Scenarios for sustainable heat supply and heat savings in municipalities - the case of Helsingør, Denmark

Local climate action is not only a domain of large cities, but also smaller urban areas that increasingly address climate change mitigation in their policy. The Danish municipality of Helsingør can achieve a substantial CO2 emissions reduction by transforming its heat supply and deploying heat savings. In this paper, we model the heating system of Helsingør, assess it from a simple socio- and private-economic perspective, develop future scenarios, and conduct an iterative process to derive a cost-optimal mix between district heating, individual heating and heat savings. The results show that in 2030 it is cost-optimal to reduce the heating demand by 20–39% by implementing heat savings, to deploy 32%–41% of district heating and to reduce heating-related CO2 emissions by up to 95% in comparison to current emissions. In 2050, the cost-optimal share of district heating in Helsingør increases to between 38 and 44%. The resulting average heating costs and CO2 emissions are found to be sensitive to biomass and electricity price. Although the findings of the study are mainly applicable for Helsingør, the combined use of the Least Cost Tool and modelling with energyPRO is useful in planning of heating and/or cooling supply for different demand configurations, geographical region and scale.
DEBAT: Fjernvarmen kan bidrage til at sikre et billigt, grønt dansk energisystem i fremtiden, men regeringens forsyningssstrategi medfører en række risici for samfundsøkonomien, som bør håndteres, skriver DTU-forskere, Marie Münster og Daniel Møller Sneum.

General information
State: Published
Optimization of a flexible multi-generation system based on wood chip gasification and methanol production

Flexible multi-generation systems (FMGs) consist of integrated and flexibly operated facilities that providemultiple links between the different sectors of the energy system. The present study treated the design optimization of a conceptual FMG which integrated a methanol-producing biorefinery with an existing combined heat and power (CHP) unit and industrial energy utility supply in the Danish city of Horsens. The objective was to optimize economic performance and minimize total CO2 emission of the FMG while it was required to meet the local district heating demand plus the thermal utility demand of the butchery. The design optimization considered: Selection, dimensioning, location and integration of processes; operation optimization with respect to both hourly variations in operating conditions over the year as well as expected long term energy system development; and uncertainty analysis considering both investment costs and operating conditions. Applying a previously developed FMG design methodology, scalable models of the considered processes were developed and the system design was optimized with respect to hourly operation over the period 2015–2035. The optimal design with respect to both economic and environmental performance involved a maximum-sized biorefinery located next to local industry rather than in connection with the existing CHP unit. As the local industry energy demands were limited when compared to the biorefinery dimensions considered, process integration synergies were found to be marginal when compared to the economic and environmental impact of the biorefinery for the present case. Assessing the impact of uncertainties on the estimated FMG performances, the net present value (NPV) of the optimal design was estimated to vary within the range 252.5–1471.6 M€ in response to changes of ± 25% in investment costs and methanol price, and considering two different electricity price scenarios. In addition, a change in the interest rate from 5% to 20% was found to reduce the lower bound of the NPV to 181.3 M€ for reference operating conditions. The results suggest that the applied interest rate and operating conditions, in particular the methanol price, would have a much higher impact on the economic performance of the designs than corresponding uncertainties in investment costs. In addition, the study outcomes emphasize the importance of including systematic uncertainty analysis in the design optimization of FMG concepts.

General information
State: Published
Organisations: Department of Mechanical Engineering, Thermal Energy, Department of Management Engineering, Department of Chemical and Biochemical Engineering, CHEC Research Centre
Authors: Lythcke-Jørgensen, C. E. (Intern), Clausen, L. R. (Intern), Algren, L. (Ekstern), Bavnhøj Hansen, A. (Ekstern), Münster, M. (Intern), Gadsbøll, R. Ø. (Intern), Haglind, F. (Intern)
Pages: 337–359
Publication date: 2017
Main Research Area: Technical/natural sciences
Optimizing the supply chain of biomass and biogas for a single plant considering mass and energy losses

The share of renewable energy in the Danish energy sector is increasing and the goal is that biogas production should reach a production level of 17 petajoules (PJ) in 2020 according to the Danish Energy Agency. However, this goal is currently not reachable due to lack of investments in biogas plants. In this paper, a mixed integer programming (MIP) model for finding the optimal production and investment plan for a biogas supply chain is presented to ensure better economy for the full chain hopefully stimulating future investments in biogas. The model makes use of step-wise linear functions to represent capital and operational expenditures at the biogas plant; considers the chain from the farmer to the end market; and includes changes of mass and energy content along the chain by modeling the losses and gains for all processes in the chain. Biomass inputs are scheduled on a weekly basis whereas energy outputs are scheduled on an hourly basis to better capture the changes of energy prices and potentially take advantage of these changes. The model is tested on a case study with co-digestion of straw, sugar beet and manure, considering natural gas, heat, and electricity as end products. The model finds a production and investment plan for a predefined location of the plant within half an hour of central processing unit (CPU) time. The resulting project turns out to be profitable and gives a production plan for each

DOI: 10.1016/j.apenergy.2016.08.092
Publication: Research - peer-review › Journal article – Annual report year: 2016
process, which underlines the possibilities of optimizing the processes in a biogas project.
Alternatives for Future Waste Management in Denmark: Final Report of TopWaste

The TOPWASTE project has addressed the challenges of planning robust solutions for future waste management. The purpose was to identify economic and environmentally optimal solutions - taking into account different scenarios for the development of the surrounding systems, such as the energy system. During the project, four decision support tools were developed: 1. Frida - The EPA's tool for forecasting future waste generation 2. OptiWaste - a new tool for economic optimisation of investments and operation of the combined waste and energy system 3. KISS - a new lifecycle based model with focus on comparison of greenhouse gas emissions associated with different waste management alternatives 4. A new tool for techno-economic modelling of central sorting plants. The project has furthermore contributed with method development on evaluation of critical resources as well as analyses of economic and organisational factors with influence on the future waste management. The results of the project clearly show the importance of taking scenarios for the future development of surrounding systems into account when deciding how the future waste management should be, both when it comes to the economic, environmental and resource efficiency of waste management solutions. The following chapters addresses these issues by answering some of the main research questions of the project.

General information
State: Published
Organisations: Department of Management Engineering, Energy Economics and Regulation
Authors: Møller Andersen, F. (Intern), Cimpan, C. (Ekstern), Dall, O. (Ekstern), Habib, K. (Ekstern), Holmboe, B. (Ekstern), Münster, M. (Intern), Pizarro Alonso, A. R. (Intern), Wenzel, H. (Ekstern)
Number of pages: 56
Publication date: 2016

Publication information
Place of publication: Lyngby
Publisher: Department of Management Engineering, Technical University of Denmark
ISBN (Electronic): 978-87-93458-40-6
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: TopWaste.pdf

Relations
Projects:
Alternatives for Future Waste Management in Denmark
Source: PublicationPreSubmission
Source-ID: 123635916
Publication: Research › Report – Annual report year: 2016

A method for aggregating external operating conditions in multi-generation system optimization models
This paper presents a novel, simple method for reducing external operating condition datasets to be used in multi-generation system optimization models. The method, called the Characteristic Operating Pattern (CHOP) method, is a visually-based aggregation method that clusters reference data based on parameter values rather than time of occurrence, thereby preserving important information on short-term relations between the relevant operating parameters. This is opposed to commonly used methods where data are averaged over chronological periods (months or years), and extreme conditions are hidden in the averaged values. The CHOP method is tested in a case study where the operation of a fictive Danish combined heat and power plant is optimized over a historical 5-year period. The optimization model is solved using the full external operating condition dataset, a reduced dataset obtained using the CHOP method, a monthly-
averaged dataset, a yearly-averaged dataset, and a seasonal peak/off-peak averaged dataset. The economic result obtained using the CHOP-reduced dataset is significantly more accurate than that obtained using any of the other reduced datasets, while the calculation time is similar to those obtained using the monthly averaged and seasonal peak/off-peak averaged datasets. The outcomes of the study suggest that the CHOP method is advantageous compared to chronology-averaging methods in reducing external operating condition datasets to be used in the design optimization models of flexible multi-generation systems.

**General information**

State: Published
Organisations: Department of Mechanical Engineering, Thermal Energy, Department of Management Engineering, École Polytechnique Fédérale de Lausanne
Authors: Lythcke-Jørgensen, C. E. (Intern), Münster, M. (Intern), Ensinas, A. V. (Ekstern), Haglind, F. (Intern)
Pages: 59-75
Publication date: 2016
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Applied Energy
Volume: 166
ISSN (Print): 0306-2619
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.78 SJR 3.058 SNIP 2.573
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.912 SNIP 2.61 CiteScore 6.4
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.254 SNIP 3.28 CiteScore 6.93
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 3.164 SNIP 3.377 CiteScore 6.59
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.854 SNIP 3.108 CiteScore 5.69
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.473 SNIP 2.84 CiteScore 5.5
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.516 SNIP 2.25
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.003 SNIP 1.781
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.974 SNIP 1.215
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.179 SNIP 1.709
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.979 SNIP 1.293
Scopus rating (2005): SJR 1.043 SNIP 0.996
A methodology for designing flexible multi-generation systems
An FMG (flexible multi-generation system) consists of integrated and flexibly operated facilities that provide multiple links between the various layers of the energy system. FMGs may facilitate integration and balancing of fluctuating renewable energy sources in the energy system in a cost- and energy-efficient way, thereby playing an important part in smart energy systems.

The development of efficient FMGs requires systematic optimization approaches. This study presents a novel, generic methodology for designing FMGs that facilitates quick and reliable pre-feasibility analyses. The methodology is based on consideration of the following points: Selection, location and dimensioning of processes; systematic heat and mass integration; flexible operation optimization with respect to both short-term market fluctuations and long-term energy system development; global sensitivity and uncertainty analysis; biomass supply chains; variable part-load performance; and multi-objective optimization considering economic and environmental performance.

Tested in a case study, the methodology is proved effective in screening the solution space for efficient FMG designs, in assessing the importance of parameter uncertainties and in estimating the likely performance variability for promising designs. The results of the case study emphasize the importance of considering systematic process integration when developing smart energy systems.
Municipal solid waste has seen increasing annual volumes for many decades in contemporary Europe and constitutes, if not properly managed, an environmental problem due to local pollution and greenhouse gas emissions. From an energy perspective, waste is also an alternative fuel for power and heat generation; energy recovery from waste represents an effective measure to reduce landfilling and avoid disposal emissions while simultaneously reducing the equivalent demand for primary energy supply. A key factor for obtaining the full synergetic benefits of this energy recovery is the presence of local heat distribution infrastructures, without which no large-scale recovery and utilisation of excess heat is possible. In this paper, which aims to estimate municipal solid waste volumes available for heat recovery in European district heating systems in 2030, a literature and data review is performed to establish and assess current and future EU (European Union) waste generation and management. Main conclusions are that more heat can be recovered from current Waste-to-Energy facilities operating at low average heat recovery efficiencies, that efficient incineration capacity is geographically concentrated, and that waste available for heat recovery in 2030 is equally determined by total generation volumes by this year as by future EU deployment levels of district heating.
Design and optimization of flexible multi-generation systems

This thesis focuses on the design of flexible multi-generation systems, which are dynamic and integrated energy conversion systems characterized by the ability to adjust operation in response to fluctuating operating conditions. It is the hypothesis that these systems may support the balancing of variable renewable energy sources in a cost-effective way by linking the different sectors in the energy system with local energy supply systems.

A key challenge faced in the development of flexible multi-generation systems is the knowledge gap between process design practices, which simplify energy system variations and dynamics, and energy system analysis, which fails to consider process integration synergies in local systems. The primary objective of the thesis is to derive a methodology for linking process design practices with energy system analysis for enabling coherent and holistic design optimization of flexible multi-generation systems.

A methodology is presented for optimizing the design of flexible multi-generation systems which considers: Selection, dimensioning, location and integration of processes; operation optimization with respect to both hourly variations in operating conditions as well as long term energy system development; biomass supply chains and local resource availability; combined with global sensitivity and uncertainty analysis. The methodology includes a novel method for aggregating external operating condition datasets, named the CHOP method. In addition, three case studies focusing on integrating biomass processing and energy conversion technologies in existing combined heat and power plants in Denmark are conducted using the developed methods.

The outcomes of this thesis indicate that the developed design methodology is efficient in screening for promising designs of flexible multi-generation systems. In addition, the case study results emphasize the importance of considering flexible operation, systematic process integration, and systematic assessment of uncertainties in the design optimization. It is recommended that future research focus on assessing system impacts from flexible multi-generation systems and performance improvements from storage options.

General information

State: Published
Organisations: Department of Mechanical Engineering, Thermal Energy, Department of Management Engineering, Systems Analysis
Authors: Lythcke-Jørgensen, C. E. (Intern), Haglind, F. (Intern), Clausen, L. R. (Intern), Münster, M. (Intern)
Number of pages: 298
Publication date: 2016

Publication information

Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
ISBN (Electronic): 9788774754749
Original language: English

Series: DCAMM Special Report
Number: S218
ISSN: 0903-1685
Main Research Area: Technical/natural sciences
Biomass conversion, Design optimization, Energy conversion, Flexible multi-generation, Operation optimization, Polygeneration, Process integration, Smart energy

Electronic versions:
S218_Chrisotffer_Ernst_Lythcke_Jrgensen.pdf

Relations
Projects:
Design and optimization of flexible multi-generation systems
Publication: Research › Ph.D. thesis – Annual report year: 2017

Integration of large-scale heat pumps in the district heating systems of Greater Copenhagen

This study analyses the technical and private economic aspects of integrating a large capacity of electric driven HP (heat pumps) in the Greater Copenhagen DH (district heating) system, which is an example of a state-of-the-art large district heating system with many consumers and suppliers. The analysis was based on using the energy model Balmorel to...
determine the optimum dispatch of HPs in the system. The potential heat sources in Copenhagen for use in HPs were determined based on data related to temperatures, flows, and hydrography at different locations, while respecting technical constraints. The Balmorel model was developed further in order to provide a better representation of HPs, for analysing the seasonal variations of COP (Coefficient of Performance), and to represent the difference in performance of HPs connected to either distribution or transmission networks. The optimization yields roughly 3500 FLH (full load hours) for the HPs connected to the DH distribution networks when considering a current scenario. In a zero carbon-dioxide emission scenario expected in year 2025, approximately 4000 FLH, are achieved. In the case where HPs are connected to the DH transmission network at elevated temperatures, their operation decreases by roughly 1000 FLH. No significant impact was found when comparing fixed and varying operation characteristics of the HP.

**General information**
State: Published
Organisations: Department of Mechanical Engineering, Thermal Energy, Department of Management Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems, Technical University of Denmark, EA Energy Analysis A/S
Authors: Bach, B. (Ekstern), Werling, J. (Ekstern), Ommen, T. S. (Intern), Münster, M. (Intern), Morales González, J. M. (Intern), Elmegaard, B. (Intern)
Pages: 321-334
Publication date: 2016
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Energy
Volume: 107
ISSN (Print): 0360-5442
Ratings:
- BFI (2017): BFI-level 2
- Web of Science (2017): Indexed Yes
- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 5.17 SJR 1.999 SNIP 1.798
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 2.276 SNIP 2.046 CiteScore 5.03
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 2.647 SNIP 2.63 CiteScore 5.7
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 2.54 SNIP 2.593 CiteScore 5.02
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 2
- Scopus rating (2012): SJR 1.998 SNIP 2.25 CiteScore 4.25
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 1.609 SNIP 2.043 CiteScore 4
- ISI indexed (2011): ISI indexed yes
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 1.814 SNIP 2.725
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 2
- Scopus rating (2009): SJR 1.729 SNIP 2.313
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 1.106 SNIP 1.444
- Scopus rating (2007): SJR 0.913 SNIP 1.481
Local sustainable district energy cases from across Europe

In the progRESsHEAT project, six local cases are analysed. The main objective of the progRESsHEAT project is to support policy makers and public authorities at local, regional and national level in the development and implementation of integrated strategies and policies to enforce the use of renewable and efficient heating and cooling solutions in their regions. The main pillar of the strategy development process are local case studies for six municipalities. The goal of these case studies is to develop heating and cooling strategies through a profound analysis of (1) heating and cooling demands with respect to future developments, (2) long-term potentials 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 together with the authorities.

For this purpose we apply a geographic information system (GIS) and map the energy demands based on modelling of buildings and industry, the potential RE sources (including biomass, solar, geothermal, etc.) as well as waste heat sources and the existing energy production plants locally for each municipality. The district energy system of each municipality is then modelled in a coherent energy system analysis tool (EnergyPRO) which combines the detailed demand side modelling with the geographical overview of the resources and the existing production plants. The costs of providing district energy is then entered into a cost curve tool where the cheapest solution is found, depending on the location and type of building, comparing 1) district energy costs to 2) costs of increased energy efficiency and 3) costs of individual energy solutions. Thereby, the most cost effective solutions to increase RES heating and cooling at local level are identified. Recent results from the local case studies will be presented, illustrating business cases for district heating in different regions in EU as well as the key success factors and main challenges and barriers for increased efficiency and sustainability of the European heating and cooling sector.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Vienna University of Technology
Authors: Münster, M. (Intern), Kranzl, L. (Ekstern)
Number of pages: 1
Publication date: 2016
Event: Abstract from Sustain-ATV Conference 2016, Kgs. Lyngby, Denmark
Main Research Area: Technical/natural sciences
Links:
http://www.sustain.dtu.dk/

Bibliographical note
Sustain Abstract E-3
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Modelling alternative fuel production technologies for the future Danish energy and transport system

General information
State: Published
Organisations: Department of Management Engineering
Economic and environmental optimization of waste treatment

This article presents the new systems engineering optimization model, OptiWaste, which incorporates a life cycle assessment (LCA) methodology and captures important characteristics of waste management systems. As part of the optimization, the model identifies the most attractive waste management options. The model renders it possible to apply different optimization objectives such as minimizing costs or greenhouse gas emissions or to prioritize several objectives given different weights. A simple illustrative case is analysed, covering alternative treatments of one tonne of residual household waste: incineration of the full amount or sorting out organic waste for biogas production for either combined heat and power generation or as fuel in vehicles. The case study illustrates that the optimal solution depends on the objective and assumptions regarding the background system - illustrated with different assumptions regarding displaced electricity production. The article shows that it is feasible to combine LCA methodology with optimization. Furthermore, it highlights the need for including the integrated waste and energy system into the model. © 2014 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis, Swedish Environmental Research Institute
Authors: Münster, M. (Intern), Ravn, H. (Ekstern), Hedegaard, K. (Intern), Juul, N. (Intern), Söderman, M. L. (Ekstern)
Number of pages: 10
Pages: 486-495
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Waste Management
Volume: 38
ISSN (Print): 0956-053X
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4 SJR 1.354 SNIP 2.044
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.739 SNIP 2.256 CiteScore 4.33
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.777 SNIP 2.482 CiteScore 3.43
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.822 SNIP 2.435 CiteScore 3.39
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.611 SNIP 2.184 CiteScore 2.91
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.698 SNIP 2.085 CiteScore 2.99
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.555 SNIP 1.78
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.502 SNIP 1.899
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.378 SNIP 2.13
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.035 SNIP 1.767
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.046 SNIP 1.749
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.059 SNIP 1.65
Scopus rating (2004): SJR 1.289 SNIP 1.939
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.847 SNIP 1.269
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.561 SNIP 0.874
Scopus rating (2001): SJR 0.456 SNIP 0.696
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.271 SNIP 0.451
Scopus rating (1999): SJR 0.262 SNIP 0.479
Original language: English
Biogas, Life cycle assessment, Multiple objective optimization, Organic household waste, Waste treatment
Electronic versions:
Optimization_article_141201_clean.pdf. Embargo ended: 13/01/2017
DOIs:
10.1016/j.wasman.2014.12.005
Source: FindIt
Source-ID: 2263135826
Publication: Research - peer-review › Journal article – Annual report year: 2015
Joint optimisation of the future Danish waste and energy system

In this article the impact of the future development of the energy system on the feasibility of waste treatment options is analysed. In the article two different optimization tools are used: a regional electricity model (Balmorel) and a national waste treatment and district heating model (OptiWaste). When performing optimization by minimizing the socio-economic costs, into future energy systems with high wind power production, it proves feasible primarily to incinerate waste in large scale combined heat and power (CHP) plants, whereas more incineration takes place in decentralized CHP plants in future scenarios with higher biomass consumption, where the average heat prices are higher. In both scenarios, biogas produced from organic waste is upgraded and fed into the natural gas grid and waste is incinerated rather than being centrally sorted in a material recovery facility.

General information
State: Published
Organisations: Systems Analysis, Energy Systems Analysis, Department of Management Engineering, University of Southern Denmark
Number of pages: 17
Publication date: 2015

What is the future potential for imports of combustible municipal waste to countries with extensive district heating networks? - A case study of Denmark

In Europe landfilling is the most widely used method for managing municipal solid waste. By contrast, the northern European waste market is characterized by high capacities from energy recovery plants, mostly incineration in cogeneration facilities. In Denmark, there is an overcapacity of incineration plants and this study aims to analyse if import of waste is beneficial during an interim period to divert landfilling or if it might be profitable to invest in overcapacity in the long-term in those countries where heat from incineration can be recovered. The energy and waste management system are described through linking of mathematical models, taking a holistic approach. In the short-term it pays off to import waste, avoiding landfilling; however, in the longer-term, benefits from waste trading will depend on the price of heat markets.

General information
State: Published
Organisations: Systems Analysis, Energy Systems Analysis, Department of Management Engineering
Authors: Pizarro, A. R. (Intern), Münster, M. (Intern), Salvucci, R. (Intern), Ljunggren Söderman, M. (Ekstern), Ravn, H. (Ekstern)
Number of pages: 20
Publication date: 2015

What is the impact of different energy futures on the optimal waste treatment?

General information
State: Published
Organisations: Systems Analysis, Energy Systems Analysis, Department of Management Engineering
Authors: Münster, M. (Intern), Pizarro Alonso, A. R. (Intern), Salvucci, R. (Intern), Ravn, H. (Ekstern)
Number of pages: 1
Design optimization of flexible biomass-processing polygeneration plants using characteristic operation periods

This paper presents a method for including expected operating conditions in the design optimization of flexible biomass-processing polygeneration plants through the definition of characteristic operation periods. The method is verified in a superstructure-based, multi-objective design optimization scheme applied on a conceptual polygeneration plant that considers the integrated production of power, heat, ethanol, and biomethane. The design is optimized with respect to net present value and total CO2 emission impact. The results suggest that the best solution with respect to net present value is the production of heat and power using a gas turbine and a natural gas boiler, while the best solution with respect to CO2 emission savings includes full-scale ethanol and biomethane production, as well as a straw boiler for utility heat production. Solving the same design optimization problem using yearly average operation conditions instead of the characteristic operation periods approach, one of the two efficient solutions obtained was found to be suboptimal when evaluated against the actual operating conditions. Furthermore, the predicted objective function values for the optimal designs were found to differ significantly from what was obtained in the evaluation against actual conditions. These results underline the importance of considering expected operation and operating conditions when designing flexible polygeneration plants.
Optimising waste treatment and energy systems - focusing on spatial and temporal issues

The aim of the TOPWASTE project is to evaluate current and future optimal treatment of waste fractions in terms of economy and the environment, with a focus on recycling versus Waste-to-Energy technologies. After optimization of the waste management system, results must be analysed so as to identify drivers and barriers that efficient waste utilization in Denmark is facing and discuss the economic and/or environmental benefits that might arise from a change of the current waste management system.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Authors: Pizarro Alonso, A. R. (Intern), Münster, M. (Intern), Ravn, H. (Ekstern)
Number of pages: 1
Publication date: 2014
Event: Poster session presented at Conference on Energy and Environment for the Future, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences

Spatial issues when optimising waste treatment and energy systems – A Danish Case Study

This study addresses the challenge of including geographical information related to waste resources, energy demands and production plants, and transport options in the optimization of waste management. It analyses how waste may serve as an energy source through thermal conversion and anaerobic digestion. The relation to the energy sector is taken into account. The geographically specific potentials and utilization possibilities of waste are taken into account. Thus, the relative location of the resources (in this study waste and manure for co-digestion) is accounted for. Also the location of the resources relative to their utilization (in this study mainly the location of district heating networks) is considered. The temporal dimension is important for the energy sector which displays distinct variations over the year, week and day, and this is reflected by a subdivision of the extension of the year. The study provides an analysis of the Danish waste and energy systems with a spatial and temporal resolution.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Authors: Pizarro Alonso, A. R. (Intern), Münster, M. (Intern), Petrovic, S. (Intern), Ravn, H. (Ekstern)
Number of pages: 15
Publication date: 2014
Host publication information
Title of host publication: Proceedings Venice 2014, 5th International Symposium on Energy from Biomass and Waste
Publisher: CISA Publisher
Main Research Area: Technical/natural sciences
Source: PublicationPreSubmission
Source-ID: 105175880
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Challenges when performing economic optimization of waste treatment: A review

Strategic and operational decisions in waste management, in particular with respect to investments in new treatment facilities, are needed due to a number of factors, including continuously increasing amounts of waste, political demands for efficient utilization of waste resources, and the decommissioning of existing waste treatment facilities. Optimization models can assist in ensuring that these investment strategies are economically feasible. Various economic optimization models for waste treatment have been developed which focus on different parameters. Models focusing on transport are one example, but models focusing on energy production have also been developed, as well as models which take into account a plant’s economies of scale, environmental impact, material recovery and social costs. Finally, models combining different criteria for the selection of waste treatment methods in multi-criteria analysis have been developed. A thorough updated review of the existing models is presented, and the main challenges and crucial parameters that need to be taken into account when assessing the economic performance of waste treatment alternatives are identified. The review article will assist both policy-makers and model-developers involved in assessing the economic performance of waste treatment alternatives.

General information
This article presents an optimization model that incorporates LCA methodology and captures important characteristics of waste management systems. The most attractive waste management options are in the model identified as part of the optimization. The model renders it possible to apply different optimization objectives such as minimizing costs or greenhouse gas emissions or to prioritize several objectives given different weights. An illustrative case is analyzed, covering alternative treatments of 1 tonne residual household waste: incineration of the full amount or sorting out organic waste for biogas production for either CHP generation or as fuel in vehicles. The case study illustrates, that what is the optimal solution depends on the objective and assumptions regarding the background system – here illustrated with different assumptions regarding displaced electricity production. The article shows that it is feasible to combine LCA approaches with optimization and highlights the need for including the integrated waste and energy system into the model.

Future waste treatment and energy systems – examples of joint scenarios

Development and use of scenarios for large interdisciplinary projects is a complicated task. This article provides practical examples of how it has been carried out in two projects addressing waste management and energy issues respectively. Based on experiences from the two projects, recommendations are made for an approach concerning development of scenarios in projects dealing with both waste management and energy issues. Recommendations are given to develop and use overall scenarios for the project and leave room for sub-scenarios in parts of the project. Combining different types of scenarios is recommended, too, in order to adapt to the methods and tools of different disciplines, such as developing predictive scenarios with general equilibrium tools and analysing explorative scenarios with energy system analysis tools. Furthermore, as marginals identified in differing future background systems determine the outcomes of consequential life cycle assessments (LCAs), it is considered advisable to develop and use explorative external scenarios based on possible marginals as a framework for consequential LCAs. This approach is illustrated using an ongoing Danish research project.
Influence of individual heat pumps on wind power integration – Energy system investments and operation

Individual heat pumps are expected to constitute a significant electricity demand in future energy systems. This demand becomes flexible if investing in complementing heat storage capabilities. In this study, we analyse how the heat pumps can influence the integration of wind power by applying an energy system model that optimises both investments and operation, and covers various heat storage options. The Danish energy system by 2030 with around 50–60% wind power is used as a case study. Results show that the heat pumps, even without flexible operation, can contribute significantly to facilitating larger wind power investments and reducing system costs, fuel consumption, and CO2 emissions. Investments in heat storages can provide only moderate system benefits in these respects. The main benefit of the flexible heat pump operation is a reduced need for peak/reserve capacity, which is also crucial for the feasibility of the heat storages. Socio-economic feasibility is identified for control equipment enabling intelligent heat storage in the building structure and in existing hot water tanks. In contrast, investments in new heat accumulation tanks are not found competitive.
Policy schemes, operational strategies and system integration of residential co-generation fuel cells

This study presents a holistic approach for the commercialisation of fuel cells for stationary applications. We focus our analyses on microCHP based on SOFC units fired with natural gas. We analyse the interaction of operational strategies under different ownership arrangements, required support levels and system integration aspects. The operational strategies, support mechanisms and ownership arrangements have been identified through actor analysis involving experts from Denmark, France and Portugal. With regard to operational strategies, the actor analyses led us to distinguishing between a heat-driven strategy, with and without time-differentiated tariffs, and an electricity price driven strategy for the operation as a virtual power plant. The corresponding support schemes identified cover feed-in tariffs, net metering and feed-in premiums. Additionally, the interplay of the microCHP units with the national energy systems has been analysed. Our main findings are that net metering would be an appropriate tool to support FC based microCHP in Denmark, whereas a price premium would be the preferable tool in France and Portugal.

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General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis, Department of Chemical and Biochemical Engineering, Center for BioProcess Engineering, European Institute for Energy Research, Simbiente
Pages: 3050-3063
Publication date: 2013
Main Research Area: Technical/natural sciences

Publication information
Volume: 38
Issue number: 7
ISSN (Print): 0360-3199
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.74 SJR 1.142 SNIP 1.286
System and market integration of wind power in Denmark

Denmark has more than 10 years’ of 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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General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Aalborg University, EMD International A/S, Copenhagen Energy A/S, University of Southern Denmark
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Pages: 143-156
Publication date: 2013
Main Research Area: Technical/natural sciences

Publication Information
Journal: Energy Strategy Reviews
Volume: 1
ISSN (Print): 2211-467X
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.836 SNIP 0.904 CiteScore 1.9
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.374 SNIP 1.103 CiteScore 1.82
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.345 SNIP 0.996 CiteScore 1.85
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.662 SNIP 1.066 CiteScore 1.53
Original language: English
Wind power, Wind power integration, Wind power cost, Energy system analysis, Electricity markets
Electronic versions:
DOIs: 10.1016/j.esr.2012.12.003

Bibliographical note
This study is part of the research project Coherent Energy and Environmental System Analysis (CEESA), partly financed by the Danish Council for Strategic Research. The rest has been financed by the companies and institutions of the authors.

Source: dtu
Source-ID: u::7280
Publication: Research - peer-review › Journal article – Annual report year: 2012

Wind power integration with heat pumps, heat storages, and electric vehicles – Energy systems analysis and modelling

The fluctuating and only partly predictable nature of wind challenges an effective integration of large wind power penetrations. This PhD thesis investigates to which extent heat pumps, heat storages, and electric vehicles can support the integration of wind power. Considering the gaps in existing research, main focus is put on individual heat pumps in the residential sector and the possibilities for flexible operation, using the heat storage options available.

Extensive model development is performed that significantly improves the possibilities for analysing individual heat pumps and heat storages in an energy system context. Energy systems analyses reveal that the heat pumps can even without flexible operation contribute significantly to facilitating larger wind power investments and reducing system costs, fuel consumption, and CO2 emissions. When equipping the heat pumps with heat storages, only moderate additional benefits
are achieved. Hereof, the main benefit is that the need for investing in peak/reserve capacities can be reduced through peak load shaving. It is more important to ensure flexible operation of electric vehicles than of individual heat pumps, due to differences in the load profile.

Future waste treatment and energy production – an example of development of joint scenarios

Development and use of scenarios for large interdisciplinary projects is a complicated task. The article gives practical examples of how this has been done in two projects addressing waste management and energy issues respectively. Based on experiences from the two projects, recommendations are made for an approach for development of scenarios dealing with both waste management and energy issues. It is recommended to develop and use overall scenarios for the common project and leave room for sub-scenarios in parts of the project and to combine different types of scenarios to adapt to the methods and tools of different disciplines. Furthermore, it is recommended to develop and use explorative external scenarios based on possible marginals as a framework for consequential life cycle assessment (LCA). The approach is illustrated for an ongoing Danish research project.
The role of district heating in the future Danish energy system

In the EU and in Denmark, the aim is to reduce dependence on fossil fuels and to use energy more efficiently. District heating and combined heat and power have significant potential with regard to achieving this aim. New technologies may make individual solutions such as electric heating, heat pumps and micro-CHP more attractive than previously. Therefore, the competitive conditions between district heating and other types of heating may change in the future. The question is therefore whether district heating can contribute to ensuring the sustainability of future energy systems? Denmark is used as a case as the country has a high share of district heating and produces 20% of the electricity with wind power. The analyses are carried out using the electricity market model Balmorel, which facilitates cost optimization of operation and investments in energy production plants as well as electricity transmission. To be able to perform the analysis an extension of the model is developed, where it is also possible to optimize between investments in individual heating plants or in expansion of the district heating networks, depending on investment costs, energy density of the potential areas and their distance to existing district heating networks. Results show that district heating may contribute to the sustainability and security of supply of future energy systems and that under the given assumptions it is cost effective to increase the share of district heating up to 55-57% of the heat demand although substantial heat saving measures are installed.
Using evaluation strategically to promote active learning

Rationale:
The challenge presented here is how to utilise evaluation to promote active learning. The method used is constructive alignment (Biggs & Tang, 2007) of learning objectives, learning and evaluation along with further considerations including which competences are promoted, the time consumption for the evaluation. The case presented is from a Master course, which is organised around two projects: a feasibility study and a national energy system analysis. In both cases the students work in groups with a somewhat loosely defined project. In general the course is very well suited for discussions and organising the course with group work allows for plenty of that. Furthermore, as group work is how many companies organise work today – the ability to cooperate well in groups is assessed to be an important competence for engineering students to achieve. The course is taught using the principle of inductive learning (Prince & Felder, 2006) with the students being presented with the case from the beginning and subsequently achieving the tools to perform the projects. This is both frustrating and motivating for the students as they know why they need to have the tools, but they feel they get them too late. The students have formerly been assessed through two group reports (each 25% of final grade) and an individual oral examination (50% of final grade). The students work a lot and learn a lot through working with the reports, but it is also very time consuming to write them as well as to grade them. For this purpose it was decided to change one report into a poster including a 15 minute group oral presentation. The oral examination allows for individual assessment of the students, for assessment of conceptual understanding and for learning during the examination. This type of evaluation is however very time consuming and a written examination will facilitate a better evaluation of whether the core elements of
the course (including the tools used for the two projects) are achieved at an individual level, so it was decided to have a 4 hour written examination instead. Evaluation of conceptual understanding was undertaken through more open ended questions.

Results:
Using a poster instead of a report for one of the projects was found to be very successful. The students used most of their time on discussing and using the tool, and less on reporting, which was the purpose. When asked, they claimed to have learned as much as if they had needed to hand in a report and where pleased to have the chance to try to report in the format of a poster. It was however difficult to evaluate the quality of the work within the given format and time frame. The written exams with use of computers made it possible to have individual evaluations of the use of the tools, which were taught in the course. Furthermore, from the student questions received in the time up to the exam it was obvious that the students were practising the use of the tools, thereby ensuring an additional learning loop in this respect (Argyris & Schön, 1978). Overall the results of using the new types of evaluation were positive, with a few outstanding issues to be resolved, including: 1) high evaluation pressure for a 5 ECTS course 2) clearer definition of goals and more time for evaluating posters 3) leaner 2 hour written exam.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis
Authors: Münster, M. (Intern)
Number of pages: 2
Publication date: 2012
Event: Abstract from The 11th Active Learning in Engineering Education Workshop, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
Assessment, Group work, Poster session, Written exam, Learning loops
Electronic versions:
Marie Münster 2012_ALE_Abstract final.pdf
Source: dtu
Source-ID: u::4585
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2012

Analyses of models for promotion schemes and ownership arrangements
Micro-Combined Heat and Power systems may contribute to changing the energy system at the residential level. Being a part of a distributed generation system, the stationary fuel cells constitute a promising element in a potentially sustainable and environmentally friendly energy system. Fuel cell based microCHP will be able to contribute to an innovative system where the customer produces his own heat and partly his own electricity. Furthermore, stationary fuel cells as a part of a distributed generation system are also regarded as a potential to improve the national security of supply as well as increase the national competitiveness. The stationary fuel cell technology is still in a rather early stage of development and faces a long list of challenges and barriers of which some are linked directly to the technology through the need of cost decrease and reliability improvements. Others are linked to the political stage, where the necessary support schemes have to be in place in combination with guarantees that the political objectives for the future energy system does not change dramatically. One of the main challenges of the fuel cell technology is the efficiency while others are the cost as well as the reliability of the fuel cell. It is questionable if investors such as households or energy companies are willing to engage in the fuel cell technology before these conditions have improved. In order to assure actual market penetration of fuel cells, political objectives, which will contribute to assuring that the investors face long term planning perspectives and regulation in the field has to be clear and contribute to creating the market opportunities e.g. through investments in R&D. In this work package, we address the issues of necessary support schemes and the effect on the future energy system. If the single countries should opt to support stationary fuel cells, we find that in Denmark it would be promising to apply the net metering based support scheme for households with an electricity consumption exceeding the electricity production from the fuel cell. In France and Portugal the most promising support scheme is price premium when the fuel cell is run as a part of a virtual power plant. From a system perspective, it appears that it is more important which kind of energy system (represented by country) the FC’s are implemented in, rather than which operation strategy is used. In an energy system with lots of fossil fuel (Denmark and Portugal), the potential CO2 emission reductions are relatively large compared to an energy system dominated by e.g. fossil-free nuclear.

General information
State: Published
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Number of pages: 69
Publication date: 2011

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Assessment of Building Integrated Energy Supply and Energy Saving Schemes on a National Level in Denmark

Until now buildings are most seen as creating a demand for energy. However, if we want to develop an energy system being independent of fossil fuels in the future, this will require new higher standards for energy efficiency and a radical introduction of new and renewable energy technologies, all together implying that buildings in the future might act as prosumers that is both demanding and producing energy. In this report we look at the overall consequences for the energy system of introducing new technologies as photovoltaics and heat pumps in combination with strong energy conservation measures. A number of energy system scenarios are prepared based on technical simulations for single-family houses carried out by the University of Aalborg.

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Authors: Münster, M. (Intern), Morthorst, P. E. (Intern), Birkl, C. (Intern)
Number of pages: 35
Publication date: 2011

Publication information
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Original language: English
Main Research Area: Technical/natural sciences
Energy systems analysis
Electronic versions:
Assessment of building integrated.pdf

Relations
Projects:
Assessment of Building Integrated Energy Supply and Energy Saving Schemes on a National Level in Denmark
Source: orbit
Source-ID: 312641
Publication: Research › Report – Annual report year: 2011

Challenges when Performing Economic Optimization of Waste Treatment

New investments in waste treatment facilities are needed due to a number of factors including continuously increasing waste amounts, political demands for efficient utilization of the waste resources in terms of recycling or energy production, and decommissioning of existing waste treatment facilities due to age and stricter environmental regulation. Optimization models can assist in ensuring that these investment strategies will be economically feasible. Various economic optimization models for waste treatment have been developed which focus on different parameters. Models focusing on transport are one example but models focusing on energy production have also been developed as well as models which take into account the plants economies of scale, environmental impact, material recovery and social costs. Finally, models combining different criteria for selection of waste treatment methods in multi criteria analysis have been developed.
A thorough updated review of the existing models is presented and the main challenges and the crucial parameters to take into account when assessing the economic performance of waste treatment alternatives are identified. The review article will assist both policy makers and model developers involved in assessing economic performance of waste treatment alternatives.

General information
State: Published
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Number of pages: 8
Publication date: 2011
Coherent Energy and Environmental System Analysis

This report presents a summary of results of the strategic research project “Coherent Energy and Environmental System Analysis” (CEESA) which was conducted in the period 2007-2011 and funded by the Danish Strategic Research Council together with the participating parties. The project was interdisciplinary and involved more than 20 researchers from 7 different university departments or research institutions in Denmark. Moreover, the project was supported by an international advisory panel. The results include further development and integration of existing tools and methodologies into coherent energy and environmental analysis tools as well as analyses of the design and implementation of future renewable energy systems. For practical reasons, the work has been carried out as an interaction between five work packages, and a number of reports, papers and tools have been reported separately from each part of the project. A list of the separate work package reports is given at the end of this foreword while a complete list of all papers and reports can be found at the end of the report as well as at the following website: www.ceesa.dk.

This report provides a summary of the results of the different project parts in a coherent way by presenting tools and methodologies as well as analyses of the design and implementation of renewable energy systems – including both energy and environmental aspects.

General information

State: Published
Organisations: Department of Civil Engineering, Section for Building Physics and Services, Residual Resource Engineering, Department of Environmental Engineering, Department of Electrical Engineering, Automation and Control, Electric Energy Systems, Department of Management Engineering, Systems Analysis, Energy Systems Analysis, Aalborg University, University of Southern Denmark, Pöyry Energy Consulting, Copenhagen Business School, University of Copenhagen
Number of pages: 93
Publication date: 2011

Publication information
Publisher: Department of Development and Planning, Aalborg University
Original language: Danish
Main Research Area: Technical/natural sciences
Electronic versions:
Coherent_energy.pdf

Bibliographical note
A strategic research project financed by The Danish Council for Strategic Research Programme Commission on Sustainable Energy and Environment

Relations
Projects:
Coherent Energy and Environmental System Analysis
New customer services
This chapter focuses on the challenge of motivating energy service customers to make best use of available smart technologies. This can be done through economic incentives, but also through information and education, regulation and reorganisation, and by improving services or customer comfort (Figure 37).

Optimization of use of waste in the future energy system
Alternative uses of waste for energy production become increasingly interesting when considered from two perspectives, that of waste management and the energy system perspective. This paper presents the results of an enquiry into the use of waste in a future energy system. The analysis was performed using the energy system analysis model, Balmorel. The study is focused on Germany and the Nordic countries and demonstrates the optimization of both investments and production within the energy systems. The results present cost optimization excluding taxation concerning the use of waste for energy production in Denmark in a 2025 scenario with 48% renewable energy. Investments in a range of waste conversion technologies are facilitated, including waste incineration, co-combustion with coal, anaerobic digestion, and gasification. The most economically feasible solutions are found to be incineration of mixed waste, anaerobic digestion of organic waste, and gasification of part of the potential RDF (refuse derived fuel) for CHP (combined heat and power) production, while the remaining part is co-combusted with coal. Co-combustion mainly takes place in new coal-fired power plants, allowing investments to increase in comparison with a situation where only investments in waste incineration are allowed.

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Transport Economics, Department of Transport, Danish Development Centre for District Heating
Authors: Münster, M. (Intern), Møller Andersen, F. (Intern), Meza, M. J. F. (Intern), Jensen, T. C. (Intern), Hofmeister, M. (Ekstern)
Number of pages: 86
Pages: 55-60
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
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1778(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Ris-R-1778(EN), Risø-R-1778
Electronic versions:
ris-r-1778.pdf
Source: orbit
Source-ID: 313850
Publication: Research - peer-review → Book chapter – Annual report year: 2011

General information
State: Published
Authors: Münster, M. (Intern), Meibom, P. (Intern)
Pages: 1612-1622
Publication date: 2011
Main Research Area: Technical/natural sciences

Publication information
Journal: Energy
Volume: 36
Issue number: 3
ISSN (Print): 0360-5442
Ratings:
- BFI (2017): BFI-level 2
- Web of Science (2017): Indexed Yes
- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 5.17 SJR 1.999 SNIP 1.798
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 2.276 SNIP 2.046 CiteScore 5.03
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 2.647 SNIP 2.63 CiteScore 5.7
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 2.54 SNIP 2.593 CiteScore 5.02
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 2
- Scopus rating (2012): SJR 1.998 SNIP 2.25 CiteScore 4.25
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 1.609 SNIP 2.043 CiteScore 4
- ISI indexed (2011): ISI indexed yes
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 2
- Scopus rating (2010): SJR 1.814 SNIP 2.725
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 2
- Scopus rating (2009): SJR 1.729 SNIP 2.313
- Web of Science (2009): Indexed yes
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 1.106 SNIP 1.444
- Scopus rating (2007): SJR 0.913 SNIP 1.481
- Web of Science (2007): Indexed yes
- Scopus rating (2006): SJR 0.875 SNIP 1.306
- Web of Science (2006): Indexed yes
- Scopus rating (2005): SJR 0.965 SNIP 1.203
- Web of Science (2005): Indexed yes
- Scopus rating (2004): SJR 0.711 SNIP 1.115
- Scopus rating (2003): SJR 1.093 SNIP 1.496
- Scopus rating (2002): SJR 0.952 SNIP 1.287
- Scopus rating (2001): SJR 1.091 SNIP 1.078
- Web of Science (2001): Indexed yes
- Scopus rating (2000): SJR 0.82 SNIP 0.992
- Web of Science (2000): Indexed yes
- Scopus rating (1999): SJR 0.632 SNIP 0.659

Original language: English

Intelligent energy systems

DOIs:
10.1016/j.energy.2010.12.070

Relations
Projects:
Optimization of use of waste in the future energy system
Comparing Waste-to-Energy technologies by applying energy system analysis

Even when policies of waste prevention, re-use and recycling are prioritised a fraction of waste will still be left which can be used for energy recovery. This article asks the question: How to utilise waste for energy in the best way seen from an energy system perspective? Eight different Waste-to-Energy technologies are compared with a focus on fuel efficiency, CO2 reductions and costs. The comparison is carried out by conducting detailed energy system analyses of the present as well as a potential future Danish energy system with a large share of combined heat and power as well as wind power. The study shows potential of using waste for the production of transport fuels. Biogas and thermal gasification technologies are hence interesting alternatives to waste incineration and it is recommended to support the use of biogas based on manure and organic waste. It is also recommended to support research into gasification of waste without the addition of coal and biomass. Together the two solutions may contribute to alternate use of one third of the waste which is currently incinerated. The remaining fractions should still be incinerated with priority to combined heat and power plants with high electric efficiency.
Long-term affected energy production of waste to energy technologies identified by use of energy system analysis

Affected energy production is often decisive for the outcome of consequential life-cycle assessments when comparing the potential environmental impact of products or services. Affected energy production is however difficult to determine. In this article the future long-term affected energy production is identified by use of energy system analysis. The focus is on different uses of waste for energy production. The Waste-to-Energy technologies analysed include co-combustion of coal and waste, anaerobic digestion and thermal gasification. The analysis is based on optimization of both investments and production of electricity, district heating and bio-fuel in a future possible energy system in 2025 in the countries of the Northern European electricity market (Denmark, Norway, Sweden, Finland and Germany). Scenarios with different CO2 quota costs are analysed. It is demonstrated that the waste incineration continues to treat the largest amount of waste. Investments in new waste incineration capacity may, however, be superseded by investments in new Waste-to-Energy technologies, particularly those utilising sorted fractions such as organic waste and refuse derived fuel. The changed use of waste proves to always affect a combination of technologies. What is affected varies among the different Waste-to-Energy technologies and is furthermore dependent on the CO2 quota costs and on the geographical scope. The necessity for investments in flexibility measures varies with the different technologies such as storage of heat and waste as well as expansion of district heating networks. Finally, inflexible technologies such as nuclear power plants are shown to be affected.

General information
State: Published
Authors: Münster, M. (Intern), Meibom, P. (Intern)
Pages: 2510-2519
Publication date: 2010
Main Research Area: Technical/natural sciences

Publication information
Journal: Waste Management
Volume: 30
Issue number: 12
ISSN (Print): 0956-053X
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4 SJR 1.354 SNIP 2.044
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.739 SNIP 2.256 CiteScore 4.33
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.777 SNIP 2.482 CiteScore 3.43
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.822 SNIP 2.435 CiteScore 3.39
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.611 SNIP 2.184 CiteScore 2.91
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.698 SNIP 2.085 CiteScore 2.99
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.555 SNIP 1.78
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.502 SNIP 1.899
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.378 SNIP 2.13
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.035 SNIP 1.767
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.046 SNIP 1.749
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.059 SNIP 1.65
Scopus rating (2004): SJR 1.289 SNIP 1.939
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.847 SNIP 1.269
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.561 SNIP 0.874
Scopus rating (2001): SJR 0.456 SNIP 0.696
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.271 SNIP 0.451
Scopus rating (1999): SJR 0.262 SNIP 0.479
Original language: English
Energy systems analysis, Systems analysis
DOIs:
10.1016/j.wasman.2010.04.015

Relations
Projects:
Long-term affected energy production of waste to energy technologies identified by use of energy system analysis
Source: orbit
Source-ID: 262638
Publication: Research - peer-review › Journal article – Annual report year: 2010

Nye energiteknologier. Forskning, udvikling og demonstration: Baggrundsrapport til Klimakommissionen

General information
State: Published
Authors: Jørgensen, B. H. (Intern), Münster, M. (Intern)
Number of pages: 103
Publication date: 2010

Publication information
This report was commissioned by the Danish Climate Commission in 2009 to analyse how research, development and demonstration (RD&D) on sustainable energy technologies can contribute to make Denmark independent on fossil energy by 2050. It focuses on the RD&D investments needed as well as adequate framework conditions for Danish knowledge production and diffusion within this field. First part focuses on the general aspects related to knowledge production and the challenges related to research. Energy technologies are categorized and recent attempt to optimize Danish efforts are addressed, including RD&D prioritisation, public-private partnerships and international RD&D cooperation. Part two describes the development and organisation of the Danish public RD&D activities, including benchmark with other countries. The national energy RD&D programmes and their contribution to the knowledge value chain are described as well as the coordination and alignment efforts. Part Three illustrates three national innovation systems for highly different technologies – wind, fuel cells and intelligent energy systems. Finally, six recommendations are put forward: to make a national strategic energy technology plan; to enforce the coordination and synergy between national RD&D programmes; to strengthen social science research related to the transition to a sustainable energy system; to increase public RD&D expenditure to at least 0.1% of GDP per year; to strengthen international RD&D cooperation; and to make a comprehensive analysis of the capacity and competence needs for the energy sector. The authors were assisted by a reference group with participation from the Danish Energy Authority, the Danish Research and Innovation Agency, the TSO energinet.dk and the Climate Commission secretariat. The report conclusions and recommendations are solely the responsibility of the authors.

**General information**

State: Published
Authors: Jørgensen, B. H. (Intern), Münster, M. (Intern)
Number of pages: 104
Publication date: 2010
Energy System Analysis of Waste-to-Energy technologies

Alternative uses of waste for energy production becomes increasingly interesting both from a waste management perspective - to deal with increasing waste amounts while reducing the amount of waste deposited at landfills – and from an energy system perspective - to improve the flexibility of the energy system in order to increase the share of renewable energy and reduce greenhouse gas emissions. The focus of this PhD thesis is the analysis of the optimal use of waste for energy production in Denmark, now and in the future. The object of analysis is waste which is not reused or recycled, but can be used for energy production. Different Waste-to-Energy technologies are analysed through energy system analysis of the current Danish energy system with 13-14% renewable energy, as well as possible future Danish energy systems with 43% (2025) and 100% renewable energy (2050), respectively. The technologies include combustion, thermal gasification, anaerobic digestion, fermentation, and transesterification technologies producing electricity, heat, or transport fuel. The influences on and from the surrounding countries Norway, Sweden, Finland and Germany are included in some of the analyses. The analyses are performed in two Danish energy models: the EnergyPLAN model developed at Aalborg University and the Balmorel model developed at the former TSO, ElkraftSystem. A set of important aspects related to the modelling of waste and Waste-to-Energy technologies have been identified, and both models have been developed and improved in this respect in the course of the PhD project.

Given the assumptions applied, an optimal use of waste in the current and future Danish energy systems is mainly for combined heat and power (CHP) production. It is assessed as feasible to sort out 4% of the mixed combustible waste as a wet organic waste fraction and 19% as refuse derived fuel (RDF) consisting of paper, plastic, and waste wood. The following combination of Waste-to-Energy technologies is found to be optimal:
1) Incineration for CHP of the main amount of waste (77% of total) with the highest possible electricity and heat efficiencies.
2) Biogas production from the full potential of organic household waste and manure, assuming that untreated manure is available equal to 5% of the current untreated potential and that a treatment price of 3 EUR/GJ can be obtained for organic waste. The biogas should be used for CHP or transport fuel, depending on the CO2 quota costs and declared goal (reduced costs or reduced CO2 emissions).
3) Thermal gasification of RDF for CHP combined with co-combustion of the remaining RDF with coal in new coal-fired power plants, if reduced CO2 emissions are not the main goal. This is under the assumptions that the new coal-fired plants would, to a large extent, be built anyway; that the efficiencies of the waste incineration plants do not decrease due to a decreased heating value of the mixed waste used for incineration, and RDF is available for free. Affected or “marginal” energy production has been identified as input to life cycle assessments. The main conclusion in this respect is that the affected energy production always consists of a combination of energy technologies, which can be identified by the use of energy system analysis. Which technologies are affected depends on the time perspective (shortterm or long-term), the energy system analysed, the area analysed (Denmark or Nordic and German electricity markets), as well as on assumptions regarding capacities, efficiencies, costs, and prices. When modelling Denmark along with its surrounding countries and including investments as part of the optimisation, technologies located outside Denmark are affected by the changed uses of waste in Denmark. Furthermore, not only flexible technologies, such as coal-fired power plants, which are capable of reacting to short-term changes in demand, are affected, but also inflexible technologies, such as nuclear power.

General information
Energy Systems Analysis of Waste to Energy Technologies by use of EnergyPLAN

Even when policies of waste prevention, re-use and recycling are prioritised, a fraction of waste will still be left which can be used for energy recovery. This report asks the question: How to utilise waste for energy in the best way seen from an energy system perspective? Eight different Waste-to-Energy technologies are compared with a focus on fuel efficiency, CO2 reductions and costs. The comparison is made by conducting detailed energy system analyses of the present system as well as a potential future Danish energy system with a large share of combined heat and power and wind power. The study shows the potential of using waste for the production of transport fuels such as upgraded biogas and petrol made from syngas. Biogas and thermal gasification technologies are interesting alternatives to waste incineration and it is recommended to support the use of biogas based on manure and organic waste. It is also recommended to support research into gasification of waste without the addition of coal and biomass. Together, the two solutions may contribute to an alternate use of one third of the waste which is currently incinerated. The remaining fractions should still be incinerated with priority given to combined heat and power plants with high electrical efficiencies.
Importance of Flexible Use of Waste for Energy for the National Energy System

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy
Authors: Münster, M. (Intern), Meibom, P. (Intern)
Number of pages: 19
Publication date: 2009

Host publication information
Title of host publication: Proceedings (cd-rom)
Place of publication: Cagliari (IT)
Publisher: CISA, Environmental Sanitary Engineering Centre
Main Research Area: Technical/natural sciences
Conference: 12th International Waste Management and Landfill Symposium, Cagliari, Italy, 05/10/2009 - 05/10/2009
Climate and energy systems, Energy systems analysis
Electronic versions:
Importance_Sardinia_090701.pdf
Links:
http://www.sardiniasymposium.it/sardinia2009/

Relations
Projects:
Importance of Flexible Use of Waste for Energy for the National Energy System
Source: orbit
Source-ID: 254017
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

Uncertainties related to the identification of the marginal energy technology in consequential life cycle assessments
When performing life cycle assessment (LCA) assumptions regarding the energy use are often decisive for the outcome. In this paper, current approaches of identifying marginal electricity and heat technologies for consequential LCAs are challenged. The identification of marginal energy technologies is examined from three angles: The marginal electricity technology is identified in Danish historical and potential future energy systems. The methods of identifying and using marginal electricity and heat technologies in key LCA studies are analysed. Finally, the differences in applying energy system analysis and assuming one marginal technology are illustrated, using waste incineration with energy substitution as a case. The main problem with the current approach is the use of one single marginal technology. It is recommended to use fundamentally different affected technologies and identify these in several possible and fundamentally different future scenarios. If possible, the affected technologies should also be identified based on energy system analyses considering the technical characteristics of the technologies involved. Some results in this paper may be applicable to other affected technologies than energy.

General information
State: Published
Organisations: Energy Systems Analysis, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Residual Resource Engineering, Department of Environmental Engineering, Aalborg University
Authors: Mathiesen, B. (Ekstern), Münster, M. (Intern), Fruergaard, T. (Intern)
Pages: 1331-1338
Publication date: 2009
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Cleaner Production
Volume: 17
Issue number: 15
ISSN (Print): 0959-6526
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.83 SJR 1.615 SNIP 2.382
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.609 SNIP 2.383 CiteScore 5.57
This paper presents a comparative energy system analysis of different technologies utilising organic waste for heat and power production as well as for transport. Technologies included in the analysis are second-generation biofuel production, gasification, fermentation (biogas production) and improved incineration. It is argued that energy technologies should be assessed together with the energy systems of which they form part and influence. The energy system analysis is performed by use of the EnergyPLAN model, which simulates the Danish energy system hour by hour. The analysis shows that most fossil fuel is saved by gasifying the organic waste and using the syngas for combined heat and power production. On the other hand, least greenhouse gases are emitted if biogas is produced from organic waste and used for...
combined heat and power production; assuming that the use of organic waste for biogas production facilitates the use of manure for biogas production. The technology which provides the cheapest CO2 reduction is gasification of waste with the subsequent conversion of gas into transport fuel.

General information
State: Published
Organisations: Aalborg University
Authors: Münster, M. (Intern), Lund, H. (Ekstern)
Pages: 636-644
Publication date: 2009
Main Research Area: Technical/natural sciences

Publication information
Journal: Energy
Volume: 34
Issue number: 5
ISSN (Print): 0360-5442
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.17 SJR 1.999 SNIP 1.798
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.276 SNIP 2.046 CiteScore 5.03
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.647 SNIP 2.63 CiteScore 5.7
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.54 SNIP 2.593 CiteScore 5.02
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.998 SNIP 2.25 CiteScore 4.25
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.609 SNIP 2.043 CiteScore 4
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.814 SNIP 2.725
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.729 SNIP 2.313
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.106 SNIP 1.444
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.913 SNIP 1.481
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.875 SNIP 1.306
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.965 SNIP 1.203
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.711 SNIP 1.115
Scopus rating (2003): SJR 1.093 SNIP 1.496
Modelling Waste-To-Energy Technologies In National Energy Systems

This paper presents a broad range of new Waste-to-Energy technologies which hold the potential for increasing the flexibility of national energy systems and the quantity of renewable energy produced in the systems. The technologies make it possible to store energy and increase the amount of renewable energy in the transport sector by producing biofuels. Moreover, they can increase the energy efficiency of waste used for energy production when compared to incineration. Two factors are particularly important to take into account when modelling the flexibility of Waste-to-Energy plants: the regulating possibilities of the plants and the possibility to store input and output fuels.
Host publication information
Title of host publication: Applied Simulation and Modelling
Publisher: ACTA Press
Editor: De Felice, F.
Main Research Area: Technical/natural sciences

Relations
Projects:
Modelling Waste-To-Energy Technologies In National Energy Systems
Source: dtu
Source-ID: u::4142
Publication: Research - peer-review › Book chapter – Annual report year: 2008

Varmepumper og Lavtemperatur-fjernvarme - Rapportering fra to workshops

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Systems Analysis Division, Energy Systems Analysis, Department of Management Engineering, Department of Civil Engineering, Section for Building Physics and Services, Teknologisk Institut, Thisted Varmevejr, Københavns Energi A/S, Svensk Fjernvarmeforening, Aalborg University, Fredericia Fjernvarme, EA Energianalyse A/S
Authors: Morthorst, P. E. (ed.) (Intern), Münster, M. (Intern), Pedersen, S. (Ekstern), Toft Hansen, L. (Ekstern), Marcus-Møller, C. (Ekstern), Larsson, E. (Ekstern), Blarke, M. (Ekstern), Meibom, P. (Intern), Larsen, H. V. (Intern), Hellmers, C. (Ekstern), Svendsen, S. (Intern), Werling, J. (Ekstern)
Number of pages: 47
Publication date: 2008

Publication information
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Original language: Danish
Main Research Area: Technical/natural sciences
Electronic versions:
Varmepumper_og_lavtemperatur.pdf

Bibliographical note
Forfattere: Poul Erik Morthorst og Marie Münster
Source: dtu
Source-ID: u::4136
Publication: Research › Report – 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
Authors: Grohnheit, P. E. (Intern), Karlsson, K. B. (Intern), Münster, M. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences
Electronic versions:
2008_153.pdf
Source: orbit
Source-ID: 231878
Publication: 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
Authors: Grohnheit, P. E. (Intern), Karlsson, K. B. (Intern), Münster, M. (Intern)
Bliver fjernvarmen en del af fremtidens energisystem?

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Systems Analysis Division, Energy Systems Analysis
Authors: Münster, M. (Intern), Hansen, L. P. (Intern)
Pages: 12-14
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Fjernvarmen
Issue number: 2
ISSN (Print): 0106-6234
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Original language: Danish
Electronic versions:
BliverFjernvarmenEnDelAfFremtidensEnergisystem.pdf

Bibliographical note
Populær artikel i FJERNVARMEN no. 2 2007
Marie Münster og Lise-Lotte Pade Hansen

Relations
Projects:
Bliver fjernvarmen en del af fremtidens energisystem?
Source: dtu
Source-ID: u::4145
Publication: Communication › Journal article – Annual report year: 2007

Energy system analyses of the marginal energy technology in life cycle assessments

General information
State: Published
Organisations: Department of Environmental Engineering
Authors: Mathiesen, B. (Ekstern), Münster, M. (Intern), Fruergaard, T. (Intern)
Pages: 15-18
Publication date: 2007
Main Research Area: Technical/natural sciences

Host publication information
Title of host publication: SETAC Europe 14th Case Studies Symposium - Extended abstracts. LCA of energy - Energy in LCA, 3-4 December 2007, Göteborg, Sweden
Publisher: SETAC
Main Research Area: Technical/natural sciences
Conference: SETAC Europe 14th Case Studies Symposium - Extended abstracts. LCA of energy - Energy in LCA, 3-4 December 2007, Göteborg, Sweden, 01/01/2007
Production of bio-fuel, electricity and heat through gasification of waste

Up to 20% of the electricity in Denmark comes from wind power and the goal is to increase the percentage. This puts great demand on the flexibility of the remaining energy system. In Denmark 27% of the waste produced in 2004 was incinerated mainly in CHP plants delivering power as base load. In order to increase the flexibility of the system a project is analysed, were waste is gasified and then used either for heat and power production or for bio-fuel production depending on the price of electricity. A national energy system analysis of the technology is carried out using the deterministic simulation model, EnergyPLAN, developed at Aalborg University.

The analysis shows that the gasification project shows great potential with regards to saving fossil fuel when the syngas for combined heat and power production and it provides the cheapest CO2 reduction when used for transport fuel, compared to other waste handling alternatives.

General information
State: Published
Organisations: Technical University of Denmark
Authors: Münster, M. (Intern)
Number of pages: 3
Publication date: 2007

Host publication information
Title of host publication: Proceedings
Main Research Area: Technical/natural sciences

Relations
Projects:
Production of bio-fuel, electricity and heat through gasification of waste
Source: dtu
Source-ID: u::4141
Publication: Research › Article in proceedings – Annual report year: 2007

Use of Waste for Heat, Electricity and Transport – Challenges when performing Energy System Analysis

This paper presents a comparative energy system analysis of different technologies utilizing organic waste for heat, power and fuel for transport production. Technologies included in the analysis are 2nd generation biofuel production, gasification, fermentation (biogas production) and improved incineration. It is argued that it is important to assess energy technologies together with the energy systems of which they form part and influence. The energy system analysis is performed using the EnergyPLAN model, which simulates the Danish energy system hour by hour. The analysis shows that most fuel is saved by gasifying the organic waste and using the syngas for combined heat and power production. On the other hand least greenhouse gases are emitted if biogas is produced from organic waste and used for combined heat and power production. The technology which provides the cheapest CO2 reduction is gasification of waste with subsequent conversion of the gas into transport fuel.

General information
State: Published
Organisations: Technical University of Denmark
Authors: Münster, M. (Intern)
Number of pages: 17
Publication date: 2007

Host publication information
Title of host publication: Proceedings
Main Research Area: Technical/natural sciences
Electronic versions:

Relations
Projects:
Production of bio-fuel, electricity and heat through gasification of waste
Source: dtu
Source-ID: u::4141
Publication: Research › Article in proceedings – Annual report year: 2007
Fremtidens Fjernvarme - Litteraturstudie

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Systems Analysis Division, Energy Systems Analysis
Authors: Münster, M. (Intern), Hansen, L. P. (Intern)
Number of pages: 29
Publication date: 2006

Publication information
Publisher: Forskningscenter Risø, Afdelingen for Systemanalyse
Main Research Area: Technical/natural sciences
Electronic versions:
Fremtidens_Fjernvarme_061127_til_pdf.pdf

Bibliographical note
Marie Münster, Lise-Lotte Pade Hansen

Relations
Projects:
Fremtidens Fjernvarme - Litteraturstudie
Source: du
Source-ID: u::4135
Publication: Research › Report – Annual report year: 2006

Maabjerg BioEnergy - a biogas project with numerous advantages
Unfortunately, from the same area water is discharged directly into a number of large wetlands consisting of sandy and highly permeable soil, which the EU has designated habitat areas. Altogether this causes a problem with surplus nutrients (phosphorous and nitrogen, in particular) which get washed out to creeks and the underground water. Particularly in order to adhere to recent legislation concerning utilisation of nitrogen, it is necessary for the farmers to increase the availability and exploitation of the nitrogen.

General information
State: Published
Organisations: Technical University of Denmark, Rambøll Danmark A/S
Authors: Münster, M. (Intern), Juul-Kristensen, B. (Ekstern)
Number of pages: 4
Publication date: 2005
Main Research Area: Technical/natural sciences

Publication information
Journal: Danish Board of District Heating -- News from DBDH
Issue number: 2
Original language: English
Electronic versions:
Maabjerg_BioEnergy.pdf
Source: du
Source-ID: u::4181
Publication: Communication › Journal article – Annual report year: 2005

Vedvarende energi i Norden - Et sammenlignende studie af de nordiske landes vedvarende energipolitikker og virkemidler

General information
State: Published
Organisations: Rambøll Danmark A/S, Technical University of Denmark
Authors: Hansen, E. (Ekstern), Münster, M. (Intern), Boldt, J. (Ekstern)
Kom godt i gang med livscyklustankegangen!

General information
State: Published
Organisations: Aalborg University, Technical University of Denmark
Authors: Remmen, A. (Ekstern), Münster, M. (Intern)
Number of pages: 56
Publication date: 2002

Electronic versions:
Kom_godt_i_gang_med_livscyklustankegangen.pdf

Bibliographical note
Miljønyt nr. 65, 2002
Arne Remmen og Marie Münster
Source: dtu
Source-ID: u::4147
Publication: Communication › Book – Annual report year: 2002

Projects:

Modelling of the gas system as an integrated part of the future energy system
Department of Management Engineering
Period: 15/09/2016 → 14/09/2019
Number of participants: 3
Phd Student:
Pedersen, Rasmus Bo Bramstoft (Intern)
Supervisor:
Ravn, Hans V. (Intern)
Main Supervisor:
Münster, Marie (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD
FutureGas
An effective and economically efficient integration of gas, renewable based gas as well as natural gas, requires three issues to be fulfilled: 1) In an overall system context, gas should be integrated where the system benefits are highest; 2) Gas should be used optimally, that is where the economic net gains are largest taking into account the cost of possible conditioning; and 3) If needed then conditioning of gas should be carried out in the most cost-efficient way. Conditioning here refers to cleaning, upgrading, mixing and/or pressurising to achieve a desired gas quality. Of course, this reflects that the high value areas for gas utilization depend on how gas enters into the energy system. Thus, to find the most efficient and cost-competitive solutions it is crucial in an energy system perspective to address the need, possibilities and cost-effectiveness for conditioning gas to be injected into the gas grids and how different gases most economically and efficiently can be utilized. A central part of this project is therefore to model both renewables injected to the gas grid as well as alternative uses of gas in an overall system context.

The aim of the FutureGas project is twofold:
1) In an energy system context to facilitate the integration of the gas system with the power system, the district heating system and the transportation sector taking into account possible synergies. Despite the huge amounts of energy being transported through the gas grid, it is currently only loosely coupled to the rest of the energy system mainly through use of gas in CHP plants.
2) To facilitate a cost-efficient uptake of renewable gases, hereby in the longer term substituting natural gas and fossil fuels. A number of renewable gases exist, differing in their possible application in the energy system and in their costs and requirements for conditioning. The best and most cost-effective solutions for utilising and conditioning a variety of renewable gases depend on the development of the entire energy system.

In FutureGas these two issues will be looked into with regard to energy system integration, gas conditioning and, finally, economic/policy perspectives. To enable this, a novel modelling framework will be developed comprising the total energy system with an international market dimension and handling risk and uncertainty. Moreover, this new framework will facilitate combined modelling of the physical energy systems with markets and policy instruments. Thus this project has a truly interdisciplinary nature. The major part of the research will be concentrated on addressing the gas supply side on conditioning of RE gases and operation of the gas grid in combination with the demand side (CHP, industry and transport) all in a system context, on developing the gas dimension in advanced system modelling and, finally, on identifying the required policy and market structures for a successful implementation.

Thus the overall vision of FutureGas is to pave the way for an effective and cost-efficient transition to an energy system independent of fossil fuels, ensuring a strong integration of gas with the entire energy system, an economically optimal conversion to renewable gases substituting natural gas in the long run and good access to gas markets for a wide range of gas producing technologies.

Department of Management Engineering
Systems Analysis
Energy Systems Analysis
Management Science
Operations Research
Energy Economics and Regulation
Novo Nordisk Foundation Center for Biosustainability
Aarhus University
Chalmers University of Technology
University of Exeter
Florence School of Regulation - European University Institute
Delft University of Technology
Danish Gas Technology Centre A/S
HMN Naturgas
Danish Energy Association
Dansk Gas Distribution
NGF Nature Energy
RAM-lose
EA Energy Analysis A/S
Hydrogen Denmark
PlanEnergi
Energinet.dk
Danish Energy Agency
Period: 01/02/2016 → 31/01/2020
Number of participants: 10
Project ID: 82524
Number of related Ph.D. students: 4
Project participant:
Pisinger, David (Intern)
Wiese, Frauke (Intern)
Sadegh, Negar (Intern)
Aryal, Nabin (Intern)
Phd Student:
Nielsen, Lise Skovsgaard (Intern)
Pedersen, Rasmus Bo Bramstoft (Intern)
Amirkhizi, Tara Sabbagh (Intern)
Buchholz, Stefanie (Intern)
Project Manager, academic:
Morthorst, Poul Erik (Intern)
Münster, Marie (Intern)

Financing sources
Source: Other public support (public)
Name of research programme: Innovation Fund Denmark

Modelling, Transport Fuels and Future Scenarios for the Danish Energy System
Department of Management Engineering
Period: 01/07/2015 → 30/06/2018
Number of participants: 3
Phd Student:
Venturini, Giada (Intern)
Supervisor:
Gallachóir, Brian Pádraig Ó (Ekstern)
Main Supervisor:
Münster, Marie (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet

Relations
Activities:
69th Semi-Annual ETSAP Meeting
Project: PhD

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.

Department of Management Engineering
Systems Analysis
Vienna University of Technology
Fraunhofer Institute for Systems and Innovation Research ISI
Institute for Resource Efficiency and Energy Strategies - IREES GmbH
OÖ Energiesparverband
ee energy engineers GmbH
Gate 21
Instituto de Engenharia Mecanica e Gestao Industrial - INEGI
Agentia Pentru Management ul Energienei si Protectia Mediului Brasov - ABMEE
City of Litoměrice
Energy Cities, the European association of local authorities in energy transition
Period: 01/03/2015 → 01/10/2017
Number of participants: 6
Acronym: progRESsHEAT
Project participant:
Karlsson, Kenneth Bernard (Intern)
Münster, Marie (Intern)
Petrovic, Stefan (Intern)
Kitzing, Lena (Intern)
Ben Amer-Allam, Sara (Intern)
Salvucci, Raffaele (Intern)

Relations
Related projects:
Geographical representations of renewable energy Systems
Strategic research centre for 4th Generation district heating technologies and systems

Modelling use of biomass and waste in future energy systems
Department of Management Engineering
Period: 01/12/2014 → 01/06/2018
Number of participants: 4
Phd Student:
Pizarro Alonso, Amalia Rosa (Intern)
Supervisor:
Pisinger, David (Intern)
Ravn, Hans V. (Intern)
Main Supervisor:
Münster, Marie (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

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.

Department of Management Engineering
Systems Analysis
DTU Climate Centre
Energy Systems Analysis
Roskilde Universitet
University College Cork
Danish Energy Agency
Danish Energy Association
CONCITO
Danish Board of Technology

E4SMA
Period: 01/01/2014 → 01/01/2019
Number of participants: 4
Transport, Energy, TIMES-DK, Renewable energy, Electric vehicles
Acronym: COMETS
Number of related Ph.D. students: 3
Project participant:
Münster, Marie (Intern)
Pizarro Alonso, Amalia Rosa (Intern)
Project Manager, organisational:
Karlsson, Kenneth Bernard (Intern)
Project Manager, academic:
Gregg, Jay Sterling (Intern)
Project

Value Chain Optimisation in Biogas Production
Department of Management Engineering
Period: 15/08/2013 → 27/09/2017
Number of participants: 4
Phd Student:
Jensen, Ida Græsted (Intern)
Supervisor:
Juul, Nina (Intern)
Pisinger, David (Intern)
Main Supervisor:
Münster, Marie (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.

Relations
Activities:
Modelling of Biogas Supply Chains
Project: PhD

Optimization of value chains for biogas production in Denmark
DSF
Department of Management Engineering
Systems Analysis
Energy Systems Analysis
Management Science
University of Southern Denmark
University of Copenhagen
Aarhus University

Knowledge Centre for Agriculture
Period: 01/03/2013 → 31/12/2016
Number of participants: 6
Acronym: BioChain
Number of related Ph.D. students: 2
Project participant:
Klinge Jacobsen, Henrik (Intern)
Juul, Nina (Intern)
Münster, Marie (Intern)
Pisinger, David (Intern)
Nielsen, Lise Skovsgaard (Intern)
Jensen, Ida Græstes (Intern)

Relations
Activities:
Modelling of Biogas Supply Chains
Project

City Development, Urban Systems and the Impacts of Climate Extremes
Department of Management Engineering
Period: 15/12/2012 → 19/01/2017
Number of participants: 7
Phd Student:
Kaspersen, Per Skougaard (Intern)
Supervisor:
Ambjerg-Nielsen, Karsten (Intern)
Madsen, Henrik (Intern)
Main Supervisor:
Drews, Martin (Intern)
Examiner:
Münster, Marie (Intern)
Kreibich, Heidi (Ekstern)
Sandholt, Inge (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut/centerfinansieret
Project: PhD

Modelling and optimisation of novel polygeneration plants
Department of Mechanical Engineering
Period: 01/09/2012 → 19/01/2017
Number of participants: 7
Phd Student:
Lythcke-Jørgensen, Christoffer Ernst (Intern)
Supervisor:
Clausen, Lasse Røngaard (Intern)
Münster, Marie (Intern)
Main Supervisor:
Haglind, Fredrik (Intern)
Examiner:
Morthorst, Poul Erik (Intern)
Ahlgren, Erik (Intern)
Pistikopoulos, Efstratios N. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut, samfinansiering

Relations
Publications:
Design and optimization of flexible multi-generation systems
Project: PhD

Strategic research centre for 4th Generation district heating technologies and systems
Department of Civil Engineering
Section for Building Physics and Services
Department of Management Engineering
Aalborg University
University of Southern Denmark
Chalmers University of Technology
Halmstad University
Linnaeus University
Tsinghua University
University of Zagreb
Period: 01/01/2012 → 31/12/2017
Number of participants: 4
Fjernvarme
Acronym: 4DH
Project participant:
Svendsen, Svend (Intern)
Karlsson, Kenneth Bernard (Intern)
Münster, Marie (Intern)
Li, Hongwei (Intern)

Financing sources
Source: Public research council
Name of research programme: Det Strategiske Forskningsråd
Amount: 37,000,000.00 Danish Kroner
Project

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.

Department of Management Engineering
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.

Department of Management Engineering

Energy Systems Analysis

DTU Climate Centre

NIFU Nordic Institute for Studies in Innovation, Research and Education

Lund University

VTT - Technical Research Centre of Finland

Period: 01/08/2011 → 30/09/2016
Number of participants: 6

Energy system

Acronym: TOPNEST
Project ID: 82124/ 1200272
Project participant:
Karlsson, Kenneth Bernard (Intern)
Münster, Marie (Intern)
Skytte, Klaus (Intern)
Anderson, Tessa Kate (Intern)
Gregg, Jay Sterling (Intern)

Project Manager, organisational:
Bolwig, Simon (Intern)

Financing sources

Source: Forsk. Andre offentlige og private - Udenlandske
Name of research programme: Nordic Energy Research
Amount: 440,000.00 Danish Kroner
The Optimal Treatment of Waste

Affald udgør i dag en betydelig del af energiproduktionen i Danmark. Andelen forventes at stige i fremtiden, hvis affaldsmængderne stiger og energiudnyttelsen fortsat bliver bedre. For at kunne integrere blandt andet vindkraft er det afgørende, at det øvrige energisystem kan agere fleksibelt, hvilket især er en udfordring med affald. Øget liberalisering ændrer derudover rammerne for affaldshåndtering og dens regulering. For at kunne sikre opnåelse af mål vedrørende fx andelen af affald der genanvendes under de ændrede forhold, er det nødvendigt at udvikle nye beslutningsstøtteværktøjer til både affaldsforbrændingsanlæg og myndigheder. I dette projekt udvikles 4 typer værktøjer til planlægning af affaldshåndtering med fokus på både genanvendelse og energiproduktion. Til brug for affaldsforbrændingsanlæggene udvikles i samarbejde med et større affaldsforbrændingsanlæg to nye beslutningsstøtteværktøjer: en model der optimerer affaldshåndtering set fra et økonomisk perspektiv og en model der vurderer affaldshåndtering fra et miljø- og ressourcemæssigt perspektiv. Begge modeller opskaleres til at håndtere nationale analyser til brug for nationale myndigheder. Dette kombineres med videreudvikling af to øvrige nationale modeller: en økonometrisk model til fremskrivning af affaldsmængder (FRIDA) og en energi system analyse model (Balmorel). Dette vil gøre det muligt at analysere og vurdere betydningen af at anvende affald til energiproduktion i fremtidens energi system.

Department of Management Engineering
Aalborg University
University of Southern Denmark
KTH - Royal Institute of Technology
Lund University
RAM-lose
Holmboe Consult
Swedish Environmental Research Institute

Amagerforbrænding
Renonord
Period: 01/01/2011 → 31/12/2014
Number of participants: 4
Affald
Acronym: TOPWASTE
Project ID: 1200268/ 82156
Project participant: Møller Andersen, Frits (Intern)
Juul, Nina (Intern)
Larsen, Helge V. (Intern)
Project Manager, organisational: Münster, Marie (Intern)

Financing sources
Source: Public research council
Name of research programme: Det Strategiske Forskningsråd
Amount: 14,999,724.00 Danish Kroner

Relations
Publications:
Challenges when Performing Economic Optimization of Waste Treatment
Alternatives for Future Waste Management in Denmark

Nye energi teknologier : Forskning, udvikling og demonstration
This report was commissioned by the Danish Climate Commission in 2009 to analyse how research, development and demonstration (RD&D) on sustainable energy technologies can contribute to make Denmark independent on fossil energy by 2050. It focuses on the RD&D investments needed as well as adequate framework conditions for Danish knowledge production and diffusion within this field. Report available on http://www.risoe.dtu.dk/Knowledge_base/publications/Reports/ris-r-1760.aspx
Risø National Laboratory for Sustainable Energy
Period: 01/10/2009 → 01/06/2010
Number of participants: 2
Energy technology innovation. Strategic energy technology policies
Project participant:
Münster, Marie (Intern)
Jørgensen, Birte Holst (Intern)

Financial sources
Source: Indtægtsdækket virksomhed UK 90
Name of research programme: Indtægtsdækket virksomhed UK 90
Amount: 300,000.00 Danish Kroner

Integration af avindkraft (Integration of Wind power)
Department of Management Engineering
Period: 01/09/2009 → 27/08/2013
Number of participants: 8
Phd Student:
Hedegaard, Karsten (Intern)
Supervisor:
Detlevsen, Nina (Ekstern)
Meibom, Peter (Intern)
Münster, Marie (Intern)
Main Supervisor:
Morthorst, Poul Erik (Intern)
Examiner:
Klinge Jacobsen, Henrik (Intern)
Ahlgren, Erik (Intern)
Østergaard, Poul Alberg (Ekstern)

Financial sources
Source: Internal funding (public)
Name of research programme: Institut/centerfinansieret
Project: PhD

Socio-Economic and Energy Systems Analysis of Micro Fuel Cells (SEE-µFC)
Department of Management Engineering
Risø National Laboratory for Sustainable Energy
EDF R&D
Simbiente
Period: 01/10/2008 → 01/10/2010
Number of participants: 5
Brændselsceller, Individuel energiforsyning
Acronym: FC4Home
Project ID: 1200242
Project participant:
Münster, Marie (Intern)
Pade, Lise-Lotte (Intern)
Ropenus, Stephanie (Intern)
Schröder, Sascha Thorsten (Intern)
Project Manager, organisational:
Morthorst, Poul Erik (Intern)

Financial sources
Source: Forskningsprojekter - Miljø- og Energiministeriet
Name of research programme: Energiteknologisk Udviklings- og Demonstrationsprogram (EUDP)
Amount: 290,000.00 Danish Kroner

**Relations**

**Publications:**
- Support Schemes and Ownership Structures
- Analyses of models for promotion schemes and ownership arrangements
- Fuel cell based micro-combined heat and power under different policy frameworks - An economic analysis
- Policy schemes, operational strategies and system integration of residential co-generation fuel cells
- System analysis on operational strategy
- National Cases combining promotion scheme, ownership structure and operational strategy for Denmark, France and Portugal

**Efektiv fjernvarme i fremtidens energisystem**

Department of Management Engineering
EA Energianalyse A/S
RAM-lose
Dansk Fjernvarme Forening
CTR I/S
Fredericia Fjernvarme
Skanderborg Fjernvarme
Københavns Energi A/S

Period: 01/04/2007 → 15/12/2008
Number of participants: 4

**Fjernvarme**
Project ID: 1200222
Project participant:
Münster, Marie (Intern)
Karlsson, Kenneth Bernard (Intern)
Larsen, Helge V. (Intern)

Project Manager, organisational:
Morthorst, Poul Erik (Intern)

**Financing sources**
Source: Forsk. EU - Rammeprogram
Name of research programme: EFP Energistyrelsen
Amount: 362,067.60 Danish Kroner

**Relations**

**Publications:**
- Efektiv fjernvarme i fremtidens energisystem
- The role of district heating in the future Danish energy system

**Coherent Energy and Environmental System Analysis**
Gennem internationale aftaler har Danmark forpligtet sig til at reducere CO2-udledningerne samt til at øge anvendelsen af vedvarende energikilder. Regeringens Energi Strategi 2025 identificerer tre store udfordringer for energisektoren: 1) Reduktion i CO2-udledninger, 2) forsyningssikkerhed og mindsket afhængighed af olie fra politisk ustabile regioner, samt 3) øget konkurrencekraft for danske virksomheder på et globaliseret energimarked. Dette projekt forkaiser på alle ovennævnte udfordringer.

Department of Management Engineering
Department of Environmental Engineering
Department of Electrical Engineering
Electric Energy Systems
Aalborg University
University of Southern Denmark
Royal Veterinary and Agricultural University
Copenhagen Business School
Anvendt KommunalForskning
DONG Energy A/S
Period: 01/01/2007 → 31/12/2010
Number of participants: 6
Acronym: CEESA
Project ID: 1200211
Project participant:
Münster, Marie (Intern)
Møller Andersen, Frits (Intern)
Pade, Lise-Lotte (Intern)
Astrup, Thomas (Intern)
Østergaard, Jacob (Intern)
Project Manager, organisational:
Morthorst, Poul Erik (Intern)

Financing sources
Source: Public research council
Name of research programme: Forsknings og innovationsstyrelsen – programkomiteen for energi og miljø
Amount: 14,958,866.00 Danish Kroner

Relations
Publications:
Danish Wind Power Export and Cost
Coherent Energy and Environmental System Analysis
Control Architecture Modeling for Future Power Systems
Project

EFP07 – Bygningsintegreret Energiforsyning
Department of Management Engineering
Statens Byggeforskningsinstitut
Aalborg University
Danish Technological Institute
Period: 01/01/2007 → 01/09/2008
Number of participants: 2
Individuel energiforsyning
Acronym: BIEF
Project ID: 1200218
Project participant:
Münster, Marie (Intern)
Project Manager, organisational:
Morthorst, Poul Erik (Intern)

Financing sources
Source: Forskningsprojekter - Miljø- og Energiministeriet
Name of research programme: Energiforskningsprogrammet (EFP)
Amount: 2,345,000.00 Danish Kroner
Relations
Publications:
Assessment of Building Integrated Energy Supply and Energy Saving Schemes on a National Level in Denmark
Project

Rapport om fremtidens fjernvarme
Rapporten afdækker 2 problemstillinger:
1. Hvad findes der af eksisterende rapporter, udredninger og analyser, der belyser fjernvarmes rolle i fremtidige energisystemer og/eller fremtidige perspektivvise fjernvarmeløsninger.
2. Hvilke rapporter, udredninger og analyser om fjernvarme er der behov for som indspil til scenarier og overvejelser om fremtidens energiforsyning med henblik på at sikre, at de mulige gevinst, som fjernvarme kan bidrage med, ikke overses på bekostning af mindre hensigtsmæssige (energieffektive) energisystemer.

Department of Management Engineering
Number of participants: 2
Fjernvarme
Project ID: 1200207
Project participant:
Münster, Marie (Intern)
Pade, Lise-Lotte (Intern)

Financing sources
Source: Forsk. Private danske - Andre
Name of research programme: Dansk Fjernvarme F&U
Amount: 50,000.00 Danish Kroner

Relations
Publications:
Fremtidens Fjernvarme - Litteraturstudie
Bliver fjernvarmen en del af fremtidens energisystem?
Project

Environmentally sustainable utilization of waste resources for energy production
Department of Environmental Engineering
Department of Management Engineering
Residual Resource Engineering
Aalborg University
Elsam A/S
Period: 01/01/2006 → 31/12/2008
Number of participants: 3
Acronym: ENSUWE
Project ID: 1200196
Project participant:
Münster, Marie (Intern)
Fruergaard, Thilde (Intern)
Project Manager, organisational:
Astrup, Thomas (Intern)

Financing sources
Source: Public research council
Name of research programme: Forskningstyrelsen – programkomiteen for energi og miljø
Amount: 4,700,000.00 Danish Kroner

Relations
Publications:
Importance of Flexible Use of Waste for Energy for the National Energy System
Energy Systems Analysis of Waste to Energy Technologies by use of EnergyPLAN
Long-term affected energy production of waste to energy technologies identified by use of energy system analysis
Optimization of use of waste in the future energy system
Uncertainties related to the identification of the marginal energy technology in consequential life cycle assessments
Energy system analyses of the marginal energy technology in life cycle assessments
Waste-to-energy technologies in TIMES models
Use of Waste for Heat, Electricity and Transport – Challenges when performing Energy System Analysis
Production of bio-fuel, electricity and heat through gasification of waste
Modelling Waste-To-Energy Technologies In National Energy Systems
Affaldsteknologiers CO₂-fortrængning i energisystemet
Comparing Waste-to-Energy technologies by applying energy system analysis
Use of waste for heat, electricity and transport—Challenges when performing energy system analysis

Project

Activities:

**Economic Optimization of Waste Treatment and Energy Production in Denmark**
Period: 30 Sep 2013 → 4 Oct 2013
Marie Münster (Lecturer)
Department of Management Engineering

Description
Conference proceeding

Related event

**14th International Waste Management and Landfill Symposium**
30/09/2013 → 04/10/2013
Sardinia, Italy
Activity: Talks and presentations › Conference presentations