, et al. (2008). "The dynamics of sustainable innovation journeys." Technology Analysis & Strategic Management **20**(5): 521-536.

Geels, F. W. and J. Schot (2007). "Typology of sociotechnical transition pathways." Research Policy **36**(3): 399-417.

Glomsrod, S. and T. Y. Wei (2005). "Coal cleaning: a viable strategy for reduced carbon emissions and improved environment in China?" Energy Policy **33**(4): 525-542.

Godoe, H. and S. Nygaard (2006). "System failure, innovation policy and patents: Fuel cells and related hydrogen technology in Norway 1990-2002." Energy Policy **34**(13): 1697-1708.

Golombek, R. and M. Hoel (2008). "Endogenous technology and tradable emission quotas." Resource and Energy Economics **30**(2): 197-208.

Greening, L. A. and S. Bernow (2004). "Design of coordinated energy and environmental policies: use of multi-criteria decision-making." Energy Policy **32**(6): 721-735.

Gritsevskyi, A. and N. Nakicenovic (2000). "Modeling uncertainty of induced technological change." Energy Policy **28**(13): 907-921.

Haberl, H., K. H. Erb, et al. (2001). "How to calculate and interpret ecological footprints for long periods of time: the case of Austria." Ecological Economics **38**: 25-45.

Halvorsen, B. and B. M. Larsen (2001). "Norwegian residential electricity demand - a microeconomic assessment of the growth from 1976 to 1993." Energy Policy **29**(3): 227-236.

Hansen, K., K. Hammarlund, et al. (2003). "Public Acceptance of Wave Energy." Proceedings from the 5th European Wave Energy Conference, University College Cork, Ireland 2003.

Hekkert, M., R. A. A. Suurs, et al. (2007). "Functions of innovation systems: A new approach for analysing technological change." Technological Forecasting and Social Change **74**(4): 413-432.

Holden, E. and I. T. Norland (2005). "Three challenges for the compact city as a sustainable urban form: Household consumption of energy and transport in eight residential areas in the greater Oslo region." Urban Studies **42**(12): 2145-2166.

Ibenholt, K. (2002). "Explaining learning curves for wind power." Energy Policy **30**(13): 1181-1189.

IEA (2003). Energy to 2050: Scenarios for a sustainable future. Paris, OECD/IEA.

Itaoka, K., A. Saito, et al. (2004). "Public acceptance of CO2 capture and storage technology: a survey of public opinion to explore influential factors." Paper presented at the 7th International Conference on Greenhouse Gas Control Technologies, Vancouver, Canada, 5-7 September 2004.

Jacobsson, S. and A. Bergek (2004). "Transforming the energy sector: the evolution of technological systems in renewable energy technology." Industrial and Corporate Change **13**(5): 815-849.

Jacobsson, S. and A. Johnson (2000). "The diffusion of renewable energy technology: an analytical framework and key issues for research." Energy Policy **28**: 625-640.

Jacobsson, S. and V. Lauber (2006). "The politics and policy of energy system transformation - explaining the German diffusion of renewable energy technology." Energy Policy **34**(3): 256-276.

Jacobsson, S., B. A. Sandén, et al. (2004). "Transforming the energy system - The evolution of the German technological system for solar cells." Technology Analysis & Strategic Management **16**(1): 3-30.

Jaffe, A. B., R. G. Newell, et al. (2002). "Environmental policy and technological change." Environmental & Resource Economics **22**(1-2): 41-69.

Johnson, A. and S. Jacobsson (2003). The development of a growth industry - the wind turbine industry in Germany, Holland and Sweden. Change, Transformation and Development. J. S. Metcalfe and U. Cantner. Heidelberg, Physica-Verlag**:** 197ff.

Jumbe, C. B. L. (2004). "Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi." Energy Economics **26**(1): 61-68.

Junginger, M., A. Faaij, et al. (2005). "Global experience curves for wind farms." Energy Policy **33**(2): 133-150.

Kasa, S. (2003). "Vekstmaskiner og horisontale nettverk: klimapolitiske posisjoner og strategier overfor utslippsintensiv industri i fem norske industrikommuner." Tidsskrift for samfunnsforskning **44**(3): 367-[389], [490].

Kemp, R. and D. Loorbach (2006). Transition management: a reflexive governance approach. Reflexive Governance for Sustainable Development. J.-P. Voß, D. Bauknecht and R. Kemp. Cheltenham, Edward Elgar**:** 103-130.

Kemp, R., D. Loorbach, et al. (2007). "Transition management as a model for managing processes of co-evolution towards sustainable development." International Journal of Sustainable Development and World Ecology **14**(1): 78-91.

Kjaerland, F. (2007). "A real option analysis of investments in hydropower The case of Norway." Energy Policy **35**(11): 5901-5908.

Klitkou, A., S. Nygaard, et al. (2007). "Tracking techno-science networks: A case study of fuel cells and related hydrogen technology R&D in Norway." Scientometrics **70**(2): 491-518.

Klitkou, A., T. E. Pedersen, et al. (2008a). Competitive policies in the Nordic Energy Research and Innovation Area: Country reports. Oslo, NIFU STEP.

Klitkou, A., T. E. Pedersen, et al. (2008b). Competitive policies in the Nordic Energy Research and Innovation Area: Technology reports. Oslo, NIFU STEP.

Klitkou, A., T. E. Pedersen, et al. (2008c). Competitive policies in the Nordic Energy Research and Innovation Area: Special reports. Oslo, NIFU STEP.

Klitkou, A., T. E. Pedersen, et al. (2008d). Competitive policies in the Nordic Energy Research and Innovation Area: Synthesis report. Oslo, NIFU STEP.

Lafferty, W. M. and A. Ruud, Eds. (2008). Promoting sustainable electricity in Europe: challenging the path dependence of dominant energy systems. Cheltenham, Edward Elgar.

Liu, W. Q., L. Gan, et al. (2002). "Cost-competitive incentives for wind energy development in China: institutional dynamics and policy changes." Energy Policy **30**(9): 753-765.

Malerba, F., Ed. (2004). Sectoral systems of innovation and production: concepts, issues and analyses of six major sectors in Europe. Cambridge, Cambridge University Press.

Maribu, K. M., R. M. Firestone, et al. (2007). "Distributed energy resources market diffusion model." Energy Policy **35**(9): 4471-4484.

Markard, J. and B. Truffer (2008). "Technological innovation systems and the multi-level perspective: Towards an integrated framework." Research Policy **37**(4): 596-615.

McDowell, W. and M. Eames (2006). "Forecasts, scenarios, visions, back casts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature. ." Energy Policy **34**(11): 1236-1250.

Menz, F. C. and S. Vachon (2006). "The effectiveness of different policy regimes for promoting wind power: Experiences from the states." Energy Policy **34**(14): 1786-1796.

Meyer, N. I. and A. L. Koefoed (2003). "Danish energy reform: policy implications for renewables." Energy Policy **31**(7): 597-607.

Midttun, A. and A. L. Koefoed (2005). Green Innovation in Nordic Energy Industry: Systemic Contexts and Dynamic Trajectories. Towards Environmental Innovation Systems. M. Weber and J. Hemmelskamp. Berlin, Heidelberg, Springer**:** 115-136.

Mork, E. (2001). "Emergence of financial markets for electricity: a European perspective." Energy Policy **29**(1): 7-15.

Navrud, S. and K. G. Bråten (2007). "Consumers' preferences for green and brown electricity: A choice modelling approach." Revue D Economie Politique **117**(5): 795-811.

Negro, S. O., M. Hekkert, et al. (2008). "Stimulating renewable energy technologies by innovation policy." Science and Research Policy **35**(6): 403-416.

Nelson, R. R., Ed. (1993). National innovation systems: a comparative analysis. New York, Oxford University Press.

Nesbakken, R. (1999). "Price sensitivity of residential energy consumption in Norway." Energy Economics **21**(6): 493-515.

Nesbakken, R. (2001). "Energy consumption for space heating: A discrete-continuous approach." Scandinavian Journal of Economics **103**(1): 165-184.

Nyrud, A. Q., A. Roos, et al. (2008). "Residential bioenergy heating: A study of consumer perceptions of improved woodstoves." Energy Policy **36**(8): 3169-3176.

OECD (2007). Innovation and growth: Rationale for an Innovation Strategy. Paris, OECD.

Olsen, O. J., E. S. Amundsen, et al. (2006). "How to play the game as the bridge between two European power markets - the case of Western Denmark." Energy Policy **34**(17): 3293-3304.

Ornetzeder, M., E. G. Hertwich, et al. (2008). "The environmental effect of car-free housing: A case in Vienna." Ecological Economics **65**(3): 516-530.

Raven, R., E. Jolivet, et al. (2009). "ESTEEM: Managing societal acceptance in new energy projects A toolbox method for project managers." Technological Forecasting and Social Change **76**(7): 963-977.

Riahi, K. and R. A. Roehrl (2000). "Greenhouse gas emissions in a dynamics-as-usual scenario of economic and energy development." Technological Forecasting and Social Change **63**((2-3)): 175-205.

Rip, A. and R. Kemp (1998). Technological Change. Human Choice and Climate Change – Resources and Technology. S. Rayner and E. L. Malone. Columbus, Battelle Press**:** 327–399.

Roracher, H., R. Bogner, et al. (2004). "Improving the Public Perception of Bioenergy in the EU. Final Report."

Rosnes, O. (2008). "The impact of climate policies on the operation of a thermal power plant." Energy Journal **29**(2): 1-22.

Ruud, A. (2010). Innovasjonspolitikk innenfor energibransjen – også til fordel for miljø? Noen perspektiver sett fra den nyopprettede FME'en CEDREN. Energiuka 2010. Oslo.

Severud, I. A. (2007). "Norway's experience of carbon dioxide storage: A basis for pursuing international commitments?" Climate Policy **7**(1): 13-28.

Shackley, S., H. Waterman, et al. (2007). "Stakeholder perceptions Of CO2 capture and storage in Europe: Results from a survey." Energy Policy **35**(10): 5091-5108.

Skaar, J. and L. Sorgard (2006). "Temporary bottlenecks, hydropower and acquisitions." Scandinavian Journal of Economics **108**(3): 481-497.

Smith, A. (2006). Niche-based approaches to sustainable development: radical activistd versus strategic managers. Reflexive Governance for Sustainable Development. J.-P. Voß, D. Bauknecht and R. Kemp. Cheltenham, Edward Elgar**:** 313-336.

Solli, J. (2003). "Vind i kalkylene." Sosiologisk tidsskrift **11**(4): 394-424, 446.

Späth, P., H. Rohracher, et al. (2006). The transition towards sustainable production systems in Austria: a reflexive exercise? Reflexive Governance for Sustainable Development. J.-P. Voß, D. Bauknecht and R. Kemp. Cheltenham, Edward Elgar**:** 355-382.

Sunnevag, K. (2000). "Voluntary agreements and the incentives for innovation." Environment and Planning C-Government and Policy **18**(5): 555-573.

Suurs, R. A. A. and M. P. Hekkert (2009). "Cumulative causation in the formation of a technological innovation system: The case of biofuels in the Netherlands " Technological Forecasting and Social Change **76**(8): 1003-1020.

Tjernshaugen, A. (2008). "Political commitment to CO_2 capture and storage: evidence from government RD&D budgets." Mitigation and Adaptation Strategies for Global Change **13**(1): 1-21.

Toke, D. (2005). "Explaining wind power planning outcomes: some findings from a study in England and Wales." Energy Policy **33**(12): 1527-1539.

Tol, R. S. J. (2002). "Estimates of the damage costs of climate change - Part II. Dynamic estimates." Environmental & Resource Economics **21**(2): 135-160.

Tol, R. S. J. (2002). "Estimates of the damage costs of climate change. Part 1: Benchmark estimates." Environmental & Resource Economics **21**(1): 47-73.

Tromborg, E., T. F. Bolkesjo, et al. (2007). "Impacts of policy means for increased use of forest-based bioenergy in Norway - A spatial partial equilibrium analysis." Energy Policy **35**(12): 5980-5990.

Unander, F. (2010). Rammer og samfunnsanalyse: et av Energi21s prioriterte FoU områder. Energiuka 2010. Oslo.

Unander, F., I. Ettestol, et al. (2004). "Residential energy use: an international perspective on long-term trends in Denmark, Norway and Sweden." Energy Policy **32**(12): 1395-1404.

Upadhyay, T. P., B. Solberg, et al. (2006). "Use of models to analyse land-use changes, forest/soil degradation and carbon sequestration with special reference to Himalayan region: A review and analysis." Forest Policy and Economics **9**(4): 349-371.

Vaage, K. (2000). "Heating technology and energy use: a discrete/continuous choice approach to Norwegian household energy demand." Energy Economics **22**(6): 649-666.

Vorkinn, M. and H. Riese (2001). "Environmental concern in a local context - The significance of place attachment." Environment and Behavior **33**(2): 249-263.

Voß, J.-P., D. Bauknecht, et al., Eds. (2006). Reflexive governance for sustainable development. Cheltenham, Edward Elgar.

Voß, J.-P. and R. Kemp (2006). Sustainability and reflexive governance: introduction. Reflexive Governance for Sustainable Development. J.-P. Voß, D. Bauknecht and R. Kemp. Cheltenham, Edward Elgar**:** 3-28.

Voß, J.-P., B. Truffer, et al. (2006). Sustainability foresight: reflexive governance in the transformation of utility systems. Reflexive Governance for Sustainable Development J.-P. Voß and D. Bauknecht, Kemp R., Edward Elgar**:** 162-189.

Wiedmann, T., M. Lenzen, et al. (2007). "Examining the global environmental impact of regional consumption activities - Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade." Ecological Economics **61**(1): 15-26.

York, R., E. A. Rosa, et al. (2003). "STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts." Ecological Economics **46**(3): 351-365.

Øverland, E. F. (2000). Norge 2030. Fem scenarier om offentlig sektors framtid. Oslo, Cappelen.