TIMES-DK: Technology-rich multi-sectoral optimisation model of the Danish energy system

As Denmark progresses towards a carbon neutral future, energy system models are required to address the challenges of the energy transition. This article describes design, input data and current usage of TIMES-DK, the first Danish energy system model that includes the complete national energy system, covering long-term technology investments. The article aims at explaining the modelling approach; highlighting strengths and reflecting upon limitations of the model; illustrating possible applications of TIMES-DK and inspiring new model developments. Some of the key strengths of the model include simultaneous optimisation of operation and investments across the complete energy system over the whole modelling horizon, explicit representation of the most important sectors of the economy, modular structure and the possibility of linking to a computable general equilibrium model for an additional insight on, e.g. public finance or CO₂-leakage. TIMES-DK is being developed in close collaboration between an energy agency, a university and a consulting firm, to improve its robustness, relevance and impact on policy making. It allows for a wide range of applications including exploratory energy scenarios and policy analysis. To meet challenges of the future, further development of the model is needed and consequently the article provides references to ongoing projects addressing current development needs, such as improved representation of transport and flexible handling of the temporal dimension. To support a democratic and transparent process around decisions for the future Danish energy system, TIMES-DK should become available to interested parties.
A Long-Term Strategy to Decarbonise the Danish Inland Passenger Transport Sector

This study applies a novel modelling framework to assess how alternative policies may contribute to a fossil-free transport sector for Denmark and the potential contribution they may have to a well-below 2Â Â°C world. The approach adopted consists of linking an energy system optimisation model, TIMES-DKMS, with a private car simulation model, the Danish Car Stock Model. The results of this study include the magnitude of CO2 abatement presented alongside the corresponding change in tax revenue generated through combinations of policies focusing on the derogation of motor taxes for low emission vehicles and banning the sale of the internal combustion engines. The resulting cumulative emissions from the Danish energy system are also compared to a range of national carbon budgets, calculated to adhere to various levels of global temperature rise at different levels of confidence. The results indicate that a ban on the sale of the internal combustion engines enforced in 2025 would enable the largest cut in cumulative greenhouse gas emissions of all the policies considered. However, none of the policies analysed comply with Denmarkâ€™s carbon budget capable of maintaining the increase of global temperature limited to 1.5Â Â°C.

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Organisations: Department of Management Engineering, Systems Analysis, University College Cork, E4SMA
Contributors: Tattini, J., Mulholland, E., Venturini, G., Ahanchian, M., Gargiulo, M., Balyk, O., Karlsson, K. B.
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Global outlook on energy technology development

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Organisations: Department of Management Engineering, Systems Analysis
Improving the representation of modal choice into bottom-up optimization energy system models - The MoCho-TIMES model

This study presents MoCho-TIMES, an original methodology for incorporating modal choice into energy-economy-environment-engineering (E4) system models. MoCho-TIMES addresses the scarce ability of E4 models to realistically depict behaviour in transport and allows for modal shift towards transit and non-motorized modes as a new dimension for decarbonising the transportation sector. The novel methodology determines endogenous modal shares by incorporating variables related to the level-of-service (LoS) of modes and consumers’ modal perception within the E4 modeling framework. Heterogeneity of transport users is introduced to differentiate modal perception and preferences across different consumer groups, while modal preferences are quantified via monetization of intangible costs. A support transport simulation model consistent with the geographical scope of the E4 model provides the data and mathematical expressions required to develop the approach. This study develops MoCho-TIMES in the standalone transportation sector of TIMES-DK, the integrated energy system model for Denmark. The model is tested for the Business as Usual scenario and for four alternative scenarios that imply diverse assumptions for the new attributes introduced. The results show that different assumptions for the new attributes affect modal shares and CO2 emissions. MoCho-TIMES inaugurates the possibility to perform innovative policy analyses involving new parameters to the E4 modeling framework. The results find that authority’s commitment to sustainability is crucial for a paradigmatic change in the transportation sector.
Introduction: Energy Systems Modelling for a Sustainable World
Since the first oil crisis more than forty years ago, concerns regarding energy security, economic impacts, air pollution, climate change, energy poverty, and societal well-being have been repeatedly calling for an energy revolution. The 2030 Agenda for Sustainable Development and the Paris Agreement on climate change are unambiguous: in order to identify the key technologies to achieve the energy revolution and the appropriate programs and policies that will bring them to the market, decision makers need robust policy analyses that encompass the relevant global, regional national and local factors, as well as increasing details and synergies across the complex issues which characterizes the energy system.
Given their intrinsic nature, energy system models are particularly well suited to provide comprehensive, integrated and robust information on the short, medium and long term transformation of the energy systems under multiple constraints—economic, technology, environment and societal factors. This chapter introduces the development and use of energy system models by the members of the IEA Technology Collaboration Programme on energy systems modelling, namely the IEA Energy Technology Systems Analysis Program (IEA-ETSAP) to support the definition of energy and climate policies in an increasing number of countries. It also provides an overview of the 23 case studies presented in this book, all exploring the potential for feasible roadmaps at global, national or local scale compatible with a well below 2 °C future. They all show that those roadmaps are extremely challenging, and early action is essential.

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Organisations: Department of Management Engineering, Systems Analysis, Eneris Environment Energy Consultants, Centre for Renewable Energy Sources, University College Cork
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Limiting Global Warming to Well Below 2 °C: Energy System Modelling and Policy Development
This book presents the energy system roadmaps necessary to limit global temperature increase to below 2°C, in order to avoid the catastrophic impacts of climate change. It provides a unique perspective on and critical understanding of the feasibility of a well-below-2°C world by exploring energy system pathways, technology innovations, behaviour change and the macro-economic impacts of achieving carbon neutrality by mid-century. The transformative changes in the energy transition are explored using energy systems models and scenario analyses that are applied to various cities, countries and at a global scale to offer scientific evidence to underpin complex policy decisions relating to climate change mitigation and interrelated issues like energy security and the energy–water nexus. It includes several chapters directly related to the Nationally Determined Contributions proposed in the context of the recent Paris Agreement on Climate Change. In summary, the book collates a range of concrete analyses at different scales from around the globe, revisiting the roles of countries, cities and local communities in pathways to significantly reduce greenhouse gas emissions and make a well-below-2°C world a reality. A valuable source of information for energy modellers in both the industry and public sectors, it provides a critical understanding of both the feasibility of roadmaps to achieve a well-below-2°C world, and the diversity and wide applications of energy systems models. Encompassing behaviour changes; technology innovations; macro-economic impacts; and other environmental challenges, such as water, it is also of interest to energy economists and engineers, as well as economic modellers working in the field of climate change mitigation.

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Modelling transport modal shift in TIMES models through elasticities of substitution

Several efforts have been directed lately towards the endogenisation of transport modes competition in Energy/Economy/Environment/Engineering (E4) models. TIMES-DKEMS is a novel methodology paving the way for applying elasticities of substitution to incorporate transport modal shift into TIMES (The Integrated MARKAL-EFOM System) models. Substitution elasticities are defined for four transport demand aggregates, each corresponding to a different distance range class. Within an aggregate, modal demands can adjust their levels according to the defined substitution elasticity and in response to changes of their shadow prices relative to a reference case. The total volume of the transport demand over the aggregate is conserved and modal shift potentials are implemented to guarantee realistic dynamics. The behavior of TIMES-DKEMS is tested under an arbitrary environmental policy, an increasingly stringent bound on CO2 emissions. Modal shares are compared with the standard version of TIMES-DK. Results show that in 2050, 11% of car mobility demand is substituted by more efficient and less costly modes such as train and coach. A sensitivity analysis on the values of substitution elasticities indicates that higher absolute values correspond to larger modal shift. Finally, other model constraints, such as mode-specific travel patterns, interact with the substitution mechanism resulting in a modal shift containment.
Reaching carbon neutral transport sector in Denmark - Evidence from the incorporation of modal shift into the TIMES energy system modeling framework

Energy/Economy/Environment/Engineering (E4) models have been rarely apt to represent human behaviour in transportation mode adoption. This paper contributes to the scientific literature by using an E4 model to analyse the long-term decarbonisation of the Danish transport sector. The study is carried out with TIMES-DK, the integrated energy system model of Denmark, which has been expanded in order to endogenously determine modal shares. The methodology extends the technology competition within the modes to competition across modes by aggregating the passenger modal travel demands into demand segments based on the distance range. Modal shift is based not only on the levelised costs of the modes, but also on speed and infrastructure requirement. Constraints derived from the National Travel Survey guarantee consistent travel habits and avoid unrealistic modal shifts. The comparison of model versions with and without modal shift identifies its positive contribution to the fulfilment of the Danish environmental targets. Four sensitivity analyses on the key variables of modal shift assess how their alternative realizations affect the decarbonisation of the transport sector and enable shifting away from car. The results indicate that less strict travel time budget (TTB) and increased speed of public bus lead to a more efficient decarbonisation by 2050.

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Contributors: Tattini, J., Gargiulo, M., Karlsson, K. B.
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Spatiotemporal and economic analysis of industrial excess heat as a resource for district heating

Industrial excess heat may often be utilised for district heating and thus replace existing expensive or CO₂-emitting technologies. Previous works analysed the distribution of excess heat by temperature intervals and their geographical distribution relative to district heating areas. A more detailed analysis of the most suitable types of industries and the costs is required, allowing a targeted exploitation of this resource. This work extends the spatial and thermodynamic analysis, to account for the temporal match between industrial excess heat and district heating demands, as well as the costs for implementation and operation of the systems. This allows the determination of cost-effective district heating potentials, as well as the analysis of different industries and technological requirements. The results show that the temporal mismatch between excess heat and district heating demand and lack of demand, reduces the theoretical substitution potential by almost 30%. If heat storages are introduced, the total potential is reduced by only 10%. A majority of the excess heat can be utilised at socio-economic heating costs lower than the average Danish district heating price and the cost of solar district heating. Excess heat from oil refineries, building material and food production can be utilised at the lowest specific costs.
STREAM—an energy scenario modelling tool

Energy system models are powerful tools used to develop decarbonisation pathways and to assess the green energy transition. This paper presents the open source energy scenario tool STREAM, by describing the modelling approach, applications, strengths, limitations, and potential future developments. STREAM is a dialogue tool, which is used by a broad audience to conduct quick analyses and to explore plausible scenarios for future integrated energy systems, covering all sectors. STREAM is a relatively simple spreadsheet, which ensures transparency, allows stakeholder involvement, and is suitable for scenario discussions and developments. Moreover, STREAM can be soft-linked with more sophisticated energy tools. STREAM contributes to the integrated energy systems modelling field by providing a fast transparent open source modelling tool, which simulates the entire energy system with detailed chronological temporal resolution, in order to provide insights related to future energy trends. Results from the STREAM model are used by researchers, stakeholders, and policy makers in developing scenarios for analysing strategic decisions regarding the desired development of future energy systems.

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The Role of Population, Affluence, Technological Development and Diet in a Below 2 °C World

The rise in anthropogenic greenhouse gas emissions and the resultant temperature anomaly in the global climate can be simplified to a function of (1) the global population, (2) economic activity and (3) technological development for thought experiments. Diet, given the embodied process emissions in producing food, is also acknowledged as an important factor. Growth in the first two factors tends to increase environmental impacts while technological development can reduce them. In this chapter, the impact from these four variables, their interdependencies and importance are illustrated. To do so, three different model frameworks are combined namely IPAT, Ecological Footprint and Integrated Assessment Modelling,
to illustrate the challenges to finding pathways to maintain a well below 2 °C world. The model setup developed for this chapter estimates the global mean temperature increase to 2100 and the needed land area to support human life as a function of population, affluence, technological development and diet. It is shown that focusing on technology development alone will likely not be enough to mitigate global warming and stay well below a 2 °C temperature increase. Therefore, the discussion about population, consumption, development and diet shifting should be high on the agenda for reducing energy demands and for increasing the feasibility of maintaining a well below 2 °C world.

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Improving the representation of modal choice into bottom-up optimization energy system models

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Industrial excess heat for district heating in Denmark
Excess heat is available from various sources and its utilisation could reduce the primary energy use. The accessibility of this heat is however dependent amongst others on the source and sink temperature, amount and potential users in its vicinity. In this work a new method is developed which analyses excess heat sources from the industrial sector and how they could be used for district heating. This method first allocates excess heat to single production units by introducing and validating a new approach. Spatial analysis of the heat sources and consumers are then performed to evaluate the potential for using them for district heating. In this way the theoretical potential of using the excess heat for covering the heating demand of buildings is determined. Through the use of industry specific temperature profiles the heat usable directly or via heat pumps is further found. A sensitivity analysis investigates the impact of future energy efficiency measures in the industry, buildings and the district heating grid on the national potential. The results show that for the case study of Denmark, 1.36 TWh of district heat could be provided annually with industrial excess heat from thermal processes which equals 5.1% of the current demand. More than half of this heat was found to be usable directly, without the need for a heat pump.

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Organisations: Department of Mechanical Engineering, Thermal Energy, Department of Management Engineering, Systems Analysis
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Use of electric vehicles or hydrogen in the Danish transport sector in 2050?: Use of electric vehicles or hydrogen

Denmark has an ambitious long-term goal to reduce greenhouse gas (GHG) emissions from the transport sector with an overall climate target to be independent of fossil-fuel consumption by 2050. We compare a likely scenario with two alternative ways to achieve the goal—either with a high percentage of electric vehicles (EV) or with a high percentage of hydrogen use for transportation. The STREAM model—an energy scenario simulating tool—is used to model the different scenarios and their integration with the electricity and heating systems. The major findings are that an increased share of EV can reduce the socioeconomic cost of the energy system in 2050. However, electricity demand for H2 generation via electrolysis is more flexible than EV charging and the production can therefore, to a larger degree be used to out-balance variable electricity surplus from a high share of wind energy in the power system, reducing the investments in backup capacity. Whether the hydrogen scenario (H2S) is more costly to implement than the EV scenario (EVS) mainly depends on the technological development—especially the improvement on the efficiency of the conversion from electricity to H2 and the cost of the hydrogen fuel cell vehicle. Therefore, the major drivers of a successful H2S are a high efficient flexible H2 production in 2050 and lower vehicle costs, which increase the stability of the power grid, compared to the EVS. Hence, from a socioeconomic view point, the technological path in innovation to achieve fossil-free transport systems should have vehicle costs and electrolyzers efficiency as their main drivers toward 2050.

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Web of Science (2017): Impact factor 2.514
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Web of Science (2016): Impact factor 2.889
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BFI (2015): BFI-level 1
Heat supply planning for the ecological housing community Munksøgård

Munksøgård is a housing community near the city of Roskilde, Denmark. In 2014, Munksøgård's residents have agreed to change the existing heat supply system. The choice of future heat supply was narrowed to heat pumps, new biomass boiler and connection to nearby district heating network. The present paper compares results from techno-economic energy system analysis, simple private-economic analysis and assessment of externalities related to the heat supply and discusses the differences in conclusions - is the economic optimal solution different from a system or private-economic point of view? The techno-economic energy system analysis is done using TIMES-DTU model, which optimizes over all sectors in Denmark and all periods until 2050. The result from this model gives the least expensive solution from the overall system point of view. A spreadsheet model has been developed to do the private-economic analysis and the evaluation of external effects related to the different solutions.

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Scopus rating (2017): CiteScore 5.6 SJR 1.99 SNIP 1.923
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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 5.17 SJR 1.974 SNIP 1.823
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.03 SJR 2.22 SNIP 2.037
Residential heat pumps in the future Danish energy system

Denmark is striving towards 100% renewable energy system in 2050. Residential heat pumps are expected to be a part of that system. We propose two novel approaches to improve the representation of residential heat pumps: Coefficients of performance (COPs) are modelled as dependent on air and ground temperature while installation of ground-source heat pumps is constrained by available ground area. In this study, TIMES-DK model is utilised to test the effects of improved modelling of residential heat pumps on the Danish energy system until 2050. The analysis of the Danish energy system was done for politically agreed targets which include: at least 50% of electricity consumption from wind power starting from 2020, fossil fuel free heat and power sector from 2035 and 100% renewable energy system starting from 2050.

Residential heat pumps supply around 25% of total residential heating demand after 2035. The improved modelling of residential heat pumps proved to have influence on the results. First, it would be optimal to invest in more ground-source heat pumps, but there is not enough available ground area. Second, the total system costs are higher when COPs are modelled as temperature-dependent compared to fixed COPs over a year.
Ringkøbing-Skjern energy atlas for analysis of heat saving potentials in building stock

Ringkøbing-Skjern municipality aims to be 100% self-sufficient in renewable energy supply starting from 2020. It is expected that the building sector will contribute by reducing energy demand by 25-50%. Technical, economic, environmental and geographical aspects need to be considered when analysing such drastic change of municipality's energy system. For that purpose, GIS-based Ringkøbing-Skjern Energy Atlas has been developed. The present paper utilises Ringkøbing-Skjern Energy Atlas together with the Heating Model to calculate potentials and costs of heat saving.
measures. The results show that the reduction of heating demand by 25% and 35% can be achieved at the annuitized full cost lower than 1.7 and 2 DKK/kWh, respectively. The results also show that significant heat saving potential lies in farmhouses and detached houses as well as in buildings built before 1950. Over 75% of very cheap heat saving potential can be harvested by insulating floors, while majority of heat saving potential cheaper than 2 DKK/kWh can be utilised by insulating floors and installing mechanical ventilation systems. After heat savings and heat supply options are compared from a private-economic perspective, it is concluded that heat savings should be directed towards buildings supplied by oil boilers, natural gas boilers and ground-source heat pumps.

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ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.25 SJR 1.935 SNIP 2.214
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4 SJR 1.566 SNIP 2.01
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China’s "energy revolution": measuring the status quo, modelling regional dynamics and assessing global impacts

As the world's largest economy in transition, China plays a growing role in global energy markets, clean technology deployment and climate change negotiations. The Chinese president Xi Jinping called in June 2014 for an "energy revolution" of the country’s “energy production and consumption habits in light of changing dynamics in global energy markets” [Xinhua, 2014]. This highlights the strategic importance of China’s energy sector in the country’s national economic planning and its associated global impacts. China furthermore has a growing research and development budget and plays an increasing role in global scientific collaboration networks. A wide range of Chinese national and provincial statistics builds the foundation of this China energy sector research and allows measuring and modelling its main regional dynamics. As the quality, reliability, and availability of China's official statistics continues to be critically debated in the scientific community, additional complexity gets introduced to many China-specific research areas, such as the ones discussed here.

This research takes thus place in a fascinating, highly complex and fast-paced research environment. The overall aim of this PhD thesis is to describe and discuss the main characteristics China’s "energy revolution" by means of (i) measuring and quantifying the status quo of China's energy sector with a focus on major regional characteristics, (ii) modelling selected future scenarios for different regions of China, and (iii) benchmarking and visualizing associated global impacts of China’s "energy revolution". The general framework of investigation was chosen as a cross-disciplinary and highly collaborative approach. Different quantitative-based, economic, technical, and financial planning tools are developed, expanded and applied in this regard. The theories underlying this research are stemming from various scientific disciplines, such as energy and power engineering, macro- and energy-economics, and power project finance. Cross-cutting aspects are the harmonization of Chinese and international energy statistics and the communication of complex scientific results for a broad scientific and public audience.

Novel scientific approaches and results of this research include: (i) a pragmatic methodology development to construct regional energy balances for China in the format of a commonly used international energy balance; (ii) a review and benchmarking exercise of 18 Chinese energy modelling tools followed by a discussion of the Chinese perspective towards a low-carbon economy; (iii) an energy system wide mapping of regional energy flows in China to evaluate main disparities; (iv) a coupling of two complex top-down and bottom-up global energy planning tools to model future regional dynamics of China's energy sector; and (v) an assessment of electricity generation costs of the first operational concentrated solar
power technologies in China. The results of this thesis are relevant for a broad scientific and public audience interested in an overview of China's ongoing energy and power system transition. The transparent, collaborative, and cross-disciplinary approach of this research allows gaining a deeper understanding of China's "energy revolution" from various economic, technical and financial perspectives, while highlighting associated complexities, such as data challenges.

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**Economic Impacts of Future Changes in the Energy System - Global Perspectives**

In a climate constrained future, hybrid energy-economy model coupling gives additional insight into interregional competition, trade, industrial delocalisation and overall macroeconomic consequences of decarbonising the energy system. Decarbonising the energy system is critical in mitigating climate change. This chapter summarises modelling methodologies developed in the ETSAP community to assess economic impacts of decarbonising energy systems at a global level. The next chapter of this book focuses on a national perspective. The range of economic impacts is regionally dependent upon the stage of economic development, the level of industrialisation, energy intensity of exports, and competition effects due to rates of relative decarbonisation. Developed nation’s decarbonisation targets are estimated to result in a manageable GDP loss in the region of 2 % by 2050. Energy intensive export driven developing countries such as China and India, and fossil fuel exporting nations can expect significantly higher GDP loss of up to 5 % GDP per year by mid-century.

**General information**

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Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis, University College Cork, NOVA University Lisbon, Luleå University of Technology, ENERIS, Swiss Federal Institute of Technology Lausanne, Paul Scherrer Institute, VTT - Technical Research Centre of Finland, National Institute for Environmental Studies, E4SMA, Norwegian University of Science and Technology, Energy research Centre of the Netherlands - ECN, Cambridge Econometrics, ParisTech, University College London, University of Cape Town
Economic Impacts of Future Changes in the Energy System - National Perspectives

In a climate constrained future, hybrid energy-economy model coupling gives additional insight into interregional competition, trade, industrial delocalisation and overall macroeconomic consequences of decarbonising the energy system. Decarbonising the energy system is critical in mitigating climate change. This chapter summarises modelling methodologies developed in the ETSAP community to assess economic impacts of decarbonising energy systems at a national level. The preceding chapter focuses on a global perspective. The modelling studies outlined here show that burden sharing rules and national revenue recycling schemes for carbon tax are critical for the long-term viability of economic growth and equitable engagement on combating climate change. Traditional computable general equilibrium models and energy systems models solved in isolation can misrepresent the long-run carbon cost and under-estimate the demand response caused by technological paradigm shifts in a decarbonised energy system. The approaches outlined within have guided the first evidence based decarbonisation legislation and continue to provide additional insights as increased sectoral disaggregation in hybrid modelling approaches is achieved.

Heat supply planning for the ecological housing community Munksøgård

Munksøgård is a housing community near the city of Roskilde, Denmark. In 2014, Munksøgård's residents have agreed to change the existing heat supply system. The choice of future heat supply was narrowed to heat pumps, new biomass boiler and connection to nearby district heating network. The present paper compares results from techno-economic energy system analysis, simple private-economic analysis and assessment of externalities related to the heat supply and discusses the differences in conclusions - is the economic optimal solution different from a system or private-economic point of view? The techno-economic energy system analysis is done using TIMES-DTU model, which optimizes over all sectors in Denmark and all periods until 2050. The result from this model gives the least expensive solution from the overall system point of view. A spreadsheet model has been developed to do the private-economic analysis and the evaluation of external effects related to the different solutions.
Optimal development of the future Danish energy system – insights from TIMES-DTU model

After a long period of transition, Danish energy system is half-way towards completely renewable in 2050. Drastic changes happened in the last forty years – the imported oil has been replaced by a mix of coal and natural gas, energy efficiency and conservation have been improved by extensive use of CHP-based district heating and heat saving measures. In the same period Denmark became well-known by integration and export of wind turbines. In line with the changes in the past, Denmark currently has very ambitious renewable energy targets, most ambitious being the 100 % renewable energy system in 2050. To achieve this, it is obvious that the present energy system needs to change, but the open question is how this should be done. In order to answer this question, the present paper uses TIMES-DTU model. TIMES-DTU is technology-rich, bottom-up, optimisation model covering all sectors of the Danish energy system, assuming full foresight and perfect competition. It simultaneously optimises investments and operation across all sectors and all time periods. Three different scenarios have been described in the present paper: (i) Base scenario without any policy constraints imposed on the model, (ii) WLP with the constraint that 50 % of electricity production should come from wind starting from 2020, and (iii) WLP-NFE scenario with the constraint that power and heat sector should be fossil fuel-free starting from 2035 and Denmark should be 100 % renewable starting from 2050. In all scenarios, Denmark was constrained to be a net exporter of electricity. The results imply that heat demand in future Danish energy system will be significantly reduced as a result of significant heat saving measures within the building stock, especially in rural and sub-urban areas. In urban areas, large district heating networks will supply between 55 and 73 % of heat supply in the years close to 2050. Electricity demand will be largely increased mainly due to transition to large scale heat pumps in the district heating networks. More than 90 % of increased demand for electricity will be based on on-shore and off-shore wind energy. WLP scenario implies less than 1 % higher total system costs compared to Base scenario, while WLP-NFE scenario implies 5-6 % higher total system costs compared to Base scenario. An additional conclusion from the current study is that Denmark has sufficient resources to achieve self-sufficiency in energy supply.
Residential heat pumps in the future Danish energy system

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Ringkøbing-Skjern Energy Atlas for municipal energy planning

Ringkøbing-Skjern is Denmark's largest municipality, located in the west part of Central Denmark Region. Its medium-term goal is to achieve 100 % self-sufficiency in renewable energy supply by 2020. To achieve this ambitious goal, future courses of action have been outlined in the municipality's energy strategy "Energy2020" and divided into five groups: increasing production from wind, bioenergy and other renewable energy sources, reducing heat demand in buildings and converting transportation sector to renewable energy. The analysis of technical, economic and environmental impacts of such a variety of technologies on the municipality's energy system requires highly detailed decision support system. For that purpose, GIS-based energy atlas has been developed for Ringkøbing-Skjern municipality. The data about energy supply and demand, transmission and distribution infrastructure, energy resources, societal and other energy data have been geographically referenced and combined with the tools built in ArcGIS software.

The data have been collected from various sources: freely accessible public databases, the municipality, district heating and electricity companies, Danish transmission system operator, etc. The focus in the energy atlas is put on the geographical level of details, such as locations of district heating pipes and wind turbines, but the objects have been described with technical parameters and historical values as well. The applicability of the energy atlas is elaborated in the present paper and it is concluded that it can be used for analysis of heat saving measures in the building stock, district heating expansion and site-selection analysis for new wind turbines or biogas plants. In addition to that, it has proven to be useful as a data container and pre-analysis tool for energy system models and as a visualization tool. The continuous updating of the atlas while maintaining the sufficient level of data confidentiality is considered crucial for its long-term value; the strategy for continuous updating is presented in a separate section. Finally, since the methods and procedures used to create the atlas are irrespective from administrative boundaries, neither obstacle is observed towards creating the GIS-based energy atlases for other Danish municipalities or for Denmark as a whole.

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The effect of microscale spatial variability of wind on estimation of technical and economic wind potential

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20150130_IEW_Paper.pdf
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Use of electric vehicles or hydrogen in the Danish transport sector
Denmark is one of the Northern European countries that have set up ambitious longterm targets to reduce GHG emissions from the transport as well as from other sectors. In Denmark the target is to make the transport sector independent of fossilfuel consumption by 2050 at the latest. This paper compares a likely scenario with two alternative ways to achieve the goal - either with a high percentage of electric vehicles (EV) or with a high percentage of hydrogen (H2) use in the transport sector. The STREAM model - an energy scenario simulating tool - provides insight into different potential energy mixes and calculates socio economic costs. It is used to model the different transport scenarios and their system integration with the electricity and heating sectors. The major findings of this paper are that an increased share of electric vehicles could significantly reduce the socio-economic cost of the energy system in 2050. Electricity demand for H2 generation via electrolysis is more flexible than EV charging and the production can therefore, to a larger degree be used to out-balance variable electricity surplus from a high share of wind and solar energy in the power system. H2 production may generate heat that can be used as district heating - replacing traditional heating plants, heat pumps and in some cases combined heat and power plants. Therefore the energy generation mix (electricity and heat) is more affected in the H2 scenario than in the EV scenario. Whether the H2 scenario is more costly to implement than the EV scenario mainly depends on the technological development - especially the improvement on the efficiency of the conversion from electricity to H2. It is found that a higher efficiency in the H2 production via electrolysis plays a more important role in decreasing the total cost of the energy system than a lower level of electrolyser capital cost. Therefore, the major driver of a successful H2 scenario is a high efficient and flexible H2 production in 2050. In other words, from a socio-economic view point this paper International Conference on Energy, Environment and Climate Change 198 estimates that the technological path in innovation should have efficiency as its main driver towards 2050.

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Experiences with biogas in Denmark
This report is primarily based on the work of the Danish biogas task force, which was established as a result of the Energy Agreement of 22 March 2012. The purpose of the task force is to examine and support concrete biogas projects in order to facilitate the projected biogas development up to 2020.
The focus of the task force was on the practical integration of the new biogas production in energy system, including the utilization of gas, the necessary infrastructure and contractual relationships. The aim was to ensure effective and appropriate integration of biogas in the Danish energy supply, which was consistent with the policy objectives, both
in regards to current challenges for specific biogas plants and the role of biogas flexible renewable energy form on longer term. The task force's final report was published in 2014.

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**Experiences with biomass in Denmark**

The Bioenergy Department in SENER have requested assistance with planning for the deployment of bioenergy (Biomass, biogas and waste incineration) in Mexico and information on Danish experiences with developing policy initiatives promoting bioenergy.

This introduction to the Danish experiences with biomass use is compiled as preparation for SENER’s potential visit to Denmark in 2014.

This report was prepared 19 June, 2014 by DTU System Analysis to Danish Energy Agency (DEA) as part of a frame contract agreement.

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**Experiences with waste incineration for energy production in Denmark**

The Bioenergy Department in SENER have requested assistance with planning for the deployment of bioenergy (Biomass, biogas and waste incineration) in Mexico and information on Danish experiences with developing policy initiatives promoting bioenergy.

This introduction to the Danish experiences with waste incineration for energy production use is compiled as preparation for SENER’s potential visit to Denmark in 2014.

This report was prepared 19 June, 2014 by COWI DTU System Analysis to Danish Energy Agency (DEA) as part of a frame contract agreement.

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Application and Development of Energy System Optimisation Models to Meet Challenges of the Future

Climate change, security of supply and local air pollution are among the challenges that are shaping the future of energy systems worldwide. In response to these challenges, various goals are set nationally and internationally that energy systems are supposed to fulfil. These include e.g. EU 20-20-20 targets or the 100% renewable energy system in Denmark in 2050. Nevertheless, the ultimate result with regard to the respective future energy systems remains an open question.

This cumulative PhD thesis deals with application and development of energy system optimisation models to address the various challenges stemming from energy use. It consists of a generic part and eleven papers focusing on different, but related topics. The generic part of the thesis serves to provide the background for the papers as well as to place them within the literature and to highlight various linkages between them. The challenges of climate change, security of supply, and local air pollution are addressed in the papers by focusing on renewable energy systems, demand side management options, climate change mitigation and resource potentials. In the process of the study the energy system optimisation models, Balmorel and TIAM, were further developed in order to enhance their capabilities.

Methodologically, this thesis heavily relies on mathematical programming and scenario analysis. This is mainly a consequence of the tools that are used (both models are formulated as linear optimisation problems) and the nature of the issues that are dealt with (i.e. high degree of uncertainty with regard to future technology characteristics, global policy development on climate mitigation, etc.). Additionally, geographic information systems are used in one of the papers to conduct a spatial analysis for estimating wind energy potentials.

One of the most interesting results obtained in the course of this study is related to a methodology for estimating wind energy potentials developed in one of the papers. It is shown that the economic wind energy potential based on microscale wind climate data can be twice as high compared to the results obtained with simulated mesoscale data (i.e. representing usually used type of data). This has a number of interesting implications for energy system modelling studies on both regional and global level; namely, more realistic wind potential estimates, higher competitiveness of wind energy, and an increased climate change mitigation potential. Other results highlight among others, the possible future roles of individual technologies (i.e. wind power in Denmark and carbon capture and storage in China) in the climate constrained world, the difficulty to achieve the 2°C target agreed upon in the Copenhagen Accord and the importance of large emerging economies in this context, and the role of district heating in the future Danish renewable energy system.

The outcomes of this work illustrate the potential of energy system optimisation models to address challenges of the future. The model development that was undertaken can be used by energy planners, modellers and researchers in order to improve reliability of their analysis. Moreover, the results of this study can be useful to policy-makers in order to inform their policy decisions with regard to climate change mitigation and energy system development.
Danish heat atlas as a support tool for energy system models

In the past four decades following the global oil crisis in 1973, Denmark has implemented remarkable changes in its energy sector, mainly due to the energy conservation measures on the demand side and the energy efficiency improvements on the supply side. Nowadays, the capital intensive infrastructure investments, such as the expansion of district heating networks and the introduction of significant heat saving measures require highly detailed decision-support tool. A Danish heat atlas provides highly detailed database with extensive information about more than 2.5 million buildings in Denmark. Energy system analysis tools incorporate environmental, economic, energy and engineering analysis of future energy systems and are considered crucial for the quantitative assessment of transitional scenarios towards future milestones, such as EU 2020 goals and Denmark’s goal of achieving fossil free society after 2050. The present paper shows how a Danish heat atlas can be used for providing inputs to energy system models, especially related to the analysis of heat saving measures within building stock and expansion of district heating networks. As a result, marginal cost curves are created, approximated and prepared for the use in optimization energy system model. Moreover, it is concluded that heat atlas can contribute as a tool for data storage and visualisation of results.
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Web of Science (2013): Impact factor 3.59
ISI indexed (2013): ISI indexed yes
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Web of Science (2012): Indexed yes
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Scopus rating (2011): CiteScore 3.03 SJR 1.24 SNIP 1.82
Web of Science (2011): Impact factor 2.216
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Web of Science (2010): Impact factor 2.072
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Scopus rating (2006): SJR 1.294 SNIP 1.797
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.542 SNIP 1.769
Scopus rating (2004): SJR 1.043 SNIP 1.467
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.879 SNIP 1.382
Scopus rating (2002): SJR 0.972 SNIP 1.467
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.794 SNIP 0.86
Scopus rating (2000): SJR 0.568 SNIP 0.72
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Research output: Research - peer-review › Journal article – Annual report year: 2014

**Electric vehicles or use of hydrogen in the Danish transport sector in 2050?**
Denmark is one of the Nordic countries that have set up ambitious long-term targets to reduce GHG emissions from the transport as well as from other sectors. In Denmark the target is to make the transport sector independent of fossil-fuel consumption by 2050 at the latest. This paper compares a likely scenario with two alternative ways to achieve the goal - either with a high percentage of electric vehicles (EV) or with a high percentage of hydrogen (H2) use in the transport sector.
The STREAM model - an energy scenario simulating tool - provides insight into different potential energy mixes and calculates socio economic costs. It is used to model the different transport scenarios and their system integration with the electricity and heating sectors.
The major findings of this paper are that an increased share of electric vehicles could significantly reduce the socio-economic cost of the system in 2050. Compared to the EV scenario, H2 generation from electrolysis is more flexible and the production can therefore to a larger degree be used to out-balance fluctuating electricity surplus from a high share of wind energy in the power system.

H2 production may generate heat that can be used as district heating - replacing traditional heating plants, heat pumps and in some cases combined heat and power plants. Therefore the energy generation mix (electricity and heat) is more affected in the H2 scenario than in the EV scenario.

Whether the H2 scenario is more costly to implement than the EV scenario mainly depends on the technological development - especially the efficiency of the electricity to H2 development. It is found that a higher efficiency in the H2 production is more important than a lower level of the capital cost. Therefore, the major driver of a successful H2 scenario is a high efficient and flexible H2 production in 2050. In other words, from a socio-economic view point this paper estimates that the technological path in innovation should have efficiency as its main driver towards 2050.

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Model for Determining Geographical Distribution of Heat Saving Potentials in Danish Building Stock

Since the global oil crisis in the 1970s, Denmark has followed a path towards energy independency by continuously improving its energy efficiency and energy conservation. Energy efficiency was mainly tackled by introducing a high number of combined heat and power plants in the system, while energy conservation was predominantly approached by implementing heat saving measures. Today, with the goal of 100% renewable energy within the power and heat sector by the year 2035, reductions in energy demand for space heating and the preparation of domestic hot water remain at the top of the agenda in Denmark. A highly detailed model for determining heat demand, possible heat savings and associated costs in the Danish building stock is presented. Both scheduled and energy-saving renovations until year 2030 have been analyzed. The highly detailed GIS-based heat atlas for Denmark is used as a container for storing data about physical properties for 2.5 million buildings in Denmark. Consequently, the results of the analysis can be represented on a single building level. Under the assumption that buildings with the most profitable heat savings are renovated first, the consequences of heat savings for the economy and energy system have been quantified and geographically referenced. The possibilities for further improvements of the model and the application to other geographical regions have been discussed.

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Contributors: Petrovic, S., Karlsson, K. B.
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Modelling tools to evaluate China’s future energy system - a review of the Chinese perspective

Research efforts to analyse China’s future energy system increased tremendously over the past decade. One prominent research area is China’s first binding CO2 emission intensity target per unit of GDP (Gross Domestic Product) and its impact on the country’s economy and energy system. This paper compares 18 energy modelling tools from ten Chinese institutions. These models have been described in English language publications between 2005 and 2013, although not all are published in peer-reviewed journals. When comparing the results for three main energy system indicators across models, this paper finds that there are considerable ranges in the reference scenarios: (i) GDP is projected to grow by 630e840% from 2010 to 2050, (ii) energy demand could increase by 200e300% from 2010 to 2050, and (iii) CO2 emissions could rise by 160e250% from 2010 to 2050. Although the access to the modelling tools and the underlying data remains challenging, this study concludes that the Chinese perspective, independently from the modelling approach and institution, suggests a rather gradual and long-term transition towards a low carbon economy in China. Few reference scenarios include an emission peak or stabilisation period before 2040. While policy scenarios frequently suggest efficiency improvements, a short-term and largescale introduction of non-fossil power technologies is rarely recommended.

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Web of Science (2017): Impact factor 4.968
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Scopus rating (2016): CiteScore 5.17 SJR 1.974 SNIP 1.823
Web of Science (2016): Impact factor 4.52
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
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Web of Science (2015): Indexed yes
The effect of microscale spatial variability of wind on estimation of technical and economic wind potential

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System and market integration of wind power in Denmark

Denmark has more than 10 years’ experience with a wind share of approximately 20 per cent. During these 10 years, electricity markets have been subject to developments with a key focus on integrating wind power as well as trading electricity with neighbouring countries. This article introduces a methodology to analyse and understand the current market integration of wind power and concludes that the majority of Danish wind power in the period 2004-2008 was used to meet the domestic demand. Based on a physical analysis, at least 63 per cent of Danish wind power was used domestically in 2008. To analyse the remaining 37 per cent, we must apply a market model to identify cause-effect relationships. The Danish case does not illustrate any upper limit for wind power integration, as also illustrated by Danish political targets to integrate 50 per cent by 2020. In recent years, Danish wind power has been financed solely by the electricity consumers, while maintaining production prices below the EU average. The net influence from wind power has been as low as 1e3 per cent of the consumer price.

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Web of Science (2017): Impact factor 2.164
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Scopus rating (2016): CiteScore 1.9 SJR 0.833 SNIP 0.883
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Scopus rating (2015): CiteScore 1.82 SJR 1.337 SNIP 1.098
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Use of Danish Heat Atlas and energy system models for exploring renewable energy scenarios

In the past four decades following the global oil crisis in 1973, Denmark has implemented remarkable changes in its energy sector, mainly due to energy conservation measures on the demand side and energy efficiency improvements on the supply side. Nowadays the optimal expansion of district heating networks in relation with significant heat saving measures that are capital intensive infrastructure investments require highly detailed decision-support tools. The Heat Atlas for Denmark provides a highly detailed database and includes heat demand and possible heat savings for about 2.5 million buildings with associated costs included. Energy systems modelling tools that incorporate economic, environmental, energy and engineering analysis of future energy systems are considered crucial for quantitative assessment of transitional scenarios towards future milestones, such as (i) EU 2020 goals of reducing greenhouse gas emissions, increasing share of renewable energy and improving energy efficiency and (ii) Denmark’s 2050 goals of covering entire energy supply by renewable energy. Optimization and simulation energy system models are currently used in Denmark. The present paper tends to provide a comprehensive insight into the use of the Heat Atlas for Denmark in recent studies dealing with municipal strategic energy planning and main scientific papers addressing those issues. A literature review of current advancements and discoveries in linking the Heat Atlas and energy system models will be presented, while special attention will be given to treating competing investments between heat supply and savings using optimization models. Main scientific contributors, their methodologies and areas for future research will be identified.

Dansk transport uden kul og olie - hvordan?: Et oplæg til debat om hvordan dansk transport bliver uafhængig af fossile brændstoffer inden 2050

Dansk transport uden kul og olie - hvordan?: Et oplæg til debat om hvordan dansk transport bliver uafhængig af fossile brændstoffer inden 2050

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Energy savings, potentials and policies

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Contributors: Møller Andersen, F., Karlsson, K. B., Togeby, M.
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Research output: Research - peer-review › Report chapter – Annual report year: 2012

100% Renewable energy systems, climate mitigation and economic growth
Greenhouse gas mitigation strategies are generally considered costly with world leaders often engaging in debate concerning the costs of mitigation and the distribution of these costs between different countries. In this paper, the analyses and results of the design of a 100% renewable energy system by the year 2050 are presented for a complete energy system including transport. Two short-term transition target years in the process towards this goal are analysed for 2015 and 2030. The energy systems are analysed and designed with hour-by-hour energy system analyses. The analyses reveal that implementing energy savings, renewable energy and more efficient conversion technologies can have positive socio-economic effects, create employment and potentially lead to large earnings on exports. If externalities such as health effects are included, even more benefits can be expected. 100% Renewable energy systems will be technically possible in the future, and may even be economically beneficial compared to the business-as-usual energy system. Hence, the current debate between leaders should reflect a combination of these two main challenges.

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Scopus rating (2017): CiteScore 8.44 SJR 3.162 SNIP 2.765
Web of Science (2017): Impact factor 7.9
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.78 SJR 3.011 SNIP 2.61
Web of Science (2016): Impact factor 7.182
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 6.4 SJR 2.835 SNIP 2.593
Web of Science (2015): Impact factor 5.746
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 6.93 SJR 3.158 SNIP 3.218
Web of Science (2014): Impact factor 5.613
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 6.59 SJR 3.06 SNIP 3.346
Web of Science (2013): Impact factor 5.261
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 5.69 SJR 2.778 SNIP 3.076
Web of Science (2012): Impact factor 4.781
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 5.5 SJR 2.416 SNIP 2.827
Web of Science (2011): Impact factor 5.106
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.531 SNIP 2.259
Web of Science (2010): Impact factor 3.915
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.992 SNIP 1.85
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.95 SNIP 1.206
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.168 SNIP 1.704
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.95 SNIP 1.277
Scopus rating (2005): SJR 1.02 SNIP 0.988
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.67 SNIP 0.844
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.713 SNIP 0.775
Scopus rating (2002): SJR 0.589 SNIP 0.779
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.368 SNIP 0.567
Scopus rating (2000): SJR 0.154 SNIP 0.498
Scopus rating (1999): SJR 0.181 SNIP 0.443
Original language: English
Keywords: DTU Climate Centre, Systems analysis
DOIs: 10.1016/j.apenergy.2010.03.001
A global or a partial climate agreement – what difference does it make?

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Flemish Institute for Technological Research, Institute for Energy Technology, DONG Energy AS
Contributors: Karlsson, K. B., Wouter, N., Lodewijks, P., Føyn, T. H. Y., Seljom, P. M. S., Balyk, O., Lüthje, M., Gregg, J. S.
Publication date: 2011
Peer-reviewed: No
Event: Abstract from ETSAP Workshop, Palto Alto, CA, United States.
Source: orbit
Research output: Research - peer-review › Journal article – Annual report year: 2010

A global renewable energy system: A modelling exercise in ETSAP/TIAM
This paper aims to test the ETSAP2-TIAM global energy system model and to try out how far it can go towards a global 100% renewable energy system with the existing model database. This will show where limits in global resources are met and where limits in the data fed to the model until now are met. Results from the modelling are global and regional energy consumption, emission of greenhouse gasses and thereby potential increase in global mean temperature. Furthermore, total system costs are compared to a reference scenario. Existing analysis with TIAM shows different ways of reaching the 2 °C target (increase in global mean temperature) and also how uncertainty on different factors influences the optimal solution. The main conclusion from existing analysis with TIAM is that the 2 °C target is possible to reach, but it will be expensive. Another very important point is that if uncertainty on the value of the climate sensitivity (Cs) is taken into account then the optimal strategy calls for early action compared to a full foresight optimisation using the most probable value of Cs.

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Energy Systems Analysis
Contributors: Føyn, T. H. Y., Karlsson, K. B., Balyk, O., Grohnheit, P. E.
Pages: 526-534
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Applied Energy
Volume: 88
Issue number: 2
ISSN (Print): 0306-2619
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 8.44 SJR 3.162 SNIP 2.765
Web of Science (2017): Impact factor 7.9
Web of Science (2016): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.78 SJR 3.011 SNIP 2.61
Web of Science (2016): Impact factor 7.182
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 6.4 SJR 2.835 SNIP 2.593
Web of Science (2015): Impact factor 5.746
China's role in global climate change mitigation: the Chinese potential for biomass & CCS

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, DONG Energy AS
Contributors: Karlsson, K. B., Lüthje, M., Gregg, J. S., Føyn, T. H. Y., Balyk, O.
Publication date: 2011
Peer-reviewed: No
Event: Abstract from ETSAP Workshop, Palto Alto, CA, United States.
Source: orbit
Source-ID: 313969
Research output: Research › Conference abstract for conference – Annual report year: 2011

Description of the CEEH integrated "Energy-Environment-Health-Cost" modelling framework system

General information
State: Published
Organisations: Systems Analysis, Energy Systems Analysis, Department of Management Engineering, DTU Climate Centre, Aarhus University, Danish Meteorological Institute, University of Southern Denmark, University of Copenhagen
Number of pages: 68
Publication date: 2011

Publication information
Publisher: Centre for Energy, Environment and Health
Original language: English
(CEEH Scientific Report; No. 1).
Electronic versions:
CEEH_Report_1_Interim_version.pdf
Research output: Research › Report – Annual report year: 2012

District heating versus individual heating in a 100% renewable energy system by 2050

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Energy Systems Analysis
Contributors: Karlsson, K. B., Balyk, O., Zvingilaite, E., Hedegaard, K.
Publication date: 2011

Host publication information
Title of host publication: 6th Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems
Source: orbit
Source-ID: 313968
Research output: Research - peer-review › Article in proceedings – Annual report year: 2011
**GHG mitigation targets and potentials in large emerging economies**

**General information**
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Føyn, T. H. Y., Karlsson, K. B., Balyk, O., Halsnæs, K.
Publication date: 2011
Peer-reviewed: No
Keywords: DTU Climate Centre, Systems analysis
Electronic versions: Føyn_paper.pdf
URLs: http://www.kth.se/itm/konferenser/iew2010?l=en_UK
Source: orbit
Source-ID: 264520
Research output: Research › Conference abstract for conference – Annual report year: 2011

**IEA-ETSAP TIMES models in Denmark: Preliminary edition**
This report presents the project “Danish participation in IEAETSAP, Annex XI, 2008-2010”, which continued the Danish participation in ETSAP under Annex XI “JOint STudies for New And Mitigated Energy Systems (JOSTNAMES): Climate friendly, Secure and Productive Energy Systems”. The main activity has been semi-annual workshops focusing on presentations of model analyses and use of the ETSAP tools (the MARKAL/TIMES family of models). Contributions to these workshops have been based on various collaborative projects within the EU research programmes and the Danish Centre for Environment, Energy and Health (CEEH). In addition, the DTU Climate Centre at Risø, which was founded in the autumn of 2008, has taken part in the ETSAP workshops, and used the ETSAP model tools for projects, papers, and presentations, as well as for a Ph.D. project.

**General information**
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, DTU Climate Centre
Contributors: Grohnheit, P. E., Karlsson, K. B., Føyn, T. H. Y.
Number of pages: 82
Publication date: 2011

**Publication information**
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
ISBN (Print): 978-87-550-3898-1
Original language: English
(Denmark. Forskningscenter Risoe. Risoe-R; No. 1774(EN)).
Keywords: Energy systems analysis, Risø-R-1774, Risø-R-1774(EN)
Electronic versions: ris-r-1774.pdf
Source: orbit
Source-ID: 276089
Research output: Research › Report – Annual report year: 2011

**Impacts of large-scale introduction of hydrogen in the road transport sector on urban air pollution and human exposure in Copenhagen**

**General information**
State: Published
Organisations: Systems Analysis, Energy Systems Analysis, Department of Management Engineering, Aarhus University
Contributors: Jensen, S., Ketzel, M., Brandt, J., Frohn, L., Winther, M., Nielsen, O., Jørgensen, K., Karlsson, K. B.
Pages: 18-24
Publication date: 2011

**Host publication information**
Title of host publication: Collection of Extended Abstracts
Publisher: Centre for Energy, Environment and Health
Large-Scale Integration of Wind Power in Integrated Assessment Models

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Balyk, O., Karlsson, K. B.
Publication date: 2011

Host publication information
Title of host publication: Proceedings
ISBN (Print): 978-3-9813870-3-2
Keywords: DTU Climate Centre
Source: orbit
Source-ID: 312393
Research output: Research › Conference abstract in proceedings – Annual report year: 2012

Optimal Investment Paths for the Danish Energy System in the CEEH Modelling System

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Karlsson, K. B., Balyk, O.
Pages: 148-150
Publication date: 2011

Host publication information
Title of host publication: Collection of Extended Abstracts
Publisher: Centre for Energy, Environment and Health (CEEH Scientific Report; No. 9).
Keywords: DTU Climate Centre, Systems analysis
Electronic versions:
Balyk_optimal investment.pdf
Source: orbit
Source-ID: 268669
Research output: Research › Conference abstract in proceedings – Annual report year: 2010

Smart city initiatives in Denmark and Europe

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Austrian Institute of Technology
Number of pages: 86
Pages: 17-22
Publication date: 2011

Host publication information
Title of host publication: Risø energy report 10 : Energy for smart cities in an urbanised world
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
ISBN (Print): 978-87-550-3905-6
(Denmark. Forskningscenter Risoe. Risoe-R; No. 1778(EN)).
Keywords: Risø-R-1778, Risø-R-1778(EN)
Electronic versions:
The cost of renewable energy: past and future

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Halsnæs, K., Karlsson, K. B.
Number of pages: 624
Publication date: 2011

Host publication information
Title of host publication: Handbook of Sustainable Energy
Volume: Chapter 13
Publisher: Edward Elgar Publishing
Editors: Galarraga, I., Gonzalez-Eguino, M., Markandya, A.
ISBN (Print): 978-1-84980-115-7
(Elgar original reference).
Source: orbit
Source-ID: 314073
Research output: Research - peer-review › Book chapter – Annual report year: 2011

The role of biomass and CCS in China in a climate mitigation perspective
As the world’s largest emitter of greenhouse gasses (GHGs), China plays a central role in the suite of options for climate change mitigation. To analyze the importance of biomass and carbon capture and storage (CCS) availability in China, varying levels of these parameters are created and then global climate scenarios are simulated using TIAM (TIMES Integrated Assessment Model). TIAM is a 16-region global energy system optimization model that includes a climate module that calculates the global concentrations of GHGs in the atmosphere. We analyze the potential for using biomass, CCS, and bioenergy CCS (BECCS) in China under the constraint of meeting a climate stabilization target such that dangerous climate change (as defined by the Copenhagen Accord) is avoided. When considering hypothetical scenarios where GHG emissions are constrained, China consumes all available domestic biomass as a relatively inexpensive fuel source. However, while BECCS does have a small role to play, in general it is cheaper to use biomass for the transportation sector and CCS with fossil fuels in order to meet both the energy demand and emissions reduction goals in the cheapest way possible. Therefore, we find that while both utilization of biomass and CCS are essential options for reducing emissions in China, BECCS is not the most cost effective option in China. CCS is nevertheless an important option for China; in the climate mitigation scenarios modeled, by 2050, China is projected to employ CCS on at least 70% of fossil energy electricity generation. When CCS is excluded, the cost of mitigation is more than doubled compared to the scenarios where CCS is included as a mitigation option.

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Lüthje, M., Karlsson, K. B., Gregg, J. S., Føyn, T. H. Y., Balyk, O.
Number of pages: 420
Pages: 258-267
Publication date: 2011

Host publication information
Title of host publication: Energy Systems and Technologies for the coming Century: Proceedings
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
(Denmark. Forskningscenter Risoe. Risoe-R; No. 1776(EN)).
Keywords: DTU Climate Centre, Risø-R-1776, Risø-R-1776(EN)
Electronic versions:
ris-r-1776.pdf
Source: orbit
Source-ID: 276716
Research output: Research - peer-review › Article in proceedings – Annual report year: 2011
100% renewable energy scenarios for Denmark

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Karlsson, K. B., Halsnæs, K.
Publication date: 2010
Peer-reviewed: No
Keywords: DTU Climate Centre, Systems analysis
Source: orbit
Source-ID: 269077
Research output: Research › Conference abstract for conference – Annual report year: 2010

A global renewable energy system - A modelling exercise in ETSAP/TIAM

General information
State: Published
Organisations: Systems Analysis Division, Energy Systems Analysis, Risø National Laboratory for Sustainable Energy, DTU Climate Centre
Contributors: Balyk, O., Føyn, T. H. Y., Karlsson, K. B.
Publication date: 2010

Event information
Event: Joint TERI-ETSAP Workshop
Location: New Delhi, India
Keywords: Energy systems analysis, Systems analysis
Electronic versions:
Energimodel.pdf
Source: orbit
Source-ID: 258515
Research output: Research › Sound/Visual production (digital) – Annual report year: 2010

Danish Wind Power Export and Cost: CEESA (Coherent Energy and Environmental System Analysis) Research Project

General information
State: Published
Number of pages: 36
Publication date: 2010

Publication information
Publisher: Department of Development and Planning, Aalborg University
ISBN (Print): 978-87-91830-40-2
Original language: English
Keywords: Energy systems analysis, Systems analysis
Source: orbit
Source-ID: 272349
Research output: Research › Report – Annual report year: 2010

Energitekniske modeller og beregninger

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Systems Analysis Division, Energy Systems Analysis
Contributors: Karlsson, K. B.
Publication date: 2010
Peer-reviewed: Unknown
Event: Abstract from Dansk Energiøkonomisk Selskabs arrangement, Frederiksberg, Denmark.
Role of hydrogen in future North European power system in 2060

The Balmorel model has been used to calculate the economic optimal energy system configuration for the Scandinavian countries and Germany in 2060 assuming a nearly 100% coverage of the energy demands in the power, heat and transport sector with renewable energy sources. Different assumptions about the future success of fuel cell technologies have been investigated as well as different electricity and heat demand assumptions. The variability of wind power production was handled by varying the hydropower production and the production on CHP plants using biomass, by power transmission, by varying the heat production in heat pumps and electric heat boilers, and by varying the production of hydrogen in electrolysis plants in combination with hydrogen storage. Investment in hydrogen storage capacity corresponded to 1.2% of annual wind power production in the scenarios without a hydrogen demand from the transport sector, and approximately 4% in the scenarios with a hydrogen demand from the transport sector. Even the scenarios without a demand for hydrogen from the transport sector saw investments in hydrogen storage due to the need for flexibility provided by the ability to store hydrogen. The storage capacities of the electricity storages provided by plug-in hybrid electric vehicles were too small to make hydrogen storage superfluous.

General information
State: Published
Contributors: Meibom, P., Karlsson, K. B.
Pages: 1853-1863
Publication date: 2010
Peer-reviewed: Yes

Publication information
Volume: 35
Issue number: 5
ISSN (Print): 0360-3199
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.1 SJR 1.116 SNIP 1.267
Web of Science (2017): Impact factor 4.229
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.74 SJR 1.145 SNIP 1.315
Web of Science (2016): Impact factor 3.582
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.46 SJR 1.27 SNIP 1.314
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.54 SJR 1.207 SNIP 1.484
Web of Science (2014): Impact factor 3.313
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.38 SJR 1.265 SNIP 1.449
Web of Science (2013): Impact factor 2.93
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
A Global Renewable Energy System

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, DTU Climate Centre, UNEP Risoe Centre on Energy, Climate and Sustainable Development (URC)
Contributors: Karlsson, K. B., Grohnheit, P. E., Føyn, T. H. Y., Balyk, O., Dhar, S.
Publication date: 2009
Peer-reviewed: No
Keywords: Climate and energy systems, Energy systems analysis
Source: orbit
Source-ID: 254189
Research output: Research - peer-review › Journal article – Annual report year: 2010
IDAs klimaplan 2050. Tekniske energisystemanalyser og samfundsøkonomisk konsekvensvurdering: Baggrundsrapport

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Aalborg University
Contributors: Mathiesen, B. V., Lund, H., Karlsson, K. B.
Number of pages: 113
Publication date: 2009

Publication information
Place of publication: København
Publisher: Ingeniørforeningen
Original language: Danish
Keywords: Climate and energy systems, Energy systems analysis
Source: orbit
Source-ID: 247335
Research output: Communication › Report – Annual report year: 2009

Low stabilization scenarios for Denmark

General information
State: Published
Organisations: DTU Climate Centre, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Halsnæs, K., Karlsson, K. B.
Publication date: 2009
Peer-reviewed: Unknown
Event: Abstract from Climate University Days, Lyngby, Denmark.
Keywords: Climate Centre, Climate and energy systems
Source: orbit
Source-ID: 253623
Research output: Communication › Conference abstract for conference – Annual report year: 2009

Optimisation of the Danish Energy System in the Light of Externality Costs

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Danish Centre for Environment and Energy, Danish Meteorological Institute, Aarhus University, University of Southern Denmark, Czech National Institute of Public Health, University of Copenhagen
Publication date: 2009
Peer-reviewed: No
Keywords: Climate and energy systems, Energy systems analysis
Electronic versions:
K.Karlsson-et-al_paper_OptimisationOfTheDanishEnergySystem.pdf
K.Karlsson_presentation.pdf
Source: orbit
Source-ID: 254182
Research output: Research › Paper – Annual report year: 2009

Anvendelse af modelerne TIMES og Balmoral til modeludvikling i CEEH

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Karlsson, K. B.
Publication date: 2008
Peer-reviewed: No
Event: Abstract from Pre-Conference Meeting, Semi-Annual ETSAP Regular Workshop, Copenhagen, Denmark.
URLs:
Hvis der er politisk vilje kan transportens CO2-udledning reduceres

Optimal investment paths for future renewable based energy systems - Using the optimisation model Balmorel

This paper investigates a possible long term investment path for the Nordic energy system focussing on renewable energy in the supply sector and on hydrogen as the main fuel for transportation, covering up to 70% of all transport in 2050. The optimisation model Balmorel [Ravn H, et al. Balmorel: A model for analyses of the electricity and CHP markets in the Baltic Sea Region. 〈www.Balmorel.com〉; 2001. [1]] covering the Nordic energy system is used. The model has been expanded to include the modelling of hydrogen production technologies, storage and hydrogen power plants. The simulation shows that with an oil price at 100 $/barrel, a CO2 price at 40 €/ton and the assumed penetration of hydrogen in the transport sector, it is economically optimal to cover more than 95% of the primary energy consumption for electricity and district heat by renewables in 2050. When the transport sector is converted as assumed 65% of the transportation relies on renewable energy.
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.74 SJR 1.145 SNIP 1.315
Web of Science (2016): Impact factor 3.582
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.46 SJR 1.27 SNIP 1.314
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.54 SJR 1.207 SNIP 1.484
Web of Science (2014): Impact factor 3.313
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.38 SJR 1.265 SNIP 1.449
Web of Science (2013): Impact factor 2.93
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.96 SJR 1.499 SNIP 1.708
Web of Science (2012): Impact factor 3.548
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.42 SJR 1.443 SNIP 1.828
Web of Science (2011): Impact factor 4.054
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.579 SNIP 1.854
Web of Science (2010): Impact factor 4.057
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.32 SNIP 1.87
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.389 SNIP 2.073
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.266 SNIP 2.197
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.061 SNIP 2.202
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.116 SNIP 1.825
Scopus rating (2004): SJR 1.232 SNIP 1.626
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.996 SNIP 1.289
Scopus rating (2002): SJR 0.748 SNIP 1.156
Scopus rating (2001): SJR 0.488 SNIP 1.197
Scopus rating (2000): SJR 0.384 SNIP 0.83
Scopus rating (1999): SJR 0.376 SNIP 0.882
Original language: English
Keywords: Renewable energy systems, Hydrogen for transportation, Optimal investments, Balmorel
DOIs:
10.1016/j.ijhydene.2008.01.031
Waste-to-energy technologies in TIMES models

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Grohnheit, P. E., Karlsson, K. B., Münster, M.
Publication date: 2008
Peer-reviewed: No
Electronic versions:
2008_153.pdf
Source: orbit
Source-ID: 231878
Research output: Research › Poster – Annual report year: 2008

Waste-to-energy technologies in TIMES models

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Grohnheit, P. E., Karlsson, K. B., Münster, M.
Publication date: 2008
Peer-reviewed: No
Event: Abstract from Pre-Conference Meeting, Semi-Annual ETSAP Regular Workshop, Copenhagen, Denmark.
URLs:
Source: orbit
Source-ID: 222897
Research output: Research › Conference abstract for conference – Annual report year: 2008

Det fremtidige danske energisystem. Teknologiscenarier

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Number of pages: 106
Publication date: 2007

Publication information
Place of publication: København
Publisher: Teknologirådet
ISBN (Print): 978-87-91614-36-1
Original language: Danish
URLs:
Source: orbit
Source-ID: 216522
Research output: Research - peer-review › Book – Annual report year: 2007

Energy scenarios: A review of methods, uses and suggestions for improvement

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Nielsen, S., Karlsson, K. B.
Pages: 302-322
Publication date: 2007
Integrating externalities in optimisation of future energy systems

State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Makroøkonomi og miljøpolitik

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Karlsson, K. B., Grinderslev, D., Werner, M., Møller Andersen, F.
Pages: 241-262
Publication date: 2007

Host publication information
Title of host publication: Miljøvurdering på økonomisk vis
Place of publication: København
Publisher: Jurist- og Økonomforbundets Forlag
Editors: Halsnæs, K., Andersen, P., Larsen, A.
ISBN (Print): 978-87-574-1292-5
Source: orbit
Source-ID: 216610
Research output: Research - peer-review › Book chapter – Annual report year: 2007

Optimal investment paths for future renewable based energy systems - Using the optimisation model Baimorel

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Karlsson, K. B., Meibom, P.
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 215416
Research output: Research › Paper – Annual report year: 2007

Præsentation og debat om projektets modelværktøj

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Werling, J., Kofoed-Wiuff, A., Karlsson, K. B.
Publication date: 2007
Peer-reviewed: No
Event: Paper presented at Konference om det fremtidige danske energisystem, Copenhagen, Denmark.
Source: orbit
Source-ID: 216088
Research output: Research › Paper – Annual report year: 2007

STREAM: A model for a common energy future

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Systems Analysis Division, Energy Systems Analysis
Contributors: Karlsson, K. B.
Pages: 230-239
The new Danish Centre of Energy, Environment and Health (CEEH) - basic ideas and framework

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Publication date: 2007
Peer-reviewed: No
Source: orbit
Source-ID: 215871
Research output: Research – Annual report year: 2007

Using data from ETSAP models in a hemispheric pollution model

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Contributors: Siggaard-Andersen, M., Karlsson, K. B., Grohnheit, P. E.
Publication date: 2007
Peer-reviewed: No
Event: Abstract from Semi-annual ETSAP regular workshop, Palo Alto, CA (US), .
URLs:
Source: orbit
Source-ID: 215511
Research output: Research – Annual report year: 2007

Miljømodeller til ADAM

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Contributors: Møller Andersen, F., Karlsson, K., Grinderslev, D., Werner, M., Jensen, T.
Pages: 26-42
Publication date: 2005
Peer-reviewed: Yes

Publication information
Journal: Nationaløkonomisk tidsskrift
Volume: 143
ISSN (Print): 0028-0453
Ratings:
BFI (2019): BFI-level 1
BFI (2018): BFI-level 1
Web of Science (2001): Indexed yes
Original language: Danish
Source: orbit
Source-ID: 170443
Research output: Research - peer-review › Report – Annual report year: 1998

Energy and Greenhouse gas balances of the utilisation of biogas for energy: - with a special focus on transportation
The utilisation of biogas for energy is an important part of the Danish energy plan for reducing Danish emissions of greenhouse gases. Implementation programmes for new biogas plants have been in operation since 1990, promoted by the Ministry of Environment and Energy. The focus of the implementation programmes has been on development of technologies for joint biogas plants, where more than one farm supplies the animal slurry. The joint biogas plants are dependent on industrial organic wastes to obtain high biogas yields for making the biogas plant economical. The industrial organic waste will, however, be the scarce factor in a further development of the joint biogas plants in Denmark. The purpose of the present study is related to the discussion on the role of transportation in the biogas fuel chain. Transportation plays a central role in the assessment of environmental advantages of utilising biogas for energy. Two different Danish joint biogas plants are evaluated with the aim of determining the role of transportation and co-fermentation on the energy and the balance of greenhouse gases from the biogas fuel cycle.

General information
State: Published
Organisations: Department of Buildings and Energy, University of Southern Denmark
Contributors: Nielsen, P. S., Karlsson, K. B., Holm-Nielsen, J. B.
Pages: 991-994
Publication date: 1998

Host publication information
Title of host publication: Biomass for Energy and Industry
Place of publication: Wurzburg
Publisher: CARMEN
Source: orbit
Source-ID: 170903
Research output: Research - peer-review › Article in proceedings – Annual report year: 1998
The role of transportation and co-fermentation in the CO2 balance for utilisation of biogas for energy

Biogas is an essential biomass source for achieving a reduction of CO2 emission by 50% in year 2030 in Denmark. The physical potential for biogas production in Denmark is more than 10 times the present biogas production in Denmark. In Denmark the largest part of the biogas production is produced at 19 decentralised joint biogas plants involving a varying number of farms (5-100). All of these plants use to some extent co-fermentation with industrial organic waste to increase biogas yield.

A fuel chain approach for utilisation of biogas for energy purposes is carried out for determining the role of increased transportation distances at large biogas plants on the total CO2 balance of the biogas plant. The advantage of constructing large biogas plants is the cost-effective possibility of using industrial organic waste to increase biogas production. In some cases co-fermentation increases biogas production up 100%. The present study evaluate optimal transportation strategies for biogas plants taking CO2 balances into account.

Heat loss from Buildings: Determination of heat loss coefficients for buildings in Denmark for SESAM computations

Projects:

Modelling Deep De-Carbonization Pathways on Different Geographical Scales (National, Regional and Global)
Simonsen, M. B., PhD Student, Department of Management Engineering
Karlsson, K. B., Main Supervisor, Department of Management Engineering
Gargiulo, M., Supervisor
01/12/2018 → 30/11/2021
Project: PhD
**progRESsHEAT: Fostering the use of renewable energies for heating and cooling**

The progRESsHEAT project aims at assisting local, regional, national and EU political leaders in developing policy and strategies to ensure a quick and efficient deployment of renewables in heating and cooling networks. The project’s aim is in line with the objectives of the Renewable Energy Directive and the Energy Performance of Buildings Directive that require Member States to develop ambitious policies as regards the use of renewable energy sources and energy efficiency in heating and cooling networks. progRESsHEAT is intended to support the market uptake of existing and emerging renewable electricity, heating and cooling technologies. More specifically, the project helps policy makers develop integrated, effective and efficient policy strategies aimed at achieving a fast and strong penetration of renewable and efficient heating and cooling systems. This includes the analysis of cross-sectoral effects between renewables and energy efficiency measures in industrial heat and cold, waste heat, heating and cooling in buildings and district heating. Together with six local authorities in six target countries across Europe (Austria, Germany, Czech Republic, Denmark, Portugal, Romania), heating and cooling strategies will be developed through a profound analysis of (1) heating and cooling demand and future developments, (2) long-term potential of renewable energies and waste heat in the regions, (3) barriers & drivers and (4) a model-based assessment of policy intervention in scenarios up to 2050. The established local energy advisory tool EnergyPRO will be used for the local studies and further developed to appropriately reflect district heating and cooling. The final versions for the investigated regions will be handed over to the authorities. In the target countries, progRESsHEAT will support the implementation of national heating and cooling plans which have to be released by member states by the end of 2015. The plans will include a policy outlook on how the potentials identified by the comprehensive assessment will be achieved. progRESsHEAT will assist national policy makers in implementing suitable policies with a model-based quantitative impact assessment of local, regional and national policies up to 2050. Policy makers and other stakeholders are strongly considered in the process. They will be offered the opportunity to learn from the experience of other players and gain deep understanding of the impact of policy instruments and their specific design. They are involved in the project via policy group meetings, workshops, interviews and webinars dedicated to policy development assistance, capacity-building and dissemination. The project is supported by the Horizon 2020 programme of the European Union.

Münster, M., Project Coordinator, Department of Management Engineering, Systems Analysis
Karlsson, K. B., Project Participant, Department of Management Engineering, Systems Analysis
Petricvic, S., Project Participant, Department of Management Engineering, Systems Analysis
Kitzing, L., Project Participant, Department of Management Engineering, Systems Analysis
Ben Amer, S., Project Participant, Department of Management Engineering, Systems Analysis
Salvucci, R., Project Participant, Department of Management Engineering, Systems Analysis
01/03/2015 → 01/10/2017
Project: Research

**Modeller i energiplanlægning med henblik på en bæredygtig udvikling**

Karlsson, K. B., PhD Student, Department of Management Engineering
Nørgaard, J., Main Supervisor, Department of Civil Engineering
Meyer, N. I., Supervisor, Department of Civil Engineering
Morthorst, P. E., Supervisor, Department of Management Engineering
Jespersen, J., Examiner, Risø National Laboratory for Sustainable Energy
Hvelplund, F., Examiner
Pedersen, S. L., Examiner
Jespersen, J., Examiner
14/01/2003 → 01/09/1997
Project: PhD

**Energy system modelling and integrated future scenario analysis of the Nordic energy and transport system through the holistic energy system tool TIME S**

Salvucci, R., PhD Student, Department of Management Engineering
Karlsson, K. B., Main Supervisor, Department of Management Engineering
Gargiulo, M., Supervisor
Uteng, T. P., Supervisor
Samfinansieret - Andet
01/05/2016 → 30/04/2019
Award relations: Energy system modelling and integrated future scenario analysis of the Nordic energy and transport system through the holistic energy system tool TIME S
Baldini, M., PhD Student, Department of Management Engineering
Klinge Jacobsen, H., Main Supervisor, Department of Management Engineering
Juul, N., Supervisor, Department of Informatics and Mathematical Modeling
Karlsøn, K. B., Examiner, Department of Management Engineering
Denny, E., Examiner
Kollmann, A., Examiner
Samfinansieret - Andet
01/10/2015 → 31/01/2019
Award relations: Energy Savings Versus Energy Supply-Modelling Energy Systems
Project: PhD

Modelling of Transport Systems in Energy System Modelling Tools
Tattini, J., PhD Student, Department of Management Engineering
Karlsøn, K. B., Main Supervisor, Department of Management Engineering
Gargiulo, M., Supervisor
Yeh, S., Supervisor
Jørgensen, B. H., Examiner, Department of Management Engineering
Ahlgren, E., Examiner, Department of Chemistry
Schäfer, A. W., Examiner
Schäfer, A. W., Examiner
Forskningsrådsfinansiering
01/07/2015 → 30/09/2018
Award relations: Modelling of Transport Systems in Energy System Modelling Tools
Project: PhD

Modelling, Transport Fuels and Future Scenarios for the Danish Energy System
Venturini, G., PhD Student, Department of Management Engineering
Münster, M., Main Supervisor, Department of Management Engineering
Gallachór, B. P. O., Supervisor
Karlsøn, K. B., Supervisor, Department of Management Engineering
Jørgensen, B. H., Examiner, Department of Management Engineering
Bolkesjø, T. F., Examiner
Krook-Riekkola, A., Examiner
Samfinansieret - Andet
01/07/2015 → 28/10/2018
Award relations: Modelling, Transport Fuels and Future Scenarios for the Danish Energy System
Project: PhD

Improved representation of renewable energy sources in integrated assessment modelling of energy and climate change policies
Balyk, O., PhD Student, Risø National Laboratory for Sustainable Energy
Karlsøn, K. B., Main Supervisor, Department of Civil Engineering
Schröder, S. T., Supervisor, Department of Management Engineering
Drews, M., Examiner, Department of Informatics and Mathematical Modeling
Espegren, K. A., Examiner
Ravn, H. V., Examiner, Risø National Laboratory for Sustainable Energy
Espegren, K. A., Examiner
Institutt/centerfinansieret
01/02/2010 → 03/12/2014
Award relations: Improved representation of renewable energy sources in integrated assessment modelling of energy and climate change policies
Project: PhD

Energy Demand Modelling
Zvingilaite, E., PhD Student, Department of Management Engineering
Klinge Jacobsen, H., Main Supervisor, Department of Management Engineering
Karlsøn, K. B., Supervisor, Department of Management Engineering
Nielsen, P. S., Examiner, Department of Management Engineering
Ahlgren, E., Examiner
Ejling Larsen, A., Examiner
Forskningsrådsfinansiering
01/04/2008 → 26/02/2013
Award relations: Energy Demand Modelling
Project: PhD

Regional and Global Energy System Modelling with focus on China
Mischke, P., PhD Student, Department of Management Engineering
Karlsson, K. B., Main Supervisor, Department of Management Engineering
Yi, W., Supervisor
Jørgensen, B. H., Examiner, Department of Management Engineering
Ahlgren, E., Examiner
Sandholt, K., Examiner
Institut, samfinansiering
15/03/2012 → 24/08/2015
Award relations: Regional and Global Energy System Modelling with focus on China
Project: PhD

Geographical representations of renewable energy Systems
Petrovic, S., PhD Student, Department of Management Engineering
Karlsson, K. B., Main Supervisor, Department of Management Engineering
Möller, B., Supervisor
Henningsen, G., Examiner, Department of Management Engineering
Balstrøm, T., Examiner
Bolkjesjø, T. F., Examiner
Balstrøm, T., Examiner
Bolkjesjø, T. F., Examiner
Institut, samfinansiering
01/11/2012 → 19/01/2017
Award relations: Geographical representations of renewable energy Systems
Project: PhD

Modelling the Effect of Emission Control Measures
Bregnbæk, C. M., PhD Student, Department of Management Engineering
Karlsson, K. B., Main Supervisor, Department of Management Engineering
Brandt, J., Supervisor
Yi, W., Supervisor
Samfinansieret - Andet
01/05/2015 → 06/01/2020
Award relations: Modelling the Effect of Emission Control Measures
Project: PhD

REEEM: Role of technologies in an Energy Efficient Economy – Model-based analysis of policy measures and transformation pathways to a sustainable energy system
Larsen, M. A. D., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre
Karlsson, K. B., Project Participant, Department of Management Engineering
Drews, M., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre
Balyk, O., Project Participant, Department of Management Engineering
01/01/2016 → 01/07/2019
Project: Research

Flex4RES: Flex4RES - Flexible Nordic Energy Systems
The Flex4RES project investigates how an intensified interaction between coupled energy markets, supported by coherent regulatory frameworks, can facilitate the integration of variable renewable energy (VRE) in turn ensuring stable, sustainable and cost-efficient Nordic energy systems. The primary objective of Flex4RES is to identify and assess regulatory and technical pathways towards coherent Nordic energy systems in 2050 based on strong interaction between different energy markets that ensure resilience, sustainability and efficiency.
Skytte, K., Project Manager, Energy Economics and Regulation, Department of Management Engineering, Systems Analysis
Kitzing, L., Project Participant, Energy Economics and Regulation, Department of Management Engineering, Systems Analysis
Karlsson, K. B., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Pizarro Alonso, A. R., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Balyk, O., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Bolwig, S., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Pade, L., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Soysal, E. R., Project Participant, Department of Management Engineering, Systems Analysis, Energy Economics and Regulation
Katz, J., Project Participant, Energy Economics and Regulation, Department of Management Engineering, Systems Analysis
Olsen, O. J., Project Participant, Department of Management Engineering, Energy Economics and Regulation, Systems Analysis
Bergaentzlé, C., Project Participant, Energy Economics and Regulation, Department of Management Engineering, Systems Analysis
Sneum, D. M., Project Participant, Energy Economics and Regulation, Department of Management Engineering, Systems Analysis
Vasileiou, T., PhD Student, Department of Management Engineering, Systems Analysis, Energy Economics and Regulation
Ravn, H. V., Project Participant, Risø National Laboratory for Sustainable Energy
Boscán Flores, L. R., Project Participant, Energy Economics and Regulation
Koivisto, M. J., Project Participant, Department of Wind Energy, Integration & Planning
Serensen, P. E., Project Participant, Department of Wind Energy, Integration & Planning
Jensen, I. G., Project Participant, Department of Management Engineering, Systems Analysis, Energy Economics and Regulation
Project ID: 82511
External Project ID: NER 76084
01/10/2015 → 31/05/2019
Keywords: Flexibility, Renewable energy, Integrated energy systems, Energy market designs, Energy policy, regulatory framework conditions, Coherent Energy Systems, Regulatory pathways, Nordic countries, Nordic Energy Research
Collaborators: Aalto University, Norwegian University of Life Sciences, RAM-løse edb, NIFU Nordic Institute for Studies in Innovation, Research and Education, KTH - Royal Institute of Technology, Nordic Energy Research
Project: Research

**COMETS: Co-Management of Energy and Transport Systems**
COMETS contributes to a cost-effective fossil free energy and transport sector by 2050, by understanding the impact on the energy system from 1) the transport sector, 2) consumer preferences and behavior regarding transportation, and 3) planning of cities and transport infrastructure.
Gregg, J. S., Project Manager, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Karlsson, K. B., Project Manager, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Münster, M., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Pizarro Alonso, A. R., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
01/01/2014 → 01/01/2019
Keywords: Transport, Energy, TIMES-DK, Renewable energy, Electric vehicles
Collaborators: University College Cork, Danish Energy Agency, Danish Energy Association, Roskilde University, E4SMA, CONCITO, Danish Board of Technology
Project: Research

**SE4ALL-C2E2: Development of the Pathways for the Sustainable Energy For All Energy Efficiency Objective**
Modeling of future energy efficiency and renewable energy pathways to meet the 2030 UN SE4ALL objectives
Gregg, J. S., Project Manager, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Karlsson, K. B., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Bolwig, S., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Balyk, O., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Solér, O., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Pérez, C. H. C., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
La Greca, S., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
01/01/2015 → 30/11/2015
Keywords: energy efficiency, Renewable energy, energy access, TIAM

ETSAP is the IEA Implementing Agreement which is known the MARKAL and TIMES models for optimisation of energy technology choice. The activities include development and use of local, national, regional and global models, data bases and technology descriptions.

Grohnheit, P. E., Project Participant, Risø National Laboratory for Sustainable Energy, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Karlsson, K. B., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis

External Project ID: 64013-0501 (EUDP)
01/01/2014 → 31/12/2016
Keywords: ETSAP, MARKAL/TIMES, TIAM
Project: Research

Danish participation in IEA-ETSAP, Annex XII, 2011-2013

The project will continue the Danish participation in the IEA Implementing Agreement ETSAP (Energy Technology Systems Analysis Programme), Annexes X and XI under the new Annex XII 'Policy Analysis Tools for Global Sustainability (PAT-SUS): E4 systems tools and joint studies'. The main activities are semi-annual workshops focusing on model analyses, and use of the ETSAP modelling tools and technology data (the MARKAL/TIMES family of models), participation in training sessions on ETSAP tools, and participation in collaborative projects using and improving the ETSAP tools. Contributions to the workshops are based on past, present and future collaborative projects, in particular within the EU research programmes and projects under the Danish Strategic Research Council. Dissemination of results of ETSAP activities will be made through participation in workshops arranged within the Danish modelling community and as Pre-Conference meetings before ETSAP meetings. The project aims at enabling Danish model studies, which are consistent with European and global models. A TIMES model for Denmark was developed within EU research projects as a part of the Pan European TIMES model, which now covers 36 European countries, using harmonised assumptions based on Eurostat data, and with results that are becoming available online (PET36). Another development within ETSAP is the TIMES Integrated Assessment Model (TIAM), which is a global model covering 15 or 16 regions and time horizon year 2100

Grohnheit, P. E., Project Participant, Department of Management Engineering
Karlsson, K. B., Project Participant, Department of Management Engineering

Project ID: 64010-0404 (EUDP)
01/12/2011 → 31/12/2013
Keywords: ETSAP, MARKAL/TIMES, TIAM
Project: Research

NETP: Nordic Energy Technology Perspectives

Nordic Energy Technology Perspectives will present scenario-based technology pathways towards a carbon-neutral Nordic energy and transport system in 2050. It will serve as a common reference document for Nordic decision-makers in energy technology policy and brand the region internationally.

Karlsson, K. B., Project Manager, Department of Management Engineering
Münster, M., Project Participant, Department of Management Engineering

Project ID: 82132
Nordic Energy Research: DKK440,000.00
01/12/2011 → 01/12/2012
Award relations: Nordic Energy Technology Perspectives
Project: Research

TOPNEST: Technology Opportunities in Nordic energy System Transitions

If Nordic energy and transport systems are to meet the 2050 energy and climate policy goals, a major transition is necessary. Fulfilling these goals may require fundamental social changes, perhaps reminiscent of an industrial revolution. Therefore industry and policymakers need insights and analyses that will help guide decision-making, avoid detrimental consequences and develop viable system transition strategies. This project explores how three renewable energy technology platforms: 1) electricity systems, 2) liquid and gaseous biofuels, and 3) hydrogen systems, may give rise to new value chains, creating entrepreneurial opportunities.

Bolwig, S., Project Manager, Department of Management Engineering
Karlsson, K. B., Project Participant, Department of Management Engineering
Münster, M., Project Participant, Department of Management Engineering
Skytte, K., Project Participant, Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Anderson, T. K., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Gregg, J. S., Project Participant, Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis
Project ID: 82124/ 1200272
Nordic Energy Research: DKK12,257,718.00
01/08/2011 → 30/09/2016
Keywords: Energy system
Collaborators: Lund University, NIFU Nordic Institute for Studies in Innovation, Research and Education, VTT - Technical Research Centre of Finland
Award relations: Technology Opportunities in Nordic energy System Transitions
Project: Research

4DH: Strategic research centre for 4th Generation district heating technologies and systems
4DH forskningscentret rets for mål er at fremme udviklingen af fremtidens 4. generations fjernvarmeteknologi. Dette er afgørende for realiseringen af såvel Danmarks mål om at blive forsslifrig i 2050 som EU’s 2020-mål. I øjeblikket leveres fjernvarme til millioner af forbrugere over 5000 europæiske fjernvarmesystemer. Denmark ligger helt i top med en fjernvarmeandeandel på ca. 50 % hvilket er grundlaget for store brændselbesparinger som følge af kraft/varme såvel som for inddragelse af vedvarende energi og udnyttelse af lavtemperaturkilder.

Svendsen, S., Project Participant, Department of Civil Engineering, Section for Building Physics and Services
Karlsson, K. B., Project Participant, Department of Management Engineering
Münster, M., Project Participant, Department of Management Engineering
Li, H., Project Participant, Department of Civil Engineering, Section for Building Physics and Services
Det Strategiske Forskningsråd: DKK37,000,000.00
01/01/2012 → 31/12/2017
Keywords: Fjernvarme
Collaborators: Halmstad University, University of Southern Denmark, Linnaeus University, University of Zagreb, Tsinghua University, Aalborg University, Chalmers University of Technology
Award relations: Strategic research centre for 4th Generation district heating technologies and systems
Project: Research

Efektiv fjernvarme i fremtidens energisystem

Morthorst, P. E., Project Manager, Department of Management Engineering
Karlsson, K. B., Project Participant, Department of Management Engineering
Larsen, H. V., Project Participant, Department of Management Engineering
Det Strategiske Forskningsråd: DKK37,000,000.00
01/01/2012 → 31/12/2017
Keywords: Fjernvarme
Collaborators: Halmstad University, University of Southern Denmark, Linnaeus University, University of Zagreb, Tsinghua University, Aalborg University, Chalmers University of Technology
Award relations: Strategic research centre for 4th Generation district heating technologies and systems
Project: Research

Reveille-project
The name is acronym for "Regulation in Energy Systems with Renewable Energy in National and Local Energy Planning". The project investigate the options for a sustainable energy system in Denmark on the basis of energy savings and renewable energy. IBE’s role was to analyse the potentials for saving heat and electricit.
Nørgaard, J., Project Manager, Department of Buildings and Energy
Karlsson, K. B., Project Participant, Department of Buildings and Energy
Ukendt: DKK71,000.00
01/06/1997 → 01/06/1998
Analysis of Barriers and Evaluation of Measures for Heat Conservation in the Greater Copenhagen Area

The project investigated the reasons why heat conservation is not promoted in Denmark in general, and in particular in areas covered by district heat and natural gas grid. Models for analysing heat demand and potentials for conservation were reviewed, and new estimates for the heat savings potentials were put forward, based on technological as well as behavioural changes. On this background workshops were run with experts in the fields, as a means to identify barriers and to suggest measures to promote heat savings.

Nørgaard, J., Project Manager, Department of Buildings and Energy
Karlsson, K. B., Project Participant, Department of Buildings and Energy

Ukendt: DKK170,000.00
01/11/1997 → 01/05/1998

Collaborators: Grontmij A/S
Award relations: Analysis of Barriers and Evaluation of Measures for Heat Conservation in the Greater Copenhagen Area
Project: Research

Activities:

Policies to drive heating and cooling towards decarbonisation: a model based ex-ante assessment
Period: 10 Jun 2018 → 13 Jun 2018
Lukas Kranzl (Speaker)
Richard Büchele (Other)
Marcus Hummel (Other)
Marie Münster (Guest lecturer)
Stefan Petrovic (Other)
Sara Ben Amer (Guest lecturer)
Kenneth Bernard Karlsson (Guest lecturer)
Tobias Fleiter (Other)
Eftim Popovski (Other)
Ali Aydemir (Other)
Jan Steinbach (Other)

Systems Analysis
Department of Management Engineering

Description
50% of final energy demand in the EU-28 is used for heating and cooling (H/C). Thus, a growing focus of climate policies is put on this sector. While national and EU policies are essential, also local initiatives and instruments are required. Thus, the key question of our paper is: Which policies are needed on the national and local level to drive heating and cooling towards decarbonisation? We analysed this question for six selected countries and local case studies within these countries. The paper covers the whole heating and cooling sector, i.e. space heating and hot water preparation in buildings, process heating in industry and district heating and electricity generation. The paper is based on the Horizon 2020 project progRESSHEAT (www.progressheat.eu).
Degree of recognition: International
Links:
https://www.iaee.org/proceedings/article/15314

Related event
41st IAEE International Conference: Transforming Energy Markets
10/06/2018 → 13/06/2018
Activity: Talks and presentations › Conference presentations

Challenges of Data Availability for Analysing the Water-Energy Nexus
Period: 5 Feb 2018 → 7 Feb 2018
Morten Andreas Dahl Larsen (Other)
Martin Drews (Speaker)
Related event

climate change and water 2018
05/02/2018 → 07/02/2018
Tours, France
Activity: Talks and presentations › Conference presentations

Challenges of Data Availability for Analysing the Water-Energy Nexus
Period: 13 Dec 2017
Morten Andreas Dahl Larsen (Speaker)
Martin Drews (Other)
Stefan Petrovic (Other)
Kenneth Bernard Karlsson (Other)
Department of Management Engineering
Systems Analysis
Degree of recognition: International

Related event

ETSAP water energy nexus workshop
13/12/2017 → 13/12/2017
Zürich, Switzerland
Activity: Talks and presentations › Conference presentations

Low carbon energy system studies for Denmark
Period: 9 Jun 2008 → …
Kenneth Bernard Karlsson (Speaker)
Risø National Laboratory for Sustainable Energy
Systems Analysis Division
Energy Systems Analysis

Description
Place: Visit of German politicians from Deutscher Bundestag, Risø (DK)
Documents:
2008_74.pdf

Related external organisation

Unknown external organisation
Activity: Talks and presentations › Conference presentations