Energy Futures Øresund: Bridging the Gaps to a Greener Tomorrow

Andronache, Veronica; Baumbach, Lea; Czunyi, Sarah; Figel, Tom; Firpo, Filipe; Hayes, Jordan; Kiryushin, Peter; Lopez, Mauricio; Mill, Adrian; Ross, Ian; Sipka, Stefan; Luka, Charlotte; Smith, Mary Ellen; Strenchock, Logan; Su, Meiling; Witter, Allison; Xin, Ouyang

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Veronica Andronache, Lea Baumbach, Sarah Czunyi, Tom Figel, Filipe Firpo, Jordan Hayes, Peter Kiryushin, Mauricio Lopez, Adrian Mill, Ian Ross, Stefan Sipka, Charlotte Luka, Mary Ellen Smith, Logan Strenchock, Meiling Su, Allison Witter & Ouyang Xin

Research Co-ordinators:
Thomas Lindhqvist &
Mikael Backman

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"Energy Futures Øresund" is the final report on the energy system of the Øresund Region. It comprises a regional overview of the current state and trends of selected energy systems, discussions on potential technological solutions to overcome barriers and an analysis of the energy strategy of the island Bornholm.

The report forms the basis for further strategic energy planning of Energi Öresund, a European Union INTERREG IV A funded cross-border co-operation between Danish and Swedish municipalities, energy companies and universities across the Øresund region. It is the outcome of intensive course work on Strategic Environmental Development at the International Institute for Industrial Environmental Economics (IIIEE) at Lund University in Sweden. The authors are students in MESPOM, an Erasmus Mundus funded Masters programme, and come from 11 countries.

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INTRODUCTION

The Øresund Region, Its Energy System Context & Key Terminology

By Adrian Mill

Scandinavia has been at the forefront of European energy policy development for many years. The trans-regional Øresund region in particular is considered a showcase for the implementation of renewable energy systems [1]. This is exemplified in the "Energi Øresund" project, a European Union (EU) part-financed regional forum for strategic energy planning commenced in 2011.

Energi Øresund is an INTERREG IV A project based on the cooperation of 16 partners, including municipalities in both Denmark and Sweden. Additional partners of the project include academic institutes and energy companies. The goal of the Energi Øresund project is to provide strategic energy planning across national boundaries, from both the supply and demand side. The project is divided into five activity areas [2]:

1. Integration of renewable energies into the existing energy portfolio, and connected needs for energy storage;
2. Energy demand of new urban areas and more efficient energy use;
3. Creation of a cooperation platform and improved communication between actors from both sides of the Sound;
4. Administration and coordination between connected projects; and
5. Networking and internal and external communication.

The project is one of several focussed on energy transition in the Øresund region. As a strategic forum, the project brings together numerous academic, governmental and industry partners from both Denmark and Sweden.

This report aims to provide policy-makers with an analysis of the energy policy and systems in the Øresund region. To achieve this, the report is structured in three chapters. The first provides an overview of the key energy policies at various governance levels that influence the Øresund region (Chapter 1). The second chapter analyses some of the key barriers identified by Energi Øresund project partners that impede progress towards energy goals (Chapter 2). Finally, a case study of the energy system of Bornholm is examined (Chapter 3). The remainder of this introduction will overview the region and its energy context, and discuss some of the key terminology used.

Regional Overview

The Energi Øresund Project focusses on a number of key regions and municipalities in the Øresund region, located in the south of Scandinavia (see figure on following page). For the purposes of this paper, a number of national, regional and municipal distinctions are made to highlight partners in the Energi Øresund project that are the focus of this report. The **Øresund Region** contains parts of **Denmark** and **Sweden**. Within Denmark is the **Sjælland Region** (English: Zealand), where the capital **Copenhagen** and adjacent municipalities **Ballerup** and **Albertslund** are located. These municipalities, in addition to several others

Constituent administrative boundaries within the Øresund region examined in this paper.

(including **Bornholm** to the east), make up the **Region Hovedstaden** (English: Danish Capital Region). Across the strait in Sweden lies the **Skåne Region** (English: Scania). Swedish municipalities involved in the project include **Malmö**, **Lund** and **Kristianstad**.

The Øresund region has a long history involving both Denmark and Sweden. The Strait of Øresund was used by Denmark as a source of taxation in the Middle Ages, and the Skåne region passed from Danish to Swedish control in 1658. Discussion regarding the construction of a connection across the Strait of Øresund began around 1872, but it was not until June 2000 that the current link between Denmark and Sweden was opened [3]. The Øresund Bridge itself is indicative of the level of policy co-ordination between the two countries. Diverse policy instruments at various governance levels have been used to further integration and regional development in the Øresund Region [3]. In this context, the Energi Øresund project emerges as a key driver in the alignment of energy policy in the region.

Energy Context

Energy policy in the Øresund region is driven at four main levels: European, regional, national and municipal. At the European level, the EU has issued numerous directives, regulations and communications that pertain to energy, with commitments to reduce gas emissions by 20%, increase renewable energy share to 20% and improve energy efficiency by 20% [4]. More influential on the Øresund region is the EU-funded INTERREG programme, aimed at facilitating closer integration and co-operation across borders in the region with a focus on sustainable development. The Energi Øresund project falls under Priority 3 of the programme.

From the regional perspective, a committee (Öresundskomiteen) was put in place in 1993 as a political initiative between Copenhagen and Malmö in order to promote the interests of the region. The main energy focus relates to sustainable development and biofuels. Other regional entities (i.e. Sjælland and Skåne) have climate strategies and energy commitments.

The Energi Øresund project is another forum used by regional actors to discuss energy issues.

National energy policy in both Denmark and Sweden has long been directed towards reducing reliance on fossil fuels and increasing the share of renewables. However, the two countries have differed in their approach to achieving these aims, with Sweden focussing on hydro-power and biogas, and Denmark developing a world-leading wind industry [5]. Both have committed to cuts to CO_2 emissions, although recently Denmark declared its ambition to achieve a 40% reduction by 2020 [6].

At the municipal level, many cities in the region have individual strategies or visions on climate change and energy. Key areas of focus include upgrading energy efficiency in residential/commercial sectors and reducing emissions from transportation and power generation [7].

Key Terminology

One of the interesting issues arising from the regional energy discourse is that there is some disparity between many of the terms used, with multiple terms being used to describe similar or related goals. This is especially pronounced between the various levels of governance. For example, one municipality aims to become 'carbon neutral' [7], while the EU's objective is 'decarbonisation' [4]. Potential outcomes of this lack of harmonisation are misunderstandings between stakeholders or, in the worst case, failure to meet prescribed goals.

The issue is further compounded by a lack of clear definitions for some of the terms employed. For example, is peat – a key biomass used for heating in Scandinavia – considered a renewable resource or a fossil fuel? Moreover, terms such as 'sustainable development' or 'green growth', while related to energy issues and featuring prominently in many strategies, are typically ill-defined by design and relate to multiple aspects of the environmental debate rather than energy issues specifically (i.e. sustainability [8]). This discussion is therefore limited to terminology referring directly to energy or a proxy, such as reduced emissions.

The table below provides a summary of some common energy terms used in the Øresund region, categorised according to the key issue that each term addresses. The first is the source of energy. Renewable (or 'green') sources of energy do not require the extraction of natural resources beyond that needed to construct

Common energy terms used administratively in the Øresund region.

	TERM	MEANING / GOAL
Energy	Renewable energy / Green energy	Energy derived from renewable sources that are naturally replenished e.g. wind, tidal, geothermal, hydro, solar, biofuels.
Energy	Bioenergy	Energy produced using fuels derived from recently living biological sources e.g. wood, straw, manure etc.
Fuel	Fossil-fuel free / Fossil-independent	No net use of fossil-derived fuels (e.g. diesel or natural gas from non-renewable natural resources) within a defined area.
Fuel	Biofuel / Renewable fuel	Fuels derived from renewable biomass sources, such as biogas and biodiesel.
CO_2 / Carbon / GHG	CO_2 neutral / Carbon-neutral / Carbon-free	On balance there is no net contribution to overall CO_2 / carbon emissions within a defined area; may include carbon offsetting.
CO_2 / Carbon / GHG	Decarbonisation	Removal and recovery of carbon (CO_2 or elemental carbon) prior to combustion, or of CO_2 post-combustion at power stations [9].
CO_2 / Carbon / GHG	Reduce carbon emissions / Greenhouse gases (GHG)	Reach a set target reduction (usually percentage) in CO_2 or GHG emissions in a set timeframe.

infrastructure, and are continually replenished by nature. These terms imply that such sources are more environmentally friendly than non-renewables. However, renewable sources include biofuels such as biodiesel, that while less polluting that conventional diesel, can contribute to health and climate change impacts as a result of combustion processes [10].

The second category is the type of fuel. The objective of several governance levels is to become fossil-fuel free (or independent) within a fixed time period. This is usually to be achieved using a combination of energy efficiency, renewable energy and biofuels [11]. Although the percentage of expenditure allocated to each goal is determined through a top-down approach, each governance level has a different idea of how the budget should be partitioned. In the Øresund region, biofuels receive a large portion of this money. Biofuels are useful in that they can be used in existing technology without major redesign. Nonetheless, growing concern is directed toward biofuel production impacts on the environment (i.e. land clearance) and food security (through displacement of food crops) [11].

The final category is the volume of carbon emitted. The relationship between fossil fuel combustion for energy purposes with the physics and chemistry of atmospheric CO_2 content and energy absorption is well established in the literature [12]. A similar trend is evident with 'greenhouse gas' (GHG) emissions. Carbon and GHGs are therefore used as a proxy measurement for energy use. The use of these terms by the various Øresund stakeholders is extremely varied, and sometimes used interchangeably. The difficulty arises from the measurement of carbon and the validity of achieving carbon-based goals. Not only can emissions be measured using different indicators at national to municipal level, but there are different methods and approaches to measurement (i.e. CO_2 vs CO_2 equivalent) that can make comparison difficult [13]. Additionally, the validity of using carbon reductions is questionable as it encourages spurious carbon-offsetting practices [14] and does not guarantee the adoption of environmentally or socially-accepted energy sources (i.e. nuclear power is carbon-free).

Biogas production facility located near Kristianstad, Skåne.

Towards a Common Vision

Despite a number of challenges relating to terminology, goal-setting and measurement, the overall renewable energy outlook in the Øresund region is positive. Clearly, the number of terms used in the discourse and the variety of stakeholders involved reflect a desire on the part of the authorities to address climate change and broader environmental issues. This is to be applauded. However, the disparity in terminology indicates there is a need for improved co-ordination between stakeholders. This is one of the key goals of the Energi Øresund project. To better understand the issue of co-ordination, the remainder of this Chapter of the report provides a more in-depth overview of each of the energy systems in question.

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THE ØRESUND REGION

Transboundary Co-operation Between Sweden & Denmark

By Lea Baumbach & Logan Strenchock

The energy sector is not strongly institutionalised in a legal sense within the Øresund Region. This is due to the highly voluntary nature of the trans-boundary cooperation initiatives in their current form. Therefore the following chapter will give an overview of the cooperation between political, academic and private actors to define what exactly the Øresund Region is, and give insights into existing projects related to the areas of Energy and Energy Efficiency.

Geography & Institutions

The geographic region on both sides of the Sound between the east of Denmark and the south of Sweden is referred to as the Øresund Region. Since the inauguration of the Øresund Bridge in the year 2000, attempts have been made to create a transnational, multi-centre metropolitan region between the City of Copenhagen and the cities of Malmö and Lund [1]. One of the results of these efforts is the so called Øresund Committee, a platform with representatives from different political levels of the Danish Region of Sjaelland and the Swedish Region of Skåne [2]. In the committee the following bodies are represented: On the Danish side these are the Capital Region Copenhagen, the Region Sjaelland, the Municipalities of Copenhagen, Frederiksberg and Bornholm, the Municipal Councils of Hovedstaden and Sjaelland; on the Swedish side these are the Region of Skåne the Cities of Malmö, Helsingborg, and Landskrona, and the Municipality of Lund [2].

The Øresund Committee sets the agenda of the cooperation and it is understood as the "embassy" of the region in front of the national parliaments [3]. The recently published Development Strategy of the committee provides a vision of the trans-boundary cooperation until the year 2020. This strategy has four focus areas; the first of which is knowledge and innovation [2]. This includes cooperative research and education projects in future energy technologies. Additionally, 420 Danish private and public enterprises formed a "CleanTechCluster" with the goal to promote technological innovations and exchange expertise in the field of wind-energy, bio-energy, electricity grids, e-mobility, ecological building technologies, fuel cells and resource efficiency [4]. An extension of this cluster towards the Swedish side is envisioned by the Øresund Committee without a concrete timeline [3].

Projects

Besides these soft (non-legally binding) cooperations, a number of research projects with concrete goals have evolved throughout the last years. These are mainly based on academic cooperation between universities on both sides of the Sound, but increasingly include partners from the private and public sector as well.

Biorefinery Øresund

Biorefinery Øresund is a research project carried out by Lund University (LU), Lund Technical University (LTH) and the Technical University of Denmark (DTU). Running from 2010 until 2013, the project aims at establishing a pilot-scale biorefinery for fuels, materials and chemicals and creating a broad foundation for the development and implementation of biorefinery in the Øresund Region. This should be achieved through the establishment of regional cooperation of all relevant actors from the academic, governmental and industrial sector. The project is expected to cover total fuel life-cycle from research over raw material extraction to production [5].

Wind in Øresund

The INTERREG IV A funded Wind in Øresund program was initiated in 2008 to promote sustainable growth in the region by expanding its capacity to produce and transmit wind based energy [5]. LTH was appointed to serve as the research facilitator for the project, in cooperation with the DTU. The initiative was developed with expectations that experts within each University's faculty would be utilised as advisors in exploring the mechanisms for regional wind energy integration [5]. Specific curriculum development within related engineering and mathematics departments in the respective universities has been coordinated to improve the area's international image as an innovative centre for wind energy research [5].

Research at DTU and LTH has focused on statistical models of projected production capacity within the region, along with new methods of adjusting consumption techniques to manage cyclical fluctuations in production [6]. The RISØ wind energy research centre at DTU operates SYSLAB, a full scale experimental wind park on the island of Bornholm; which contributes wind power integration and safety strategies [5]. The aim of the research is not only to demonstrate technologies for the integration of wind power and Smart Grid technology, but also to uncover policy instruments that will be essential for reaching the area's full alternative energy potential [6].

Øresund Ecomobility

The Øresund Ecomobility project is an additional INTERREG IV A funded project which deals with reducing greenhouse gas emissions associated with transport activities, with a total project budget near EUR 4 million [5]. The three year study initiated in 2009 has been working to create a unified network of scholars and professionals from the DTU, Malmö University, Copenhagen Business School, Copenhagen Municipality, Roskilde University, and Øresunds Logistics [5].

The collaboration is seeking to utilise experts within the fields of personal and goods transportation, supply chain management, logistics, and biofuels to contrive transition mechanisms which will result in less carbon-intensive modes of transport [7]. The overall project has been built with three stages: Thematic Knowledge Exchange Network development, Knowledge and Innovation Centre Development, along with Competence Building and Knowledge Sharing [5]. Three "knowledge exchange" networks were developed within stage one of the project. These include: Green Logistics Hub, City Transport and Logistics, and Biofuels and Energy Systems [7]. After each individual network accumulate knowledge on a relevant subject, it is expected to be dispersed within the whole system by means of the Knowledge and Innovation Centre. The role of the final stage of the project is to build competence; most often by means of publications, websites, conferences, and courses for professionals and students [7].

E-mission

The project E-mission in the Øresund Region aims at influencing as many citizens, public and private companies in the region as possible to replace their petrol or diesel powered cars with electric vehicles in order to promote a sustainable economic growth in the region. The project runs from 2010 to 2013 and has the subgoals to provide the necessary infrastructure for electric charging on both sides of the Øresund Bridge. These improvements will be accompanied by the release of an electronic map of the charging points and a broad information campaign. A summit for the mayors from the Øresund Region will help to reach the commitment of important political actors in the region. A rally with six different models of electric vehicles took place in September 2011 [8] and achieved broad media coverage.

The project is lead by Copenhagen municipality in cooperation with the municipalities of Malmö and Helsingborg, Region Skåne and Öresundskraft AB. Further municipal authorities, energy companies and organisations from the region are supporting the project. 50% of the project costs are covered by the European INTERREG IV A [5].

Sustainable Building Processes

INTERREG IV A is also funding a research project that focuses on enhancing cooperation within the building construction sector across the Øresund Region [5]. The project has been initiated after observing the similarities in construction demands within Sweden and Denmark [5]. Cross border cooperation in developing sustainable construction strategies has not been common practice due to varying standards, traditions, and governing bodies [9]. The research project aims at developing strategies to remove the barriers that limit cooperation which would otherwise be encouraged by common geography and proximity. The approach has aimed to deliver a uniform understanding of sustainable construction represented by harmonised building codes and manuals within Sweden and Denmark [9].

The partnering institutions in this three year study include: Lund University, The Technical University of Denmark, The Royal Danish Academy of Fine Arts, Danish School of Architecture, and the Danish Building Research Institute [5]. It is expected that the assimilation of building standards within the Øresund Region will lead to a more uniform adoption of sustainable building principles and best practices in new constructions, along with expanded market opportunities for both Danish and Swedish construction stakeholders [9].

Øresund Sound Settlement

The INTERREG IV A funded Øresund Sound Settlements project has been initiated to observe and respond to the transformations taking place within Sweden and Denmark, as both nations strive to develop their own best practices for a “sustainable society” [5]. The project has goals of designing strategies that streamline the process for implementing nationally developed sustainable development policy at the regional and local levels. The project has highlighted the need to follow a holistic approach when attempting to transition to more sustainable societies, as opposed to the common practice of implementing isolated technical solutions with limited big picture perspective [5]. The project’s lead partner is Lund University’s Department of Design Sciences, and the partnership also includes faculty from other universities in Sweden and Denmark along with multiple communes within each nation.

The Sound Settlement program concept has identified urban districts and housing structures as areas of focus within the Øresund Region. The project aims to bring together Danish and Swedish researchers, in cooperation with politicians, city officials and urban planners to take a more innovative look at the decision making process behind dwellings, work places, service centres, and recreational spaces within communities [5]. The project also highlighted the importance of including citizens and local businesses within the decision making process for developing sustainable urban areas, as the local level input provided by such actors is necessary to contrive effective development strategies. Researchers hope to pass along knowledge regarding energy and water saving, sustainable building and transportation infrastructure and planning, along with green economic growth strategies. Aspirations are not to transfer knowledge along, but also to encourage dialogues between stakeholders that will encourage collaborations towards common sustainable development goals.

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Photo taken by Malte Knaust on August 28 2010.

ENERGY IN DENMARK

Transitions for the Future

By Mary Ellen Smith, Allison Witter & Ouyang Xin

Denmark covers an area of 43 075 km^2, is home to 5.52 million people, and is characterised by a generally flat landscape with numerous islands. While the Danish economy grew 78% from 1980 to 2009, energy consumption remained more or less constant and carbon emissions dropped during the same period [1, 2]. This can be attributed to a focus within Danish energy policy on reduced fossil fuel use, the development of renewable energy technologies, and energy efficiency improvements [3].

The Danish Energy System

During the late 1970s and early 1980s, imported fossil fuels constituted more than 90% of Denmark's total energy consumption. District heating, electricity generation, and energy supply to households, transportation, and industry depended upon these fossil fuels, which were for the most part imported [4].

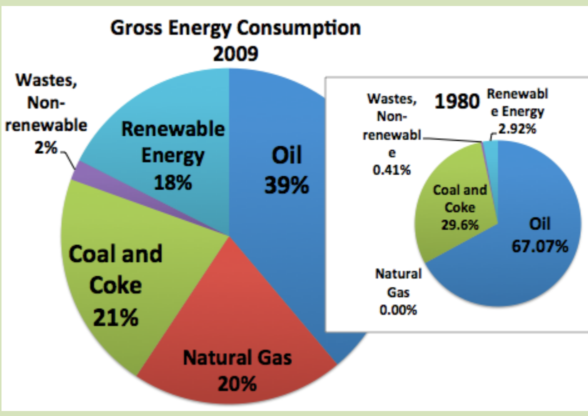
This reliance on external non-renewable energy sources drove Danish policy makers and companies to focus on improved energy savings, the development of alternative energy sources, and overall energy self-sufficiency [5]. As a result, the gross energy consumption mix in Denmark has changed markedly: by 2009, oil consumption was 42% lower than in 1980, natural gas had increased its share of consumption to 20.47%, and renewable energy had grown from 2.92% to 17.53% of total consumption [4].

Energy Self-Sufficiency

Denmark has been net energy self-sufficient since 1997. This is in part attributable to the discovery of oil and gas fields in the North Sea and to the subsequent shift from importing to exporting oil and gas [6]. However, most national oil and gas fields are declining: the average rate of decline at giant oil fields is between six and seven percent annually. Although new fields continue to be discovered, it is possible that the amount found may not compensate for these fast declines [7].

Growth in Renewable Energy

In 2010, renewable energy had a 19% share in final energy consumption and accounted for 28% of electricity production [8]. Wind energy and biomass (wood, waste, straw, etc.) converted into fuel in combined heat and power (CHP)



Gross energy consumption in Denmark in 1980 and 2009 (Elaborated from [4]).

plants are major contributors in this regard. Total installed capacity for wind power, for example, has reached 3 752 Megawatts (MW), accounting for 1.9% of the world total installed capacity and comprising a 20% share in total electricity production [8]. According to Denmark's Energy Strategy for 2050, 30% of energy shall be provided by renewable energy by 2020 [9].

Improved Energy Efficiency

Danish energy policy has additionally focused on improving efficiency during both energy production and consumption. CHP plants have become widely established and have contributed to the expansion of district heating throughout the country, with the share of district heating from CHP increasing twofold from 1980 to 2010, from 39% to 80% [4]. Energy efficiency at CHP plants can be impressive, with one plant in Copenhagen demonstrating efficiency rates up to 90% [4]. In addition, there are voluntary agreements in place whereby Danish companies agreeing to channel investments into energy efficiency projects can receive a rebate from Green Taxes [9].

On the consumption end, Danish buildings are subject to stringent energy efficiency standards. As a result, buildings constructed in 2008 consume half as much energy per square metre as houses built before 1977 [9]. Energy labelling is required in buildings over 1 000 m^2 and inspections into unnecessary energy consumption may be utilised [9]. The Finance Act of 2009 additionally promotes energy efficiency in the public sector and sets targets for government buildings [9]. Houses for sale must include energy certificates, indicating energy status and recommendations for improvements. Labelling schemes for electrical appliances as well as public campaigns have also contributed to improved energy efficiency [4].

Danish Energy Policy: Commitments and Goals

In 2011, the Danish government published its Energy Strategy for 2050, which includes the following goals:

- Complete independence from fossil fuels by 2050;
- Ranking amongst the top three energy efficient OECD countries by 2020;
- Energy savings improvements of 85% (from 2010 levels) by energy companies by 2050;
- Lowering of national primary energy consumption levels for the 2008-2011 period to 4% lower than 2006 levels;
- Decreasing greenhouse gas (GHG) emissions by 30% (from 1990 levels) by 2020; and
- Powering the transportation sector with 10% renewable energy by 2020 [10].

The above policy goals stem from Denmark's ambitious national energy strategy as well as its commitments to various European Union (EU) and international targets. With the election of Helle Thorning-Schmidt and the Social Democrats in September 2011, there has been an additional focus on energy and climate targets within Danish national policy. Some provisions within the new common government policy include decreasing GHG emissions by 40% (from 1990 levels) by 2020 (a ten percent increase over the previous government's amount, stated above) and sourcing half of Denmark's energy from wind by 2020 [11].

Greenhouse Gas Emissions

Following ratification of EU Directive 2003/87/EC on GHG emissions trading, around 380 Danish production units partake in the carbon dioxide allowance-trading scheme [12]. Additionally, under the Kyoto Protocol, Denmark pledged to reduce GHG emissions by 21% between 2008-2012 [9]. The Agreement on Green Transport (January 2009) is a long-term plan to invest in green transport and reduce GHG emissions. Up to DKK 150 billion will be invested by 2020 in order to promote railway and sustainable transport development, as well as to develop road pricing [9]. Additionally, in 2008 Denmark established a Commission on Climate Change Policy, responsible for preparing proposals on how to become a fossil fuel independent nation [3].

Energy Security

Denmark's Renewable Energy Act fosters energy security in Denmark via continued growth of the renewable energy sector, through measures such as wind power subsidies, installation of offshore wind turbines, funding for community development of local wind power systems, and provision of discounted electricity for biogas plants. Overall, there will be an allocation of DKK 25 million for renewable energy technologies and DKK 30 million over a two-year period to encourage conversion from oil burners to heat pumps. The Energy Agreement of 2008 includes provisions to create a framework for using 40% of livestock manure by 2020 to meet energy goals [12].

Future Challenges

Some key challenges have been identified on the path to achieving Denmark's stated energy goals. In particular, shifting to an energy supply based on renewables presents supply security challenges. With ever decreasing production, Denmark is unlikely to be self-sufficient in gas and oil in 2018. As a result, the Danish government could lose a notable portion of its income and there may be impacts on the prices of renewable energy and other energy sources in the future. There is further concern that fossil supply sources will run short before fossil fuel independence is achieved. In addition, the incorporation of large amounts of fluctuating electricity produced from wind power into the energy system presents a huge technical challenge, while the availability of biomass and biofuels may become stressed [3]. Hopefully these and other challenges will be overcome so that Denmark may achieve the increasingly ambitious energy and climate goals set out by its previous and current government.

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SWEDEN'S ENERGY BALANCE

Current Trends and Guiding Policies

By Charlotte Luka & Veronica Andronache

Sweden is the largest Scandinavian country, with a population of approximately nine million people. Its temperature gradient varies significantly, with a temperate environment in the South that progresses to a subarctic climate in the North. This exerts a decisive influence on the country's population distribution, and thus the infrastructure put into place to meet the energy demands of its different regions.

Sweden's Energy Balance

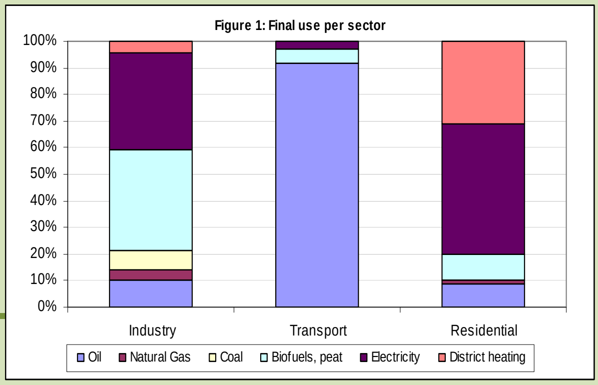
According to the Swedish Energy Agency [1], in 2009 the dominating energy sources were oil and nuclear energy, closely followed by hydropower and biofuels. The energy usage for 2009 accounted for a total of 376 TWh, with the residential and services sectors being responsible for the highest proportion of energy consumption (149 TWh or 39%), a large part of which was used for heating purposes. The second most significant consumer was the industry sector, accounting for about 36% of the total energy used, either directly or through providing power to processes such as pumps, compressors, etc. [1]. The figure below displays the use distribution of energy carriers per each sector, emphasising the dominance of oil, electricity and biofuels.

With over 44%, Sweden showed the highest level of renewable energy use in the EU in 2009. This was achieved through the implementation of a coherent and active energy policy over the past decades. Some of the main trends that shaped the Swedish energy landscape between 1970 and 2009 were identified by the Swedish Energy Agency as including:

- A significant decrease of over 47% in oil and oil products used, including a reduction of about 90% in the residential and services sectors;
- Electricity remaining the main energy carrier, with a net production increase of 126%, due to nuclear and hydropower development; and
- A 195% increase in the supply of biofuels, with biofuels now covering 38% of industry energy needs.

Energy Policies

In order to reach its ambitious climate change targets, Sweden's Government has enacted a series of policies concerning energy efficiency and the use of energy from renewable resources. In 2009, a Joint Climate and Energy Policy was approved, which united two previous bills in order to address these issues in an



Final energy use per sector [1]

integrative manner. The policy aims at increasing the share of energy coming from renewable resources, improving energy efficiency and reducing in greenhouse gas (GHG) emissions.

Furthermore, the Parliament has enacted changes to several national bills, in order to meet sustainability criteria provisioned in EU Directive No. 2009/28/EC, which promotes the use of energy from renewable resources. In particular, changes were instigated with regard to the Electricity Act, the Act Concerning Electricity Certificates, the Act Concerning Tax on Energy and the Natural Gas Act.

Concrete measures put into place in order to reach EU's targets include an Energy Efficiency Improvement Programme for energy-intensive industries and the Green Electricity Certificate system. The government further imposes taxes on electricity and fuels and on carbon dioxide and sulphur emissions, as well as a levy system on nitrogen oxide emissions.

Finally, Sweden actively participates in Joint Implementation projects and Clean Development Mechanisms as part of its commitment to continue its work under and beyond the Kyoto Protocol and the Marrakech Agreement. The total emission reductions under these programmes, together with Sweden's contribution to multilateral funds, such as the Copenhagen Green Climate Fund, reached 12-16 million tons of CO_2 equivalents [1].

Sweden's Energy Goals

Sweden's government has set itself a number of ambitious climate and energy targets for the future. By 2020, the government intends to:

- obtain half of Sweden's energy demands from renewable energy sources;
- achieve a 40% reduction in GHG emissions, as compared to 1990 levels, in those sectors not covered by the EU's Emission Trading System (ETS);
- reduce GHG emissions in sectors that are covered by the EU's ETS by 21% (in accordance with EU targets);
- use at least 10% of renewable energy in transport; and
- realise energy efficiency gains of 20% [2].

The government has come of up with three concrete action plans aimed at implementing these goals. Firstly, under the *action plan for renewable energy*, 50% of the energy used nationally must originate from renewable resources by 2020. Among others, the action plan provides for an improved electricity certificate system, a national planning framework for wind power, and ways to better connect renewable energy sources to the electricity grid [2].

Secondly, the "action plan for energy efficiency" aims to increase energy efficiency by 20%. This scheme involves investments of SEK 300 million per year from 2010 to 2014. Planned measures include improving local and regional energy initiatives, ameliorating advisory and information services, setting an example through sustainable public sector utilisation, supporting companies in reducing energy consumption through an "energy audit cheque" system, improving choice in energy efficient consumer products, and requiring individual hot water and electricity metering [2].

The third action plan involves the goal of creating a *fossil-fuel independent vehicle fleet*. The Swedish government hopes to render its fleet independent of fossil fuels by 2030. It aims to achieve this target by putting a price on GHG emissions by way of taxes, by encouraging investments in renewable fuels, as well as through the development of alternative technologies. Under this scheme, green cars will be exempt from vehicle taxes for five years and subsidies will be provided to filling station for renewable fuels [2].

Challenges to Sweden's Energy Goals

In the past, Sweden has been extremely efficient at meeting or even surpassing its energy targets and if it continues to implement its current policies with the same rigour, it is likely to achieve the transition to a sustainable energy society relatively smoothly [3].

Nevertheless, a number of challenges remain. In order to achieve the 40% reduction in GHG emissions, the production of carbon dioxide equivalents will have to be decreased by 20 million tonnes. Since 1990, only a fifth of the required reductions have been realised. The rest remains to be achieved over the next nine years. The Swedish government hopes to reach these goals through a mix of economic instruments, such as the existing carbon dioxide tax and green investments, as well as through the complete phasing out of fossil fuels for heating by 2020 [2].

The emission limits, under the EU's ETS may constitute a burden on Sweden's energy-intensive, export-oriented industries, such as iron and steel. The reason for this is that Sweden already has the lowest emissions coming from heat and electricity generation in the EU and therefore few opportunities exist to reduce emissions in export sectors which face global competition [4].

Sweden's focus on transport is commendable, as this sector constitutes four-fifths of all GHG emissions. While consumer habits in this sector may be difficult to alter, Sweden has been comparatively successful at promoting biogas vehicles both for private consumers and as part of the public fleet. In addition, a move from road to electric rail for both freight and passenger transport needs to be encouraged, in order to take advantage of the country's practically CO_2-free electricity generation [4].

The decision to massively increase the use of renewable energy implies increased exposure to variable power generation, such as solar and wind power [5]. Further investments into creating means of energy storage will therefore have to be made. Furthermore, plans to increase the use of bioenergy need to be evaluated carefully, as biomass constitutes a limited resource and it needs to be estimated where it can be employed most effectively. Importantly, Sweden needs to ensure that all biomass feedstock originates from sustainable sources [4].

A decision in 1980 to phase out nuclear energy was reversed in 2010, when provisional approval was given for the construction of a maximum of ten new nuclear power reactors, provided that each new build replaces an existing reactor [1]. The dangers inherent in nuclear power production, final waste disposal and the risk of accidents should be closely examined by the Swedish government, while bearing in mind that nuclear power constitutes a major enabling factor with regard to Sweden's ambitious GHG emission targets.

Finally, the Swedish Energy Agency notes that its energy goals may negatively impact on the aesthetic value of the country's "magnificent mountain landscape" and may deteriorate its lakes and watercourses. It furthermore acknowledges that, even if all its goals are implemented, an overall reduced climate impact will be difficult to achieve, due to the global nature of the climate problem [1].

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Windmill. Photo by Veronica Andronache, taken on 10 September 2011 in Copenhagen , Denmark.

ENERGY SYSTEM IN REGION HOVEDSTADEN

Current Status & Future Trends

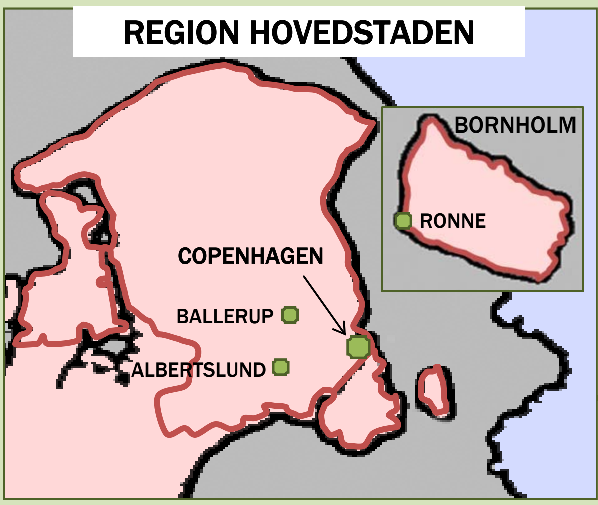
By Stefan Sipka

This section will comprise a presentation of the energy system of Region Hovedstaden (the Capital Region of Denmark). The analysis will include five subsections: general overview of Region Hovedstaden, energy supply and consumption, energy–related commitments, measures for meeting energy–related commitments, and identified energy challenges.

Overview of the Region

Region Hovedstaden is one of the five regional authorities in Denmark. It is located in the North-eastern area of the island of Zealand including the island of Bornholm (as shown in the map). The region's territorial extent is 2 561 km^2 including 29 municipalities. The total population of the region is 1.6 million [1].

Like other regional authorities the region's responsibility relates to its healthcare system, including a number of social institutions, and regional development. The responsibility regarding regional development includes the leadership in collaboration between the business community, the municipalities and the universities in order to reach the regional development goals of which one is a sustainable development [1].



Region Hovedstaden and the main towns of focus for this analysis. Inset: The island of Bornholm.

Energy Supply and Consumption

The energy consumption is based on electricity with a share of 34%, heat 59% and industrial processes 7%. The major share of energy is sourced from fossil fuels (Figure 1). The total annual electricity consumption is estimated to be 8 315 GWh. Electricity is supplied via the national energy grid owned by Energy Network to electricity companies and then sold to the consumers. The structure of energy supply regarding electricity is shown in Figures 2 and 3. Fossil fuels constitute a major part of supply with a significant share of coal. Renewable energy also contributes a share, with the largest part consisting of wind power. A minor part of nuclear energy is imported from Sweden. The total annual heat consumption is estimated to be 14 300 GWh for the area of 116 million m^2 equalling 123 kWh/m^2. Structure of energy supply regarding heat is shown in Figures 4 and 5. Heat is mainly produced from fossil fuels with a major contribution from natural gas.

Share of renewable energy is lower when compared with electricity and it is mainly based on biomass and waste [2].

District heating comprises 61% of the total heating. Furthermore 84% of district heating is based on Combined Heat and Power (CHP). The result is that less than half of energy fuel is actually needed for direct heat production in boilers [2].

Commitments

Energy is recognised by the region as an air-polluting and climate-related issue. Although other energy issues, such as energy scarcity and rising energy prices, are also identified, energy policies are nevertheless primarily recognised as a part of the Region's air-pollution and climate-related commitments [3,4,5,6,].

The region is currently developing a climate strategy which should deliver more defined and detailed energy commitments. Currently available climate strategy synopsis is capable of providing basic information for an energy-related vision and targets [5].

The vision has been identified as follows: "In 2025 the metropolitan area should be recognised as the most energy-efficient and climate-prepared region in Denmark based on strong regional and inter-municipal cooperation, where innovative public-private partnerships contribute to green growth at the highest international standard" [5].

The climate strategy also identifies five major goals out of which two are directly energy-related: energy supply goal and energy efficiency goal [5].

The energy supply goal is to optimise resource use and decrease fossil fuel consumption. The identified target for this goal is to increase the share of renewable energy to 50% out of a total energy supply by 2025 [5]. This target should also be seen inside a context of a wider national target to achieve total independence of fossil fuels by 2050 [7].

The energy efficiency goal is to reduce energy consumption in buildings. Identified target for this goal is to increase energy efficiency in existing buildings by 25% until 2025 compared to 2011 [5].

Measures

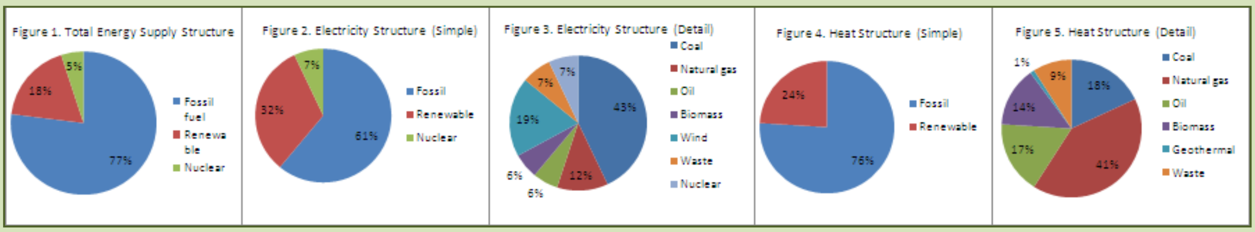
The climate strategy envisions three types of actions that could be taken in order to meet the stated goals:

- **Strategic regional ventures** between the Region and municipalities;
- **Common areas** – the voluntary participation in common platforms;
- **Recommendations** to the government, region, and municipalities which are to be accomplished by individual planning [5].

Furthermore, the climate strategy specific actions are further elaborated for each of the goals.

Energy Supply Goals

Under strategic regional venture type of action, a common strategic initiative is envisioned. The



Graphs of varying energy supply system [2].

Initiative further includes development of plans which should include regional and national stakeholders in order to implement renewable energy solutions. More specifically, it is envisioned that such strategic planning will be done in coordination with the Danish Energy Agency and Local Government Denmark, which is a voluntary organisation consisting of Danish municipalities [5].

Under "Common areas", it is envisioned that the Region and municipalities develop common cross-cutting energy initiatives. An outcome would be that the region and municipalities will be able to acquire usually costly and complex tools and knowledge for implementing energy planning [5].

Recommendations show a great variety and basically relate to the use of the region's and municipalities' administrative, economic and informative instruments in order to stimulate the conversion to renewable energy [5].

Energy Efficiency Goals

The climate strategy identifies only "common area" and "recommendations" for energy efficiency goals.

Under "common area", it asserts that common tools, models and initiatives could be established. Furthermore, it is suggested that mentioned projects should include development of energy retrofit packages, energy efficiency packages and energy service companies (ESCOs) [5].

Recommendations are related to different administrative, economic and informative instruments to be used in order to improve energy efficiency in buildings, especially in those concerning healthcare [5].

Challenges

Challenges are identified for each of the specific goals.

Energy supply challenges are the following:

- Conversion to renewable energy;
- Energy efficiency;
- Behaviour changes in public, authorities, businesses and among citizens; and
- Improved waste recycling [5].

Energy efficiency challenges are the following:

- Realizing the huge potential for energy and economic savings in renovation and new construction;
- Energy renovations of regional and municipal buildings require massive investment;
- Sustainable hospital buildings; and
- Renovation and demolition [5].

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Fire and Light-bulb Photo taken by Stefan Sipka and Mauricio Lopez taken on November 5th 2011 in Lund, Sweden.

REGION ZEALAND

By Mauricio Lopez

The Zealand Region (*Region Sjælland* in Danish) is an administrative unit in Denmark established in 2007 as a result of the Danish Municipal Reform. It is comprised of the former counties of Roskilde, West Zealand, and Storstrøm, and consists of several islands on the eastern part of Denmark including Zealand, Lolland, Falster and Møn. However, due to its dissimilar characteristics and importance, the north eastern part of the Zealand Island belongs to a different administrative region.

Each region is appointed with three main tasks: management of health care, the operation of education institutions, and the creation and implementation of regional development plans. The Zealand Region has allocated a budget of around EUR 2 billion for these tasks, mostly used in health services related expenses [1].

The Zealand Region is one of the smallest in Denmark (7 273 km^2) while it is also second with the highest population density (112 inhabitants/km^2). The population is expected to increase three percent by 2020, with a similar growth rate as the Capital Region.

Existing Energy System

The energy system in the Zealand Region is the largest source of greenhouse gases (GHG), as a result of the use of fossil fuels for transportation, heating and to provide the regional electricity supply. The energy supply is derived from the following primary sources: coal and coke, oil, natural gas and renewables. At the regional level, these sources are transformed in central power stations, combined heat and power (CHP) facilities, district heating plants, gasworks, and by private autoproducers [2].

On the demand side, the largest energy consumption is derived from transport, which is mainly satisfied with oil products. As it is also the fastest growing sector in terms of consumption, its already significant share in energy consumption will increase over time [3].

Possible Developments in the Energy System

The expected development in fuel prices, based on projections by the International Energy Agency, establishes a stable and constant growth [4]. Based on this assumption, an increase in the investment in other energy

Train station at the Roskilde Festival in 2009 with a wind turbine next to the camping area.

Private biogas facility in Lolland, Denmark. Private investment in Denmark has been fundamental for the expansion of renewables as a share of the energy mix.

sources, particularly renewables, will probably take place in Denmark. Because of the geographical and economic activities of the Zealand region, the investment in renewable energy sources is centered on wind turbines (onshore and offshore) plant construction and retrofitting focused on the use of biomass for CHP production. The biomass potential of the region has recently been assessed in a mapping project and two main sources of biomass have been identified: waste products from agriculture, industry and aquatic environments and the production of energy crops [5].

Significant savings in efficiency can be made both on the demand side and on the transformation of primary energy sources, given that so far large CHP plants are responsible for two-thirds of the losses in energy before final consumption [3].

However, the most interesting potential in the region is related to the creation of energy and environmental economic clusters. According to a study made by Oxford Research, the potential for strategic cluster formation could boost the development of environmental and energy solutions in the region [6].

Regional Commitments

The Zealand Region has committed to reach is the European Union's general climate goal, focused on reaching a 20% reduction of CO_2 emissions (relative to 1990 levels) by 2020.

The municipalities have also made agreements of their own. In 2009 many of the region's mayors (14 out of 17) signed the Covenant of Mayors, a document in which they commit to develop a Baseline Emission Inventory, which is a measurement of CO_2 emissions derived from energy consumption in their municipalities. They also commit themselves to submit a Sustainable Energy Action Plan detailing timelines and responsibilities related to the environmental objectives. The Local Government Regional Council (KKR Zealand) and Region Zealand act as Covenant Coordinators for them [7]. They coordinate the individual objectives from the municipalities into one single regional strategy.

On an individual level municipalities have also made important commitments related to the reduction of GHG emissions. Kalundborg municipality, for example, has signed a climate partnership agreement with DONG Energy (a private energy company owned by the Danish government and private shareholders) to increase energy efficiency and create renewable energy infrastructure. As a result of this partnership, a large-scale ethanol demonstration plant was conceived to showcase DONG Energy's second-generation ethanol production technology called Inbicon process. The plant is designed to fit in the industrial symbiosis model of Kalundborg Eco-industrial Park [5,8].

Goals, Strategies & Instruments

The Zealand Region has a particularly active role in devising strategies focused on environmental and energy-related issues. The whole regional strategy can be summarized in its three driving forces:

- Adaptation, regarding the effects of climate change;
- Mitigation, focused on the reduction of CO_2 emissions; and
- Innovation, as a source of potential solutions.

The main document assessing these points is the Regional Climate Strategy, which was the first one to be developed in Denmark. The main objectives regarding the regional energy system are to increase the use of renewable energy and to promote a more effective use of energy in general [9].

In order to reach these objectives, five fields of action have been established:

- Use the biomass potential in the region;
- Maintain and increase the use of regional wind power potential;
- Distribute and integrate renewable energy facilities;
- Promote energy savings in households and the public and private sector; and
- The preparation of heat and energy plants.

Challenges

The main issues are related to the integration of existing energy plants into a broader system as well as promoting the transition to from non-renewables to renewable energy sources while promoting technology shifts [9]. These challenges require the development of awareness among the population regarding the need to develop more renewable energy alternatives, and the use of these resources. The resources available in the Zealand Region make it an ideal candidate for the development of a broad strategy that integrates these elements into a regional environmental solution.

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REGION SKÅNE

Energy Challenges in the South of Sweden

By Jordan Hayes & Ian Ross

The region of Skåne is the most southern county of Sweden and differs from Region Skåne (RS) which is a public organisation that acts on behalf of the Regional Assembly. RS is responsible for health care and public transport and employs around 32 000 individuals. The region of Skåne is divided into 33 municipalities with Malmö being the largest followed by Helsingborg, then Lund. The total population of the region in 2010 was estimated around 1 240 000 which is roughly 13% of the total population of Sweden. Skåne is considered to be the fastest growing region in all of Sweden with a steady population increase from year to year. The region has an area of 11 027 square kilometers, which is about three percent of the total area of Sweden. About half the land in Skåne is farming land which is well above the national average of eight percent and 30% is covered by forest. In 2008 the gross regional product (GRP) of the region was measured to be SEK 338 billion [1].

Situation

The RS is ambitiously trying to reduce their energy use and associated greenhouse gas (GHG) emissions. In 2009 the region was using 326 GWh of energy for electricity, cooling and heating [3]. When combined with transport, this amounted to 60 000 tonnes of carbon dioxide released per year. The table to the right gives the relative percentages for electricity source of the region.

Transportation accounts for the largest GHG emissions in the Skåne region with energy production being the second largest contributor as shown on the figure on the following page. This figure can be somewhat misleading however, as energy carrier imports are not included in this estimation. Skåne imported 11 TWh hours of energy carriers in 2007. These energy sources are mainly electricity, natural gas, oil, and biomass. If these were included the total emissions for the energy category would increase by roughly 16% [2].

Skånetrafiken is the organisation that runs the region's transportation system. They estimate that the system facilitates 120 million journeys a year. While all of the trains in the region are powered by renewable energy, only 24% of all total transportation modes in the region were powered by renewable sources in 2009. Private cars accounted for two-thirds of GHG emis-

Sources of electricity production in Skåne 2008 [2].

ENERGY SOURCE	%
Bio gas and solar cells	2%
Power plants (fossil fuel)	13%
Wind	39%
Hydro	9%
Cogeneration plants	22%
Industrial back pressure (renewable)	12%
Industrial back pressure (fossil fuel)	3%

sions released by transportation in 2007, with freight accounting for one-third [2,3].

Skåne Regional Goals and Strategies

Greenhouse Gas Emissions

By 2020 GHG emissions in the region will need to be at least 30% lower than that of 1990. In order to achieve the 30% reduction goal, it has been suggested to focus on three sectors which have been identified as the main emission sectors: transportation, energy and agriculture. Some examples to reduce emissions from these sectors include energy efficiency in transportation, energy efficiency in industry, reduction of methane and nitrous oxide emissions from agriculture and increasing the use of renewable energy sources [2].

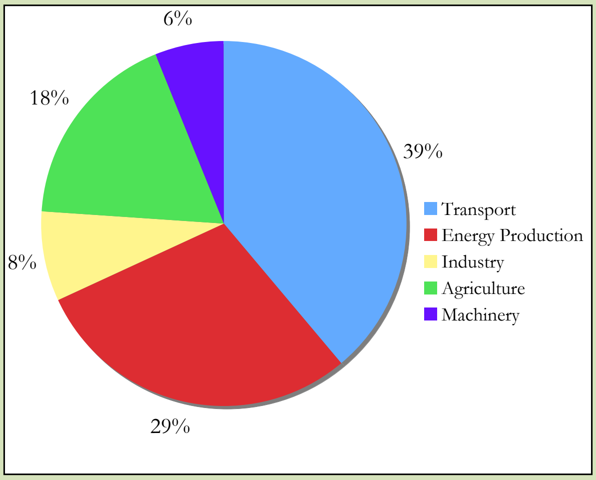
In Skåne GHGs have been decreasing since 1990. Part of the success in this reduction of GHGs has been due to private households replacing their oil fired boilers with biomass boilers or heat pumps. Other activities include reduction of heating with fossil fuels, reduced livestock in agriculture and reduced energy consumption on a per person basis [2].

Energy Use

By 2020 energy use in the region will be ten percent lower than the average from 2001 to 2005. Over the past two decades final energy consumption in the region has not changed although population growth has increased which means that energy consumption per person has dropped. Part of the success has come from all sectors except transportation becoming less energy intensive. Reductions in energy have also came from a shift away from energy intensive sectors such as engineering and chemical industries towards less energy intensive businesses such as pharmaceuticals and telecommunications. Other ways energy use has been reduced has been in logistics for transportation and building efficiency, which can help reduce total energy consumption by up to one third [2].

Renewable Electricity

By 2020 the production of renewable electricity in the region will be six TWh higher than the figures from 2002 [2]. On and off shore wind power is the renewable energy source that is expected to contribute the most to meeting the goals for 2020 [2]. It is expected that future offshore wind will contribute four TWh and onshore wind is estimated to produce 1.4 TWh [2]. There will also be a gradual transition to use additional renewable fuels such as biogas, waste and natural gas in power plants and industries [2]. There are plans to upgrade some existing hydro power plants in the Skåne region to assist in reaching renewable electricity goals, but these are not substantial. There will also be some development in small-scale renewable projects such as solar, but long-term forecasting suggest that this will not contribute significantly to reaching overall energy goals due to the large areas of land required for solar electricity production [2].



Skåne region GHG emissions as percent of contribution. Note that this is a simplified estimation based on data obtained from [3].

Transport

By 2015 GHG emissions from transport in the region will be ten percent lower than emissions from 2007 [2]. The regional commuter traffic operator in Skåne, Skånetrafiken, has also set targets to be fossil free by 2020 [1]. It aims to ensure that city busses are fossil free fueled by 2015, regional busses by 2018 and other vehicles by 2020.

Partnerships

The region of Skåne is making large efforts to improve the energy system within the county. The Swedish Environmental Protection Agency awarded RS with SEK 45 million to invest in GHG reduction programmes for the period of 2006-2012. RS has in turn been involved with various organisations in developing renewable energy markets in the Skåne region.

POLIS (identification and mobilisation of solar potential via local strategies) is a current project that Malmö is taking part in, along with 5 other European cities, that promotes sustainable city planning, focusing on solar power integration [3]. Solar Region Skåne is another organisation with a similar focus on increasing solar panel use in the region. In 2005 a subsidy programme was introduced in Sweden, which covers 70% of the cost for buildings to install PV solar panels [4].

Skåne has worked hard with industry and municipalities to expand biogas production. The goal for biogas is to increase production to three TWh by 2020 [2]. Skåne has an aspiration to create five new biogas production facilities, along with biogas bus fleets, biogas car fleets, fueling stations, and incorporated grids [3].

Skåne is also participating in the EU funded Renewable Energy Supply Chains Programme, which focuses on expanding markets for biogas, small-scale biomass, wind energy, solar energy, and hydropower [3].

Challenges

While the Skåne region has taken great strides in creating a cleaner energy system, some practical challenges still remain. Some municipalities may be hesitant to invest into biogas plants as they might own waste incineration plants, and are reluctant to have conflicting investments. Other challenges arise with the production of additional wind turbines on land and in the sea. With the production of turbines on land, the main conflict arises where buildings and different types of territorial protection may limit expansion. With respect to the development of offshore wind turbines comes the conflict with the protection of marine habitat, military defence, fisheries and coastal populations. These challenges and potential conflicts must be given adequate consideration when aiming to reach the energy goals of 2020 and beyond.

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Cover photo taken by Veronica Andronache on September 28, 2011.

COPENHAGEN, ALBERTSLUND AND BALLERUP

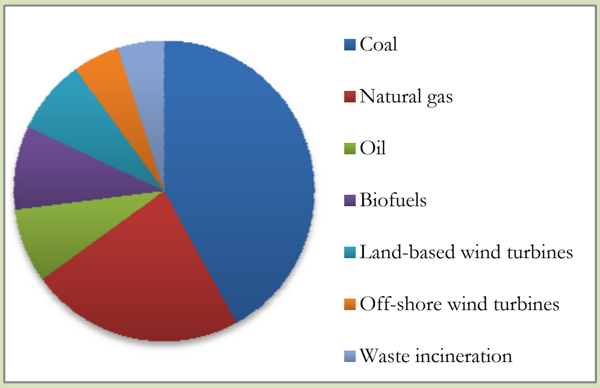
City-Level Energy Strategies

By Sarah Czunyi & Tom Figel

The Danish cities of Copenhagen, Albertslund and Ballerup are all located in the larger Copenhagen metropolitan area. All three cities have ambitious goals to reduce their energy consumption and green energy supplies, with overall commitments to achieve 20-25% carbon emission reductions by 2015 [1]. However, each city has a different strategy for reaching these goals.

Copenhagen

The city of Copenhagen is the capital of Denmark, with a core population of almost 700 000 inhabitants. Copenhagen has been an international forerunner in advancing environmental sustainability in practice, yet the city is still reliant upon 'dirty' energy sources. Electricity and heating make up the greatest proportion of the city's energy use. Although 30% of the total energy mix comes from carbon-neutral energy sources, and 98% of the city's homes are connected to a district heating system based on cogeneration plants, there still remains a high dependency on non-renewable energy sources.



Electricity consumption in Copenhagen municipality, 2005, by fuel type (Adapted from [2])

Copenhagen is currently dependent upon fossil fuels – namely coal, natural gas and oil – for 73% of its electricity needs [2].

Future Vision and Goals

In 2009, the city council passed the Copenhagen Climate Plan. This plan sets out a vision for the city to become carbon-neutral by 2025, with a specific target to reduce carbon emissions by 20% between 2005 and 2015 – a reduction of approximately 500 000 tonnes of carbon [3].

The largest proportion of Copenhagen's carbon emissions arise from electricity/heating, thus the energy supply is the priority intervention area to reach the 2015 goals. 75% of the total carbon reductions are expected to arise from changes in the energy supply mix. Specific measures to achieve this will include: use of biomass in power stations (largely replacing coal); installation of greater wind generation capacity through the erection of wind turbines or windmill parks (both on- and off-shore); increased use of geothermal power; and renovation of the district heating network to improve efficiency and decrease leakage/losses.

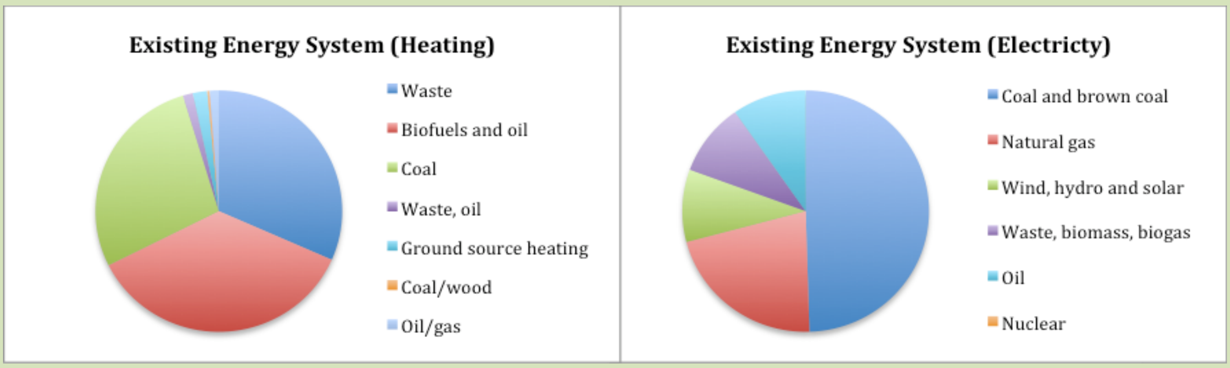
Other targets in the Plan are directed at: transport, buildings and overall urban development. Creating a greener transportation system is expected to achieve 10% of the total carbon reductions. Although Copenhagen is currently seen as one of the world's most bicycle-friendly cities, current projections do not foresee a reduction in car ownership. Carbon reductions in the transport sector will therefore be focused on: improving biking and walking infrastructure; extending public transportation; electric/hydrogen powered vehicles (both public and private); and congestion charging. Improving energy efficiency combined with construction/renovation of buildings is expected to lead to a 10% reduction in carbon emissions. This will be promoted through regulations on building's efficiency requirements, starting with an overhaul of the municipality's own buildings. Lastly, education campaigns to encourage behavioural changes to reduce electricity consumption are expected to achieve a 1% reduction in total carbon emissions. All of these measures are to be integrated into the cross-sectoral work of the municipality. [2, 4]

Albertslund

Albertslund is a suburb of Copenhagen, with a population of about 30 000. It is a fairly young city, dating from the 1960s. Within the existing energy system, the two main energy needs are for heating and electricity. For heating, the major sources are waste, biofuels/oil and coal, and for electricity, coal and natural gas are predominant in the mix.

Future Vision and Goals

Albertslund's 2015 energy strategy is mainly focused on reduction of energy consumption within the local authority's institution and operations, the transportation sector, and a principal focus on the housing and business sectors. This is driven by an overall goal to reduce carbon emissions by 25% by 2015 (an equivalent of 52 000 tons of carbon). Albertslund has begun aggressive residential housing climate renovation supported by the Danish Energy Agency, with the hope of enacting an exemplary model that will guide similar renovation projects in the future. Planned housing renovations will attain at least energy class 2, which results in a 73% reduction of energy consumption. The renovation strategy includes further use of alternative energy, conversion to low-temperature district heating, ground source heating and other technical solutions. Renovation of existing public housing (approximately 1550 homes) will be partly financed by the National Building Fund (Landsbyggefonden). New, sustainable housing developments in the city centre are also planned. Albertslund has a multifaceted strategy to work with private businesses towards sustainable business development and the reduction of energy use. Albertslund's transportation strategy focuses on creating and encouraging alternatives to car traffic, especially cycling, and working with businesses to reduce transport needs. The municipality also has strong commitments to reduce its own institutional and operational energy use, including a climate renovation of its new buildings and incorporation of passive design, increased green procurement, and retrofitting all public lighting with LED bulbs.



Albertslund existing energy system – heating and electricity energy mix (Adapted from [5])

Aside from reducing energy consumption in these four areas, the city is also investing in the sustainable development and expansion of its district heating system, as well as the incorporation of more renewable energy into its electricity supply. The district heating system, which currently covers 95% of local heat demand, will be converted to low temperature to allow for coupling with alternative energy.

Towards these goals, Albertslund has legislated commitments and invested resources within the municipality, as well as formed strategic partnerships with regional and national governments, organizations, and networks such as the Green Cities public-private network to help municipalities support private companies with climate strategy. Other networks that Albertslund has joined include: Agenda 21; International Council for Local Environmental Initiatives; and the European Union's Covenant of Mayors. [5]

Ballerup

Ballerup is located approximately 15 km northwest of Copenhagen and has about 47 000 inhabitants. The existing energy system is predominately dependent on coal and natural gas. Renewable energy, which is mostly waste-based, accounts for approximately 15% of the energy supply.

Future Vision and Goals

Ballerup's energy strategy focuses on energy conservation and increased use of renewable energy. By 2015, 25% of municipal energy consumption will come from renewable energy. Also by 2015, the majority of Ballerup's businesses, institutions, and households will be converted to district heating, which will significantly improve consumption efficiency.

The city has a long-term goal of becoming CO_2 neutral in all of its energy consumption. Ballerup has made strategic partnerships to achieve its energy goals, both with public and private institutions. Ballerup, along with Albertslund, is part of the Green Cities partnership, and has partnered with Aalborg University and the Danish Department of Community Development. To develop renewables, Ballerup is working with DONG Energy. Primary investment is in wind energy, which will cover all of the municipality's own buildings consumption demands by 2015. The municipality is significantly expanding its district heating and researching possibilities to develop district cooling a well as a biogas plant, which would also produce organic biofertiliser.

Ballerup has made strong commitments to green its own energy supply and reduce consumption, many of which are ahead of national legislation. Electricity consumption in municipal buildings is to be reduced by 10% by end of 2011 [6]. All new municipal buildings are required to be built as a zero-energy, and from 2015 as energy-plus buildings (i.e. producing extra energy which can be fed into the grid). By 2015, the majority of municipal institutions, commercial properties and households will be converted to district heating. Also by 2015, the European Eco-Management and Audit Scheme (EMAS) standard will be introduced across the municipal organisation.

One of the municipality's key strategies is to inspire businesses, which account for 60% of the municipality's total energy use, to adopt clean energy practices. The municipality will lead through example, utilizing the development of a Climate Network for businesses, and also ensure that municipal infrastructure promotes clean energy options for companies. One example is the Carbon 2.0 project, where 15 companies will reduce their CO_2 emissions by 20% before the end of 2013.

Regarding transport, focus will be on investment and infrastructure development of public transport and cycling, as well as behaviour-targeted campaigns for citizens. About 80% of Ballerup's citizens are currently commuting, so this is a major area of focus for the city. The municipality will procure clean technology in cars and buses, and investigate ways to develop more electric cars.

For households, the promotion of best practices for energy conservation and investment in energy retrofits are the highest priorities. Two citizen-oriented climate initiatives will be held each year to increase knowledge and influence citizens' climate-related behaviour. All new buildings will be built as energy class 1 (a strict energy regulation set under Danish Building regulations) from 2010. [6]

Overarching Challenges

All three cities – Copenhagen, Albertslund and Ballerup – face similar challenges with respect to their energy goals. For example, a higher reliance on renewable energy sources such as wind will require an effective and large-scale energy storage system to cope with changing weather conditions as well as changes in electricity demand [2]. Changes in biomass volumes available (for incineration) and high fluctuations in electricity prices are also potential challenges that should be addressed at the planning stage [1]. Influencing industry and households requires significant investment and careful planning. Overcoming these challenges will require sustained leadership from each city.

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Bike photo by Jim Figel, taken on 6 May 2011.

Malmö Energy System

By Peter Kiryushin

Malmö is the capital of Skåne county, situated in the south-west of Sweden. Malmö in the center of the Øresund region by the Øresund bridge, which connects Sweden and Denmark. With the population of 300 000 inhabitants Malmö is the third largest city in the country after Stockholm and Gothenburg [1]. Until the beginning of 1990's Malmö was an industrial zone. Now it is a fast developing city, where sustainability, environmental and energy issues are important parts of the development agenda. Malmö is ranked among the top green cities of the world, and has an ambitious goal to become even more "greener" in the nearest future [2].

Energy System

According to the Malmö Municipal Statistics the overall energy consumption for 2008 of the city was estimated as 7 520 GWh [1]. Malmö has a district heating system that is typical for Swedish cities. District heating system is usually better in efficiency and pollution control compared to individual boilers.

There were 2 600 GWh of heat was produced in 2006 from sources including, natural gas, waste (incineration) and solid biofuels, with a minor contribution of oil. Between 1990 and 2006 there was an 80% decrease of oil consumption due to restructuring of the city's industrial sector [3]. 5230 GWh of the overall energy consumption in 2008 were used in non-transportation sectors. Service sector is the largest energy consumer, it followed by apartments, industry and small houses. Between 1990-2008 per capita consumption in Malmö felt by 12%, partially due to economic restructing and changes in the industrial sector [1].

Vision and Goals

The city has a vision to have 100% renewable energy supply by 2030. Malmö has a strong commitment and is developing numerous innovations in order to achieve this vision. One of the prominent examples is the carbon-neutral and fully renewable-based energy system of Bo01 district in the Western Harbor. About 1 400 m^2 of solar panels have been installed in the district as well as powerful water pumps, which draw energy from natural warm water reservoirs during the summer to heat the district in winter time. Part of the electricity supply also comes from offshore Lillgrund Wind Park that is the third largest installation of off-shore wind energy in the world [1].

New Bo01 district with modern energy supply in Malmö

The main goal for energy development for 2020 is stipulated in the Malmö Energy Strategy: “Energy use in the city is characterised by efficiency, frugal use of natural resources, security and availability together with low impact on the climate, environment and health”. There are subsidiary goals, which can be categorised into three areas: increasing of energy efficiency; developing of renewables; and better planning, purchasing, security and knowledge [3].

By the year 2020 the per capita energy consumption should be decreased by 20% compared to the average of 2000-2005. By the year 2020 the municipality’s departments and companies should decrease their energy use by 30% and develop 100% renewable energy supply. Key energy saving measures and guidelines for different sectors are presented in Table 1. According to research estimations the overall energy saving potential for Malmö is estimated to 17-41% [5].

Measures and Guidelines

In 2020 renewable energy should comprise not less than 50% of the total energy supply. Malmö aims to be the leading biogas and hydrogen city in Sweden. There are a number of measures stipulated in the Energy Strategy in order to achieve the target. For heating and electricity supply and consumption, typical measures include: encouraging citizens and organisations to use renewables and minimise fossil fuel consumption; developing heat pump projects, providing sport facilities with solar heating systems, etc [3].

The key guidelines for the transport sector are:

- municipal fleet should consist of 100% environmental vehicles in the future;
- 75% of municipal fleet should use biogas by 2015;
- 20% refilling station should provide environmentally-friendly fuels; and
- Usage of electricity from renewable sources in the future.

Planning, purchasing and the security of energy improvement areas also include different measures. For example, prioritising walking, cycling and public transport; more dense, mixed adjacent, extension of district heating, and prioritising social functions of the energy system [3].

Overall, three kinds of challenges for energy development in Malmö could be identified. The first is negative environmental impact, mostly associated with air pollution emissions from transport, waste incineration and oil consumption for energy needs. The second chal-

Key energy saving measures and guidelines.

	RESIDENCES, PREMISES & COMMERCIAL BUILDINGS	INDUSTRIES	OTHER SECTORS
RESEARCHING		• Detailed analysis of potential	• Support the R&D for LED based lamps
PLANNING & ACTING	• Measures in Municipality’s building stock • Compliance with energy requirements	• Planning with regard to energy use	• Influence citizens coice on most economical vehicle • Implement recommendations for sewage works
COMMUNICATING	• Information about best examples • Communication with property owners	• Giving info during inspection visits • Increase advice to small & medium-size enterprises	

lenge is unpredictability of deliveries and delivery interruptions, which are possible for example, because of local power cuts. The third challenge is connected with high cost level in energy field. The reason is that E.ON, an energy company, is the major and most important actor in the city energy system [3].

Conclusion

In conclusion, Malmö has an ambitious vision to become fossil-free in 2030. A number of the city's achievements already proved the commitments to the vision, in particularly, development of 100% renewable energy supply in Bo01 district and significant reduction of oil consumption since 1990. However, in order to achieve the long-term vision and commitments, there are challenges to overcome related to negative environmental impact of some energy sources, interruptions of energy supply and high energy costs.

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Photo of Turning Torso, the tallest skyscraper in Malmö, Sweden and all Scandinavia, by Monika "Urbanlegend", taken February 26, 2006 Malmö, Sweden, using Fujifilm FinePix F450. It is licensed under Creative Commons 2.0. URL: http://www.flickr.com/photos/17989497@N00/106216768/

Photo of Bo01 district in Malmö was taken July 27, 2008, by "Hauggen". It is licensed under Creative Commons 2.0. URL: http://www.flickr.com/photos/hauggen/2876378926/

Lund's Energy Strategy

Achieving Zero GHG Emissions by 2050

By Filipe Firpo

Lunds Kommun (English: Lund Municipality) is strategically located in the southern part of Sweden, in Skåne County, less than an hour by train from the Danish capital Copenhagen. It holds nine urban areas, including the city of Lund, which seats its administration over a total area of 442.87 km^2 [1]. With a population of 110 824 and a density of 246 per km^2 [1], it is one of the most important municipalities in Sweden, headquarters of important and high tech companies and home of the major Swedish and largest Scandinavian education and research institute, Lund University [2]. Situated in Sweden's largest agricultural area, the region is benefited by an oceanic, relatively mild climate and with average annual temperature of 7.5°C [3], affecting its energy consumption, GHG emissions and overall balance.

Lund's Energy Balance

Green electricity

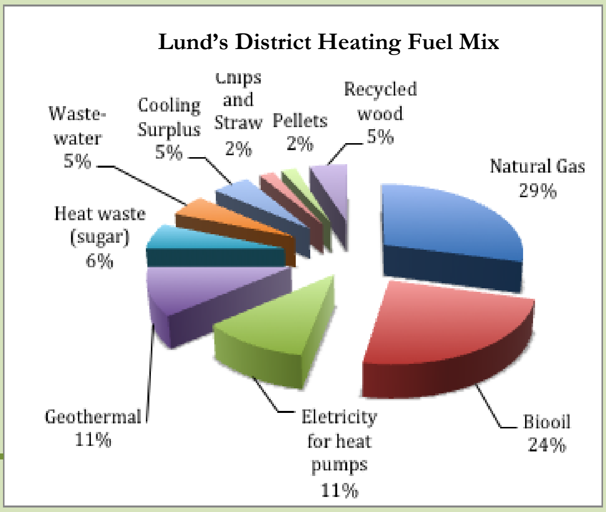
Lund's electric energy comes from a wide mix of both renewable and non-renewable sources. In the year 2010 Kraftringen Produktion AB, which is part of the Municipality owned Lunds Energi Koncernen, produced 107 GWh of electricity alone. The greatest part however, is imported from Norway (hydro sourced) [3].

Solar and wind power accounts slightly to the final amount: the total solar production was 391.8 MWh in 2010 (being 80 MWh from photo voltaic panels and 331.8 MWh from solar heat) [3]. Wind power is harvested from eight windmills ranging in power from 150 to 660 kW, which has accounted for 5 839 MWh in 2010. In the same year, a new and more modern windmill of 2.3 MW was installed [3].

Since 1998, the Municipality has bought only eco-labelled electricity, mainly from certified hydroelectric power in Norway. Moreover, energy use in the city's stock property has fallen by 17% due to high investments in energy efficiency, under the Sustainable Energy Action Plan for Lund. [6]

Effective Heating System

A broad effective and efficient District Heating (DH) network system reaches 85% of the Municipality and beyond, supplying 50 000 customers in Lund, Lomma and Eslöv municipalities. The heat production of Kraftringen Produktion reached 1 280 GWh in 2010 [3].



Lund's district heating fuel mix in 2010. Data from [3].

Since 1984 geothermal energy and heat pumps have been used and now accounts for 22% of the DH production (about 250 GWh/year) [5]. Another fraction of 29% comes from fossil fuels (natural gas). The other remaining 49% comes from a mix of other renewables sources (pellets, wood chips and straw, sugar mill and wastewater heat waste and also bio-oil) [3].

As geothermal sources are cooling down and stagnating [6], geothermal energy has been replaced by others renewables. A new CHP power plant is planned for 2014, with a co-fired boiler and afterwards a straw-fired boiler (planned for 2019), producing 550 GWh/year of heat and 300 GWh/year of electricity [4].

With these accomplishments, the heating energy matrix will be changed to a greener fuel-mix of 90% coming from renewable sources (from forest fuel and wastewater new inputs). For the mid term future there is also plans to connect Lund's DH network to the cities of Landskrona and Helsingborg [3].

In addition, the waste heat from the Max-Lab IV, a world leading national facility for materials research (based on synchrotron radiation), is also to be exploited. The recoverable energy available is predicted to be in order of 5 MW in the unit [3]. For the European Spallation Resource, a multidisciplinary research centre harnessing the world's most powerful neutron source, the energy recovery could be much more. The selection of Lund as the location for these important facilities reflects the strength, attractiveness and relevance of research there.

Local Agenda 21

The Climate Municipalities

The Municipality of Lund itself hosts the secretariat for *Klimatkommunerna* (English: The Climate Municipalities), an association of Swedish municipalities working actively on local and regional climate change mitigation strategies.

The association's ultimate goal is to reduce overall GHG emissions in Sweden [6]. Working cooperatively within the Municipalities is the only way to achieve the national target.

By establishing wind and solar power, generating the conditions for sustainable transport and designing energy-efficient buildings, the Municipality's goals for 2020 is to reduce 127 000 CO_2 tons and save 48 GWh of energy. Furthermore, additional renewable production is aimed to reach further 942 GWh, which is more than 90% of the total Municipality heating current demand [6].

Energy Goals: Challenges

Being part of Sweden's and Skåne's region environmental commitments, the Municipality faces great challenges and opportunities. Lund has signed the Covenant of Mayors in 2010, pushing its climate obligations further than the 20% EU goals by 2020. Lund's aims are actually 50% reduction in GHG emissions by that year (compared to 1990 and excluding agriculture). By 2050, its ambition is to get even close down to zero. Moreover, by being included in the Skåne region administration, Lund also aims to be fossil-fuel-free by 2020 [6].

The Bicycle Friendly City

A smart way to phase out fossil fuels and reduce emissions is investing in cycling. Lund is one of the most bicycle-friendly places in Sweden, with 5000 bike parks, 160 km cycle-paths, and half of the population as commuters. Moreover, 43% of the city's journeys are made on two fossil-free wheels: riding bicycles [6].

These figures are part of *LundaMaTs,* Lund's strategy for sustainable transport system. It encompasses 42 projects to be implemented by 2030, between 2010 and 2030. With a budget of more than SEK 1 billion (EUR 100 million), the environmental benefit comes from a reduction of 25 240 tons of CO_2/year from 2014 [6].

Public Transportation

Besides cycling incentives, *LundaMaTs* has contributed to maintain the annual distance driven in the Municipality by each of its citizen over the last ten years [6].

The urban bus network holds 11 far-reaching lines served by a frequent fleet of 40 natural gas-fuelled buses. For the regional buses, gas is used in a mix of 40-50% with renewable fuels [6]. In addition, the well-served railway is connected to the main line since 1857. Furthermore, there is a tramline planned to help commuters reach faster the suburban areas from the city centre within the next following years.

Good Housekeeping: Emissions

Apart from the population increase of 24% in the period between 1990 and 2008, the Municipality's good policy and planning has reduced the overall GHG emissions by 2%, with a following energy demand increase of only 9%. Whereas the energy surge is due to transportation needs – which has risen by 36%, the electricity and heating use per inhabitant was actually reduced by 11% and thus its emissions by 20% over the considered period above [6].

Energy Efficiency: Buildings

With an extensive District Heating system covering almost the whole inhabited area (85%), Lund is striving to phase out all household oil boilers and wood furnaces to the more energy efficient and effective DH network.

For the period 2010 - 2014, SEK 113 million (EUR 11.9 million) will be invested in energy efficiency in buildings, hot water monitoring and efficient production. This aims to an energy saving of 42 650 MWh and avoiding the release of 9 825 tonnes of CO_2 in the atmosphere. When building new homes, the city residential property company LKF, for instance, "must ensure that an energy performance of 100 kWh/m^2 is achieved.", accordingly [6].

Green lease agreements are also being proposed by the property sector, where specific environmental commitments are set between the property-owner and tenants. Vasakronan AB, the Swedish company that was selected as climate model in 2009, aims to lessen energy use by at least 3% per year, which by 2020 would represent an energy saving of 26% [6].

Public Procurement: LundaEko

Under the *LundaEko*, the environmental management programme implemented by the Municipality, only eco-labelled electricity shall be bought for its supply energy mix. Accordingly, 4 000 tonnes of CO_2 per year are expected to be saved due to this programme [6].

Following the *Action Plan for Clean Vehicles*, when purchasing new automobiles, only those that use green fuels such as biogas, biodiesel or electricity should be chosen. Moreover, any existing vehicle that can use such fuels shall do it so. For this plan, an overall reduction of 2000 CO_2 tonnes per year will be achieved [6].

The City Where Ideas Are Heard: Active Citizenship

Considered the City of Ideas, Lund's Administrative capital maintains a close dialogue with its citizens. Several projects have been so far implemented and given cooperation. Examples of these include youth projects, such as the *Ungdomsforum för Agenda 21* (English: Youth Forum for Agenda 21) and the international *Klimatting Ett* (English: Climate Gathering) [6].

The international network and cutting edge innovative knowledge of Lund University is also supported by the Municipality and often implemented. Along with the Regional Centre of Expertise on Education for Sustainable Development (RCE Skåne), they are cooperating to mitigate climate change.

Another virtuous example is the behavioural change outcomes perceived in the local population. These eco-friendly social actions are driven by the *Hållbart Universitet* (English: Sustainable University), an engaged student organisation from Lund University. The association aims to strengthen and coordinate engagement in environmental and sustainability issues.

The business arena in Lund is likewise environmentally driven, accordingly to the frontrunner Swedish values in sustainability. Under the Climate and Energy Alliance Commitment, a covenant active within ten companies since 2009, a great commitment to climate change mitigation and energy efficiency has been put in practice in roughly all sectors. So far, SEK 1 330 000 (EUR 146 000) has been invested in total on such cooperation among active citizens and others stakeholders and key players in halting climate change [6].

Towards Zero Emissions: 2050

Apart from such ambitious goal of achieving zero emissions by 2050, the relatively small Municipality of Lund takes benefit of being part of the experienced frontrunner country in sustainability: Sweden. Furthermore, by hosting its greatest University, inspiring innovative solutions comes intuitively to hand.

Great achievements in reducing emissions have been already accomplished on the transportation and energy sectors, and the greatest challenge now is agriculture, which is not part of the Covenant of Mayors signed in 2010. This sector needs to be addressed if the Municipality wants to be carbon neutral by the next decades.

Electrification and District Heating is a strategic way of achieving climate change goals and constitutes a successful business case: using a green energy labelling system for producing district heating and delivering electricity as an energy carrier is a very clever way of holding the energy supply by the Municipalities.

It adds value in the energy production chain in benefit of the whole society, especially customers and shareholders. This creates a win-win-win effective and smart business model for all stakeholders.

Nevertheless, more efficient technologies, greener electricity sourced only from renewables and full citizen engagement will be crucial to get emissions reduced by the further ambitious challenge of 85% reductions [6] necessary to achieve the ultimate goal of zero emissions.

If this envisioned setup would be likely to happen by 2050, nowhere else it would have such a more optimist scenario to become reality like in Lund Municipality.

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Photo by Thomas Lindhqvist, IIIEE, December 16, 2011.

ENERGY SYSTEM OF KRISTIANSTAD

Description and Vision

By Su Meiling

Kristianstad is a city founded in 1614 with 80 000 inhabitants and 1 300 square kilometres landscape. It is located in the southern part of Sweden belonging to Skåne province. Its area covers agricultural land, forests, plains and a coastline. Administratively, Kristianstad consists of 40 different towns and villages. It is also part of the Øresund Region which is one of the most significantly expanding regions in Northern Europe. There are 35 000 residents in the city centre. As a pro-environmental city, Kristianstad has been awarded a series of environmental prizes. In 2005 it was ranked as the *Best Climate Work in Swedish Municipalities* by the Swedish Society for Nature Conservation [1].

Energy System

Overall energy supply in Kristianstad has remained stable since 1995. Its electricity system, as part of the Swedish electricity grid is tied together with neighbouring countries. The main local energy production units are: a cogeneration plant, a biogas plant, wind turbines and one hydroelectric plant.

Biogas components derive from three resources (annual energy generation is given):

- Landfill: Gas corresponding to 20 GWh of energy are captured and further utilised;
- Sewage: Approximately 9 GWh energy are produced from the biogas from the sewage treatment plant; and
- Anaerobic digestion: 40 GWh are generated per year at the Karpalund plant from organic waste and expansion is in progress in order to increase the production.

Biogas from Karpalund substitutes around 16 million litres of fossil fuel annually in the transportation sector.

The hydro power plant at Torsebro generates 25 GWh per year. Wind power created 75 GWh in 2010 and it is further expected to increase to 500 GWh/year in the future. There are also two solar plants at Österäng and Naturum Visitor Centre, contributing to energy input in Kristianstad [2].

The capacity of the biofuel-powered combined heating and power plant Allöverket is 75 MW. The main source of biofuel is wood chips, which produced 472 GWh of energy in 2010.

Large parts of the city are served by district heating. District heating uses a variety of local energy sources such as biogas and wood fuel. It

Biogas Plant in Kristianstad.

is supplied by a small scale plant ensuring a stable heat price. 23% of energy demand in Kristianstad, is satisfied by energy input from local sources which was 607 GWh in 2008.

Commitments

The city has signed the Covenant of European Cities committing to achieve more than 20% carbon emission reduction by 2020 through the development of Sustainable Energy Action Plans. As part of the Swedish National Climate Strategy, Kristianstad has committed itself to achieve the following objectives:

- 40% greenhouse gas emission reductions by 2020 compared to 1990; and
- Municipality administration and its services to become fossil fuel free by 2020.

The objectives and goals of the energy system in Kristianstad will be aiming to be achieved through below mechanisms:

- Increase energy efficiency;
- Increase renewable fuels and the proportion of local energy resource for electricity and heat production with the target to increase renewable energy sources from 34% to 50% by 2020 and to generate 500 GWh of electricity from wind power in 2025;
- Reduce the use of petrol/diesel by increasing efficiency and phase-in of renewable fuels; and
- Influence stakeholders' energy choices to shift their environmental behaviour and consumption patterns [3].

In order to achieve the wind energy increment target, another 85 wind turbines building project is launched on the basis of existing 31 wind turbines.

The target of becoming a fossil fuel free municipality was declared in 1999 by the executive committee. The main solution would be to increase the use of bio-fuels. It is meant both to increase heat gained from biomass and electricity generated from biogas. Forty three oil-based boilers in public buildings have been converted to pellets and straw-based boilers, and the municipality has the target to convert all other oil boilers in public buildings in the future.

The municipality is encouraging cyclists and pedestrians to reduce transportation energy consumption [1].

According to the municipality's energy efficiency plan, new buildings should be close to public transport, and city planner should consider the solar and wind conditions at the site. The municipality also promotes the construction of energy-efficient buildings such as passive houses. Passive houses are buildings heated by solar energy and energy from internal resources such as people and electronic equipment in order to minimise energy loss that are obliged to restrict standards [4].

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"Photos of station for recharging bio-fuels in Kristianstad and the biogas plant in Kristianstad" by Håkan Rodhe, 12/10/2011.

HEAT ENERGY USE IN BUILDINGS

The Impact of Increasing Energy Efficiency on District and Individual Heating Systems

By Logan Strenchock & Adrian Mill

Buildings account for around 30 to 40% of world primary energy use, and consequently contribute significantly to greenhouse gas emissions [1]. As a result, improving energy efficiency in buildings is one of the key components of European energy policy. One of the ways in which governments in colder climates intend to meet emissions and climate change commitments is by reducing the amount of energy used in buildings for heating purposes.

In northern European countries, there are three main approaches towards more efficient energy use for heating in buildings. The first approach, **district heating (DH) systems**, aims to make efficiency gains by centralising heating infrastructure and operating at peak efficiency. Denmark and Sweden have widely adopted these systems, which contribute significantly to reductions in national energy consumption. In recent years, attention has shifted towards the second key approach, **individual heating systems**, of which heat pumps are a leading example. In the background to these, **energy efficient construction and renovation** has slowly become the norm in Danish and Swedish building codes. This approach puts in place efficient heat retention within buildings to reduce the overall energy demand.

Assuming that building energy efficiency continues to improve over the coming decades, an interesting question becomes apparent. As buildings become more energy- and heat-efficient, will it lead to a situation whereby district heating solutions are rendered obsolete over the medium- to long-term? In simple terms, the construction and renovation of highly energy-efficient building stock over time could, in theory, lower the heating demands from DH infrastructure to a point where it is and is no longer cost-effective to operate. This has important implications for policy-makers, as investment in DH systems in the near-term may end up becoming a considerable waste of taxpayer's money in the long-term.

To address this issue, this chapter focuses on the influence that improving building energy efficiency may have on the heating systems that policy-makers may choose to support, as well as on defining a more appropriate decision-making framework towards achieving this. The term "buildings" in this context is taken to refer primarily to residential, office and public sector buildings, as other building types (i.e. industrial and historic buildings) are typically addressed separately in EU and national policy.

Energy Efficiency Policy

The EU calculates that buildings are responsible for around 40% of energy consumption and a third of CO_2 emissions [2]. EU policy has therefore heavily encouraged the implementation of energy efficiency measures in member states. This has occurred both at the strategic level (e.g. the "20 20 by 2020" decision of the European Council in March 2007) and at the supply side and end-use level (i.e. Directive

2009/28/EC specifying the percentage of renewable technology to achieve 20-20-20 goals).

The use of DH and co-generation has been specifically supported in several directives (e.g. 2004/8/EC, 2006/32/EC). With regard to individual heating systems, heat pump and other systems using renewable energy are supported under Directive 2009/28/EC by labelling these as suitable renewable technologies for fulfilling energy efficiency targets. Energy efficiency in buildings is covered under two key Directives, 2002/91/EC and 2010/31/EU. These directives lay down a number of building energy performance requirements for member states to apply into national legislation.

National Policies & Regulations

Both Denmark and Sweden have put in place legislation to promote both supply-side and end-use energy efficiency as per EU policy requirements. The two countries have invested heavily in DH and co-generation infrastructure. Future policy intends to support further expansion, although in areas where the technology is cost-effective [3,4]. Indeed, Danish policy explicitly notes that DH may not be appropriate for low-density settlements, new low-energy housing and energy efficient renovations [5].

The market for heat pump technology in Denmark and Sweden has been supported within national energy strategies, and they have also been favoured through state-subsidised research projects and conversion subsidies for individual households [6]. However, the use of heat pumps in Denmark is a relatively recent occurrence; Sweden has been actively promoted heat pump technology for several decades.

With regard to end-use energy efficiency, both countries have introduced policies that encourage energy efficient building construction and renovation. Denmark and Sweden have gradually increased the level of energy efficiency in their building stock over the past 30 years through the introduction of more stringent building codes. In Denmark, for example, the Danish Energy Agency found that the national heating bill was reduced some 20% between 1975 and 2001 as a result of improving building codes, even though some 30% additional heated floor space was built in the interim [7].

Today, building codes in both countries incorporate maximum permitted levels for energy use per square meter, in addition to numerous other upper limits for heat and energy use. The use of upper limits, combined with subsidies and incentives for energy efficient systems, has encouraged the construction of a new wave of passive and zero-energy buildings.

Low-Energy Buildings

Definitions of “low-energy” buildings (also referred to as “passive” houses or buildings) vary worldwide, as well as between EU mem-

Table 1 – Low energy building concepts.

TERM	DESCRIPTION
Low-Energy Building	A new construction or retrofit measure that usually results in 25-50% less energy demand than what is standard technology in new buildings [8]. Varying national definitions in EU.
Passive Building	Generally used to describe a low-energy construction that heats and cools its interior without conventional heating systems. Standards and definitions based on geographical and climactic locations.
Zero Energy / Zero Carbon House	A construction where thermal energy needs are created entirely by renewable or carbon free energy sources. Can be autonomous from the traditional energy grid, or require minimal use of grid energy.
Energy-Positive Building	A construction which produces more energy from renewable sources than it imports from external sources.

ber states. The below table overviews some of the terms that exist to describe constructions with superior energy performance. The terms most often refer to constructions that exceed the energy efficiency or alternative energy standards set by national regulations.

"Passive" buildings are generally characterised as mechanically-ventilated constructions that have highly-insulated building envelopes (to the point of being nearly airtight) which require minimal amounts of energy for heating and cooling [8]. The key building components in passive structures are windows and ventilation systems, as building designs aim to avoid thermal bridges; for example, entry or escape of heat / cold from the structure [8].

No universally-agreed performance standards exist for passive buildings, although Germany's "Passivhaus" specifications are widely regarded as best-practice in the field. The term is rather a design concept that aims to maintain indoor thermal comfort at low energy costs [8]. In Denmark and Sweden, passive house strategies based on German design standards have been devised to account for the unique geographic and climactic conditions [8].

Upfront costs for energy efficient buildings are higher than standard alternatives due to the expenses associated with superior insulation of all components [9]. In Northern Europe, additional costs are estimated at about 4-6%, with a payback period of around 20 years [9]. However, cost differentials are expected to decrease rapidly in the near future [9].

Sweden has made expanding passive house construction a priority in its strategy to reduce energy demand in residential buildings 20% by 2020 and 50% by 2050 [8,9]. In 2006, Denmark initiated progressively stricter standards (in five year intervals) for constructions, striving to attain 75% less energy intensive new building stock by 2020 [10]. While a growing awareness of passive building design is apparent in both countries, they also possess similar barriers to widespread adoption. Shared obstacles include unfavourable economic conditions for new construction, consumer avoidance of upfront costs, political ignorance, weak policy initiative, perceived aesthetic or heritage impacts, and limited construction expertise [8].

District Heating

DH systems facilitate the economies of scale necessary to justify heat production from renewable energy fuel sources [11]. Benefits of DH include flexibility on fuel sources (including renewables and functional use of waste heat from industry) which helps shield DH from price fluctuations, competitive pricing and centralisation of emissions. These efficiency gains can be further bolstered through the use of Combined Heat and Power (CHP) co-generation in unison with DH transmission infrastructures [12]. CHP systems generate electricity while capturing the functional heat by-product of power generation [12]. Integrated CHP and DH networks allow captured heat to be transmitted and utilised in industrial and residential complexes, or stored for later use.

DH networks are applicable in most dense urban areas. Networks can currently be built up to 30 km from heat generation sources [12]. The main hurdle in constructing new DH networks is the sizeable initial and long-term investment required. Within Denmark and Sweden, municipalities often undertake the role of initiating projects, and national regulatory support initiatives have streamlined this process [12]. Public acceptance of large-scale heating and energy solutions has also proven to be high in Scandinavia, which contributes to the rapid growth of DH systems [11].

The main barriers associated with the implementation of DH systems are the steep initial capital investments required to establish infrastructure, along with the responsibility of system supervision by municipalities or private owners. The prioritisation of efficient heat and energy production has lessened resistance to the upfront costs associated with DH systems, as have national carbon reduction targets [12].

Beyond initial investment cost concerns, DH is also subject to competition from the electric heating market. In past decades, low electricity costs often priced out DH schemes from the market. Efficient electric heat pumps can provide approximately the same level of heating offered by DH at equal or lower prices [11].

Individual Heating Systems

Individual heating systems for buildings are the main alternative to centralised heat delivery infrastructure. Within this sector, a competitive market for heat pumps in residential buildings has developed in Scandinavia. Heat pumps function by absorbing and transferring energy from heat sources to sinks. Heat pumps have established a strong presence in Sweden and are a prioritised technology in Denmark. This makes heat pumps a significant competitor to DH systems. The reasons behind this include favourable market conditions (decreasing payback period, pricing advantages vs. fossil alternatives) along with high level of compliance with national energy strategies promoting "clean" energy futures.

Heat pumps can provide a majority of the heat required by detached residential buildings, but are most often used as efficient complimentary heat sources in structures with alternative primary sources (i.e. boilers, electric heating, DH etc). This is because heat pumps are designed to service heat demand outside of peak load demand (i.e. during the one to two weeks of coldest winter periods or hot summer periods).

The complimentary aspect of heat pumps is most evident in retrofitted homes, as significant and costly renovations would be required to optimise the benefits accorded by a heat pump. Conversely, newly-built structures with robust heat pump ventilation can function with minimal reliance on supplementary systems. Such new build heat pump systems can satisfy around 80 to 90% of their annual thermal demand, obtaining a relatively-high 50 to 60% of the thermal power needs during peak load demand periods [6].

Sweden's heat pump market is exemplary in Europe, representing one-fifth of global ground source heat pump capacity and with the highest capacity per capita in all of Europe [13]. Nationally, heat pumps are the most common space heating unit in new constructions and retrofitted single family dwellings, to the point that during the mid-to-late 2000s, ground source heat pumps accounted for nearly three-quarters of implemented heating solutions within the retrofitting sector [13].

Denmark has placed heat pumps, in combination with DH, at the forefront of their strategy for reaching a "fossil-free future" [14]. They are currently looking to utilise the successful strategies used in Sweden in order to improve upon the estimated 40,000 installed heat pumps in Denmark that currently provide 0.4% of national residential heat demand [14].

Looking to the Future: Declining Heat Demand

The economies of scale that make DH more competitively priced compared to individual heating solutions can be degraded in areas of low heat demand [15]. Low heat demand is usually associated with areas of low population density and / or a sparse dispersion of single home units. DH investment has often been avoided in such areas on cost-effectiveness grounds. Recent debate has highlighted future scenarios where widespread individual energy efficiency solutions in densely populated areas could result in similar reduced heat demand that would jeopardise the economic justification for DH infrastructure [15,16].

A high heat demand per unit area is necessary for DH to be competitively priced with local alternatives. Highly efficient buildings, potentially in combination with a widespread switch to individual heating systems (such as heat pumps), could theoretically produce a heat demand reduction large enough to disrupt the competitiveness of DH services. However, the timeframe within which conditions would become unfavourable for DH is unclear.

Few studies have examined the impacts that such a scenario might have on DH. Of the limited research that is currently available, a study by Persson and Werner at Halmstad University in 2011 is of interest [15]. This study modelled the impact of increasing energy efficiency on the cost-effectiveness of DH heat distribution networks, which are the main investment cost of a DH system. The researchers found that the low capital costs and economic competitiveness of DH in densely populated urban areas would be unlikely to affect the market for DH systems, even taking into account ambitious EU energy efficiency targets (i.e. 20% by 2020 and 50% by 2050). However, this study relied on an economic analytical approach and did explore associated environmental or social concerns in any significant depth.

How Declining Heat Demand Affects District Heating

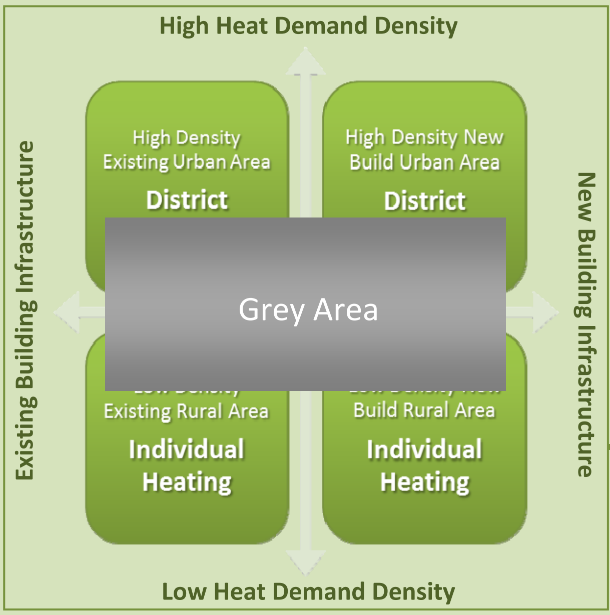
Given the above, there are three key factors to consider when deciding on the use of district-level heating networks or individual heating systems in increasingly energy efficient areas:

1. The heat demand density of the area (dense urban vs sparsely populated areas);
2. Whether the area contains existing building infrastructure or entirely new build;
3. Whether there is any existing DH infrastructure or potential for using waste heat from industry nearby.

Based on these factors, we have carried out a basic scenario-planning forecasting exercise until 2020 to determine how energy efficiency requirements in Denmark and Sweden may affect the cost-effectiveness of DH systems for various population densities and settlement maturity, shown in the figure below. Data was gathered from the literature and interviews with selected stakeholders. The year 2020 was chosen as it is a key date in Europe for delivering energy efficiency goals and because future predictions may be made less accurate by technological improvements and changing regulation. The main assumptions are:

- Building energy-efficiency in Denmark and Sweden will achieve set reduction targets of 20% by 2020;
- Energy prices continue to steadily increase over time in line with previous increases;
- Technological innovation does not dramatically increase DH efficiency; and
- DH technologies are not rendered obsolete.

Figure 1 presents the results of the scenario-planning forecasting exercise which compares the level of heat demand density (x axis) with building infrastructure maturity (y axis). The key conclusions were that DH remains competitive in dense urban areas despite declining heat demand, while there will be even less reason to use DH in sparsely-populated settings. However, there is a grey area for the cost-



Scenario-planning exercise to 2020 on the effect of energy efficiency requirements on the use of district or individual heating systems for varying heat demand densities (x-axis) and building infrastructure maturity (y-axis).

effectiveness of DH that depends on the population size and level of heat demand.

DH is likely to remain competitive in dense metropolitan districts and large cities for several reasons. One is that a stable demand exists in urban areas from multi-storey residential buildings, as well as large office blocks and industrial premises. Another is that the renovation of existing building stock in urban areas is not mandated (i.e. property owners choose if and when to renovate); consequently, there will be a slower uptake of energy efficiency measures in existing buildings. In existing urban areas, construction of new energy efficient building stock may decrease DH demand, but the number of new builds undertaken annually in these areas is typically quite low and therefore unlikely to materially affect overall heat demand.

Buildings in new build urban areas (i.e. new city districts such as Ørestad in Denmark) must conform to prevailing building regulations, and therefore will become increasingly energy efficient as time progresses. However, DH in these areas is likely to be a sound investment to 2020 as planned energy efficiency reductions in building codes by this date will not be sufficient to negate the need for DH solutions. Further, many new build districts are built in close proximity to existing cities, some of which possess their own DH systems that can be utilised.

In sparsely-populated areas, it is already well-established that implementing standard DH systems are typically not a cost-effective option [14,15]. This would be especially true in new build villages, where high energy efficiency requirements in building codes make individual solutions far more attractive. The most efficient option would be to use heat pumps, as other options (wood pellets, gas or electric boilers etc) can be less economical or emit more carbon per unit of thermal energy.

Despite this, there exist a number of instances of DH plants servicing rural areas in Denmark and Sweden. A prime example exists in the city of Aakirkaby on the Danish island of Bornholm. Spurred by progressive municipal goals for energy independence and renewable energy, a stand-alone, heat-only DH plant utilising locally-grown wood chips has been established in a rural area of around 1,300 households. As little population expansion is expected, there will be a negligible increase in future heat demand density that will be further eroded by gradual energy efficiency gains. While this approach may be cost-effective from economic and environmental perspectives in the near-term, the long-term viability is unclear.

A Decision-Making Framework for Heating Energy Efficiency

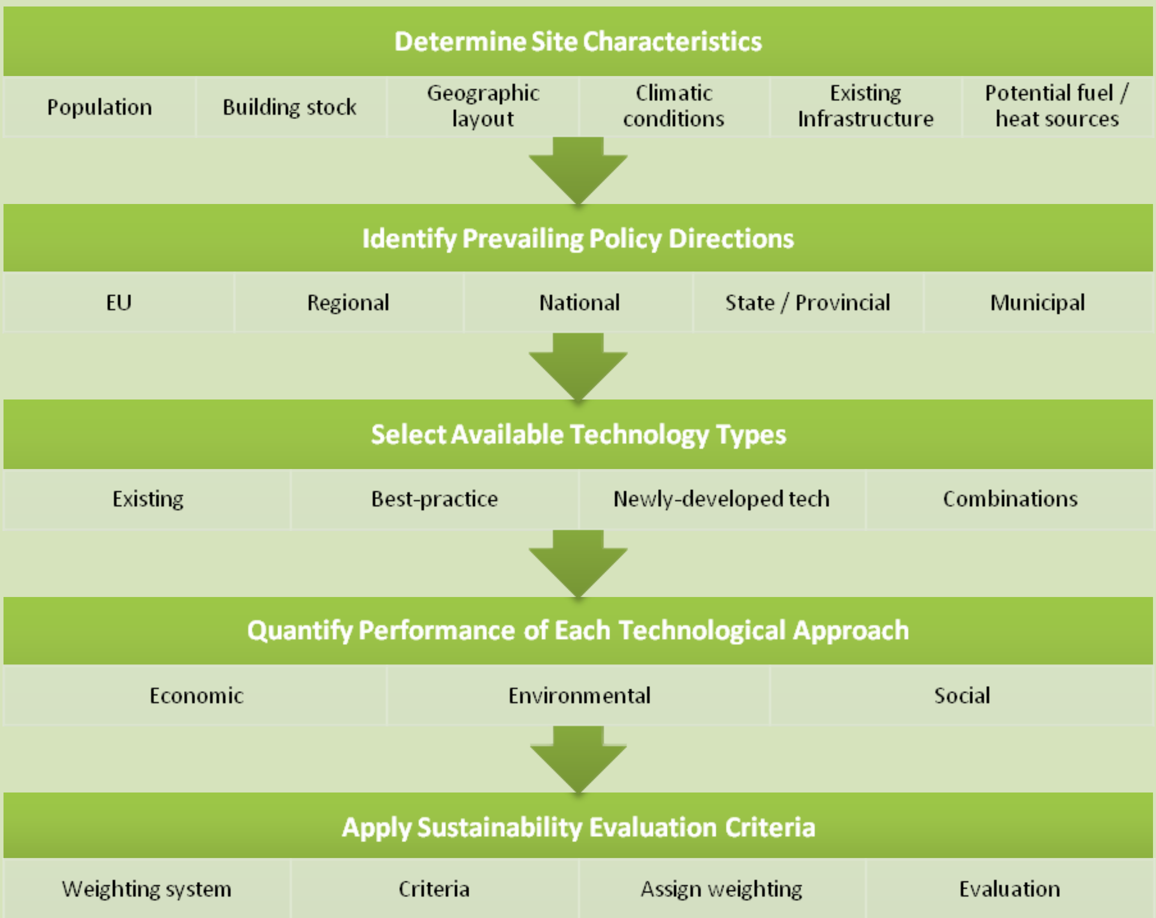
Clearly, decisions on the appropriateness of a district-level or individual heating system are a function of the predominant decision-making framework that policy-makers use to determine the most cost-effective system from a suite of available technologies. Any such framework must take into account a number of important factors, including settlement characteristics, prevailing policy directions and available technology types. However, as discussed previously, in Denmark and Sweden there is some evidence of a divergence at various governance levels in the strategic approaches employed to implement energy efficiency, resulting in conflicting or competing policy decisions. This occurs due to a number of factors, including insufficient consideration of policy directions at the various governance levels, blanket support for approaches that are in many instances only selectively appropriate, as well as failure to effectively communicate both within governance structures and towards stakeholders.

What is needed is a decision-making framework that aligns cost-effectiveness with other sustainability goals, as energy efficiency delivers numerous environmental and social benefits.

To this end, we have developed a decision-making framework for the selection of the most appropriate energy efficiency measures for a given area. This framework can be used at any governance level to determine the most appropriate technological approach to deliver energy efficiency goals in combination with sustainability principles. The five-step process aims to facilitate communication and consideration of both context and policy by providing a logical information flow that informs and narrows the focus in ensuing steps.

The first step is a data-gathering exercise to determine the functional **site characteristics** of a defined area from which cost-effectiveness can be established. Secondly, the overriding **policy directions** of each governance level are considered. This entails a comparison of complimentary, divergent and conflicting policy goals to determine where synergies exist and potential conflicts arise. The third step involves a review of **technological options** to deliver energy efficiency that accounts for prevailing site characteristics and policy directions. Here, any relevant examples of existing, best-practice or newly-developed technology are identified, as well as combinations thereof. Based on the information derived from the previous three steps, as well as available data from industry, the economic, environmental and social costs and benefits are **quantified for each technological approach**. The result of this step is a matrix of the functional criteria for a number of potential technological approaches. The final step, **evaluation using sustainability criteria**, involves the application of a weighting system that more equally emphasises economic, environmental and social impacts.

An important aspect of the framework is that it must be aligned with policy objective time horizons to ensure that the most appropriate options are considered and selected. For example,



Decision-making framework for the selection of the most appropriate energy efficiency measures.

if energy efficiency goals to 2020 are adopted, one or several technological approaches might be appropriate, e.g. site-specific combinations of DH, heat pumps and increasingly strict building codes. However, under 2050 goals it is more likely that DH would be less favoured.

Key Conclusions

Stricter energy efficiency measures for buildings, and competitively-priced individual heating solutions, are very likely to influence the cost-effectiveness of DH in the long-term. However, it is difficult to determine the approximate point in time that this will occur, as numerous factors such as increasingly stricter policy, improvements in technology and changes in behaviour are hard to predict.

This study found that energy efficiency improvements in existing urban areas are unlikely to jeopardise the attractiveness of DH in this timescale. A similar situation is expected in newly-built dense urban areas, as improving energy efficiency in building codes to 2020 is unlikely to appreciably reduce heat demand in urban areas. However, sparsely-populated areas with low heat demand density will remain poor candidates for DH unless site-specific and cost-effective heat sources are nearby (i.e. existing DH infrastructure or industrial waste heat).

What is clear is that site characteristics and prevailing policy directions impact heavily on whether DH is a viable option. The proposed decision-making framework would go some way towards aligning energy efficiency goal at various governance levels whilst considering the site context and available technologies. It also facilitates better communication through information exchange and generates a stronger case for a selected technological approach.

Finally, given the lack of research in this area, future studies should examine the point where building stock in both existing and new build urban areas reaches efficiency levels that make DH unfavourable under varying timeframes.

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SEASONAL HEAT STORAGE

Lessons from Germany and Denmark

By Lea Baumbach and Mauricio Lopez

Climate change and peak-oil confront all countries with the necessity to reduce both their dependence on fossil fuels and CO_2-emissions. Besides the trend to increase energy efficiency, the chosen strategy is the deployment of renewable energy sources.

In northern countries, the main energy consumption of private households is from spatial heat demand during the cold season from October to April. However, the sun radiation is strongest in the summer months from May to September; two thirds of the annual radiation can be collected during these months. In order to make use of the sun's thermal energy for northern countries, the excess heat during summer months must be stored for several months.

Furthermore, the use of combined heat and power generation (CHP) is typically used as a strategy in member states of the European Union where a district heating system exists. Denmark is one of the leading countries in Europe with 60% of households being connected to district heating. This existing network and the pressure to increase the use of renewable energy sources, like solar heat, has led to a growing interest to integrate seasonal heat storage, often, but not necessarily in combination with large-scale solar-thermal collectors. These technologies have been developed and tested in countries like Denmark, Germany, Austria and also Sweden [1].

The following paper aims to give an overview of the existing seasonal heat storage technologies and their application in selected case studies in Denmark and Germany. Furthermore it will derive practical and economic parameters (success factors) from these case studies which will help to provide guidance for the Energi Öresund project to decide if and how to integrate seasonal heat storage into their final energy strategy.

Overview of Technology

For long-term heat storage a variety of technologies are being researched differentiated according to the storage medium: underground thermal storage uses the natural underground layer like rocks, sand and clay. More recently the research has been extended to phase-change materials (PCM) and chemical reactions. The following four concepts are the most commonly used:

Both borehole thermal energy storage (BTES) and aquifer thermal energy storage (ATES) require specific geological conditions to be applicable, due to the nature of the technologies: BTES relies on drilled holes that provide heat to the surrounding soil, which acts as the storage medium consequently; it depends on the type of soil on which the BTES are built. However, ATES consists of using wells to transfer heat to a natural aquifer; the aquifer itself requires special thermal conductivity and natural groundwater flow conditions to be a good option for storage [3]. In both cases, it is possible to build an effective and cheaper heat storage system when the conditions are present, but if that is not the case, it is only possible to develop either the pit or tank energy storages which we will focus on in the following part.

Novo et al. [4] define tank and pit storage as man-made aquifers. In contrast to boreholes and natural aquifers hydro-geological conditions at the specific site are not as relevant for these concepts. The analysis of the solar district heating plants combined with seasonal storage in Europe shows that a higher number of plants have been built which use natural aquifers, while borehole-projects are not as common as tank and pit heat storages.

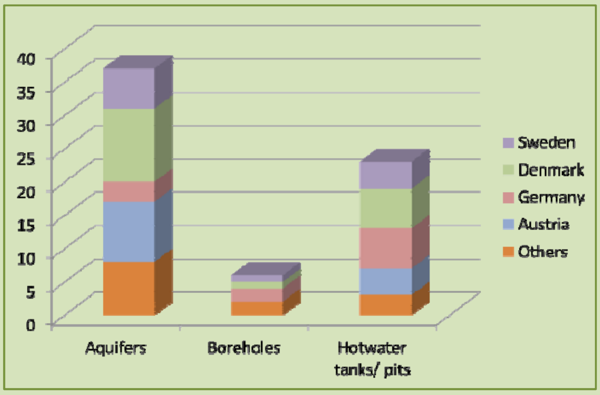
In contrast to aquifers and boreholes, man-made aquifers are insulated both on the top and along the walls. The insulation material must be sealed from water steam in order to keep thermal conductivity to a minimum over the planned use period which is up to 30 years [5]. While tank thermal energy storage is based on either a concrete or a steel body filled with water, pit thermal energy storage can also be filled with a mix of water with gravel, sand or soil and contain a water filled piping system.

The use of hot water or a mixture of water with gravel, sand or soil can have different effects on the overall performance of the system, with various advantages and disadvantages concerning each. Hot water pits have a larger thermal capacity than gravel, sand, or soil pits because of the heat absorption properties of the water. This results in shorter charge and discharge times for the hot water storage. Hot water also allows thermal stratification which increases the efficiency even more. Maintenance and leakage issues can be addressed in a hot water pit, which in the gravel, sand, or soil pits is impossible due to the fact that once filled it is virtually impossible to repair the pit.

On the other hand, the advantages of the gravel, sand, or soil pits include higher stability of the surface of the pit, which can then be used for other purposes, which is especially advantageous in urban areas where building area is scarce and expensive. Safety concerns are significantly lower. The lid itself is less expensive in the gravel, sand, or soil pits and it is much less complex to build. Although less costly as a whole, costs result from the interim buffer which is necessary for charging the gravel, sand, or soil pits and the provision of the pit filling. Even if it is more expensive, when the thermal efficiency of the system is the ultimate goal hot water pits are more convenient [6].

The storage size also plays an important role in the energy efficiency of the storage facility because heat loss depends on the surface-to-volume ratio. A small storage facility will have a much higher ratio than a bigger one, and thus the overall heat loss will be greater in the smaller facility. For seasonal storage, the facility can be considered efficient from a minimum of 1000 m³ of water [7].

The heat storage is only one component of the system. The long-term heat storage is connected to a pipe-grid that connects the storage with the consumer, either a residential area with several houses or a single consumer like office complex. The energy source in most



Number of plants in Europe built until today by country. Data collected from: [9]

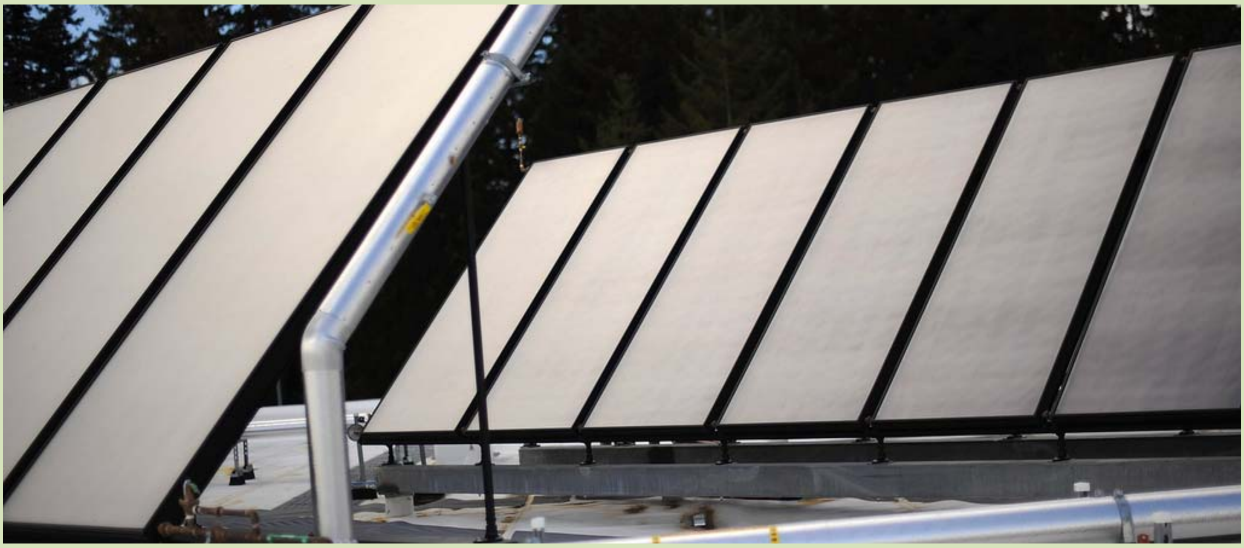
cases is a solar thermal collector field. However, excess heat from any other sources, e.g. industrial processes can be stored. In order to use the whole heat potential (below 35°C down to 10°C) or use the storage also for storing cool, a heat pump can be added to the system [4]. Most heat storages are only providing a part of the heat needed by the consumer during winter. The additional heat required is therefore usually provided by decentralized boilers.

The development of these technological features has not been isolated. Both the solar collectors and the storage facilities have been developed in the last decades, although the progress in storage technologies has been slower than expected.

History of Man-made Aquifers

Starting in the mid-1970s seasonal heat storage was investigated in Europe. Sweden was one of the first countries to build demonstration plants in 1978 and 1979 in Lambohov and Lyckebo [4]. However, after unacceptable high temperature losses due to leakages and moist insulation, Lambohov ceased operation and Sweden did not continue to build demonstration plants after the mid-1980s [6]. Denmark continued the development of these technologies during the late 1980s, while Germany started the research and construction of plants in the early 1990s. Within a comprehensive national R&D program called Solarthermie2000, Germany co-financed the construction of eight heat storage plants in the country of which five were man-made aquifers [1, 5]. While in other countries the interest in seasonal storage ceased until the current day, Germany and Denmark are still active creating and researching new plants [1].

In all countries the plants were first built in order to demonstrate that the concept of storing heat in huge aquifers actually works and to collect experiences and data about the construction process, building and insulation materials, functional performance, and design. The first plants were small-scale (less than 1000 m^3). Due to the findings of this first wave of demonstration plants, the research has moved further to improve the efficiency of the storage systems, with respect to heat-loss, cost reductions and capacity use of the storages. Often the charging systems have then been extended over the following years in order to use the storages to their full capacity. The case study on Chemnitz (see below) is an example



The technology for solar heat collectors is being constantly updated; yet, the development of seasonal heat storage technologies has fallen behind.

of an initial development of storage facilities and further development of the heat collection system in following stages.

Since the end of the 1990s, the newly built demonstration plants tended to increase in size and the design and material use became more elaborated. The studies regarding the shape and thermal stratification of the pits and tanks was also developed [3]. The combination of charging sources and storage systems then came more into focus as can be seen both in the case study of Chemnitz and in the case study of Marstal in Denmark.

Based on the evolution of 30 years of research, it becomes clear that there is still no standard concept for man-made aquifers. The projects in each country are developed due to the specific circumstances on the spot within the framework of research projects and show-cases [8]. It is estimated that by 2020 seasonal heat storages will reach the stage of being conceptualized and market applicable.

Case studies

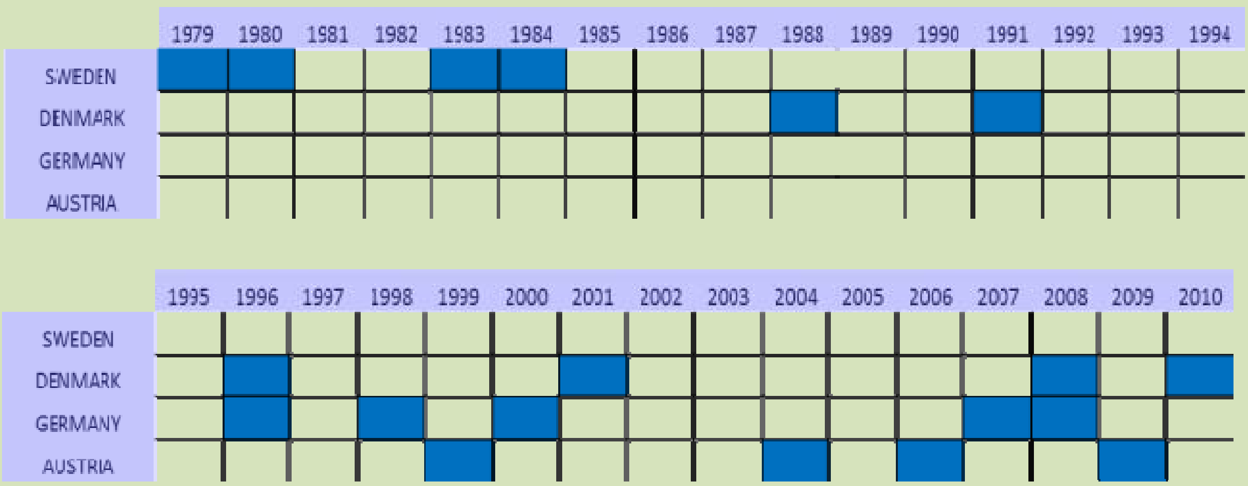
Chemnitz, Germany

In Chemnitz, Germany an 8 000 m³ gravel-water pit storage was built to provide a large office building, the Business Center Solaris, with heat. The project was based on collaboration between the University for Applied Science of Chemnitz, the University of Stuttgart and a private investor. The project was co-financed by the federal program Solarthermie2000. The project's aim was to show-case a larger scale pit heat storage than any storage built before while proving the positive economic effects of this scaling up.

The major share of the costs resulted from the construction of the water-gravel storage (29%), the collector field (28%) and supporting infrastructure (28%). Lower construction costs were achieved thanks to synergenic effects with legal circumstances: In 1996, contaminated soil had to be excavated from an industrial premise, creating the pit needed for the storage.

Indeed the costs per kWh heat were below the costs of the other storages in Germany during that time. The overall construction costs of the original plant were estimated in EUR 2.2 million, leading to heating costs of 0.24 EUR per kWh [9], which still is not competitive with heating costs from conventional sources.

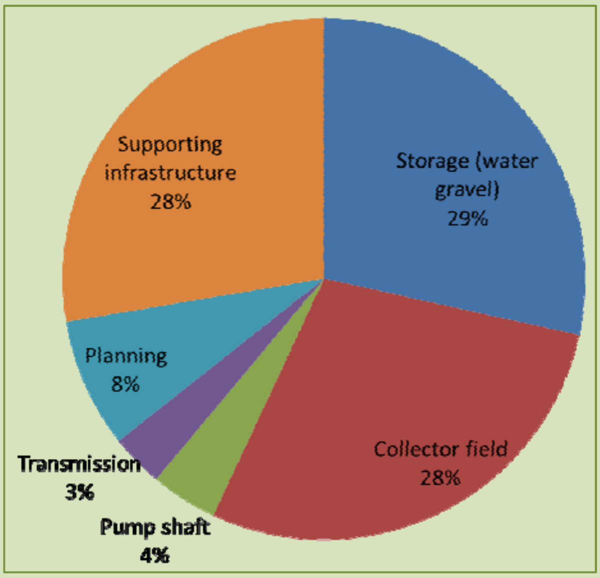
A solar thermal collector field was connected to the pit heat storage which supplies the 4 680 m² area of the Business Center Solaris



Construction timeline of man-made aquifers, most representative countries. Data collected from [9].

with energy. The storage is covered by a static lid which is used as the basis for a parking lot and a road thus not leaving the area above the storage unused [5]. The storage was originally planned for a temperature range from 45 to 85 °C. After the first installation of 540 m² of solar collectors, the maximum storage temperature only reached 60°C, leading to a 45% utilization degree. In 2000 a CHP plant was connected to the storage system, leading to a further increase of utilization [9]. In 2010 the collector area was extended to the originally planned 2 000 m² and reaches now a utilization degree of 61% [4].

Important lessons which can be drawn from the pit heat storage in Chemnitz: the concept of the gravel-water filling helps to preserve the functionality of the site under which the storage is located. However, it has the disadvantage that leakages of the lining cannot easily be fixed. The case study also proves that an increase of storage size leads to gains in performance of heat storage. Significant cost reductions for a pit heat storage can be realised when the excavation of the pit has to be done anyways due to legal regulations, for instance the cleanup of brownfields. Despite the improved design, it was not possible to achieve competitive prices for the heat in comparison to conventional sources.



Distribution of costs in Chemnitz. Data collected from: [9]

Marstal, Denmark

Marstal is a project that began in 1994 when Marstal District Heating initiated a project of a 75m^2 thermal solar heating plant. The results were good enough that a full-scale thermal solar heating plant was built two years later to further test the technologies and the conditions involved. The upscale included the extension of the plant until it reached a 2 000 m^3 volume for the storage tank.

After this the Marstal plant was subject to further expansions as a result of the SUNSTORE 2 project, extending the volume of the storage facility up to 10 000 m^3; the last expansion was made when the SUNSTORE 4 project was launched in 2010, which will ultimately expand further the heat storage facilities up to 75 000 m^3 in 2012. Financial support from the Danish Energy Agency and the EU 5th Frame program allowed Marstal to realize these expansions. At the current state of technology, public funding is still needed to finance the construction of these systems.

The most interesting aspect of this project is the combination of the different technologies of a water tank, a sand-water pit and an insulated water pond; that converge into a single system, besides the energy storage technologies used; the energy is provided by solar collectors and a CHP system, combined with bio-oil boilers. The heat is carried by heat pumps to and from the energy storage facilities, while the electricity is generated at the CHP biomass plant with an ORC (Organic Rankyne Cycle) unit, which can produce electricity with low-temperature heat. The whole system has been envisioned as a model of a community with a complete supply of energy through renewable sources.

The project is expected to be completed by 2012 with very ambitious targets in terms of cost efficiency: the cost per kWh is expected to be between EUR 0.03-0.06, while the total energy production costs are expected to be of EUR 78 per MWh_{th}, with an average investment cost of EUR 33 per m^3 for the pit storage facility [10].

Lessons Learned

If there is the objective to increase the use of solar-thermal energy, seasonal storage is needed when a mismatch between the radiation period and the heat demand phase exists. A number of conditions have to be fulfilled in order to include a man-made aquifer into the heating system:

- There are no underground caverns or aquifers for BTES and ATES;
- National or international financial support schemes are in place;
- District heating grid exists or is planned;
- High heat demand during winter;
- Scientific/ technical knowhow is available;
- Sufficient building area is available.

Once the decision is made to build a man-made aquifer, it is possible to decrease investment costs and make the project more economical with the combination of different heat sources (i.e. solar thermal and excess heat from heat systems like CHP heat pump). The cost can also be reduced if the excavation of the pit is needed due to clean-up of brownfields.

The goals set by the Öresund region in terms of CO_2 reduction and the share of renewables in the energy mix (for both heating and electricity) make it necessary to think of solar heating as part of the equation. In that sense, the authorities responsible for developing a strategy have two options regarding the heat energy storage needed for this kind of system: they can wait until the technology is developed enough to be market ready or they can devise a strategy for the engagement in R&D that will allow them to regain a leading position in the international field of sustainable solutions. For this, the cooperation between local actors is essential: When local city governments, utility companies and manufacturers join forces, prospectives for successful projects on the long-term increase.

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HOT WATER CIRCUIT PRODUCTS

Hot Water Circuit Household Appliances

By Su Meiling

Hot water circuit (HWC) products presented in this paper are currently innovated by the ASKO company, which is a Sweden-based household appliance manufacturer. The HWC products innovation is a result of the Remote Viewing Project, which is a collaboration among the Swedish District Heating Association Ltd, ASKO Company, Dalarna University, Karlstad University and energy companies such as Gothenburg Energy and Mälarenergi. HWC products are expected to be brought into market in 2012 at the time when the Remote Viewing Project is completed [1].

Initiation

The Remote Viewing Project is initiated by the Swedish District Heating Association after identifying that the district heat supply in the Nordic market is beyond demand, given the fact that district heat energy supply is just under 30% in the Nordic region, which is much higher than the international standard. Thus new potential areas that could be equipped by district heating need to be identified in order to create new markets for the district heat supply.

The objective of the Remote Viewing Project is to demonstrate that district heating could be used in *Real Areas*, which are areas with low heat density that are previously neglected [2]. The joint partner ASKO company, cooperating with Dalarna University and Karlstad University, has developed HWC products allowing washing machines, dish washers and dryers to be directly connected to the hot water supply of the district heating network. The aim of this project is to develop techniques and systems that function in an environmental friendly way by saving electricity consumption through the use of hot water to power household appliances [3].

Market Analysis

Dishwashers and washing machines with the function of connecting to hot water came into existence on the market in the 1980s [4]. Yet household appliances with hot water feed have been phased out of the market gradually until now by the claim that cold water runned machine are more efficient.

Manufacturers claim that washing machines with only cold water feed are 40% more efficient than hot water runned machines [5]. Further, cold water filled washing machines save money by avoiding the installation of a hot fill hose, hot valve, wiring to the hot valve and hose from hot valve to the dispenser. In addition, it no longer takes much water for washing, if higher temperature is needed, water could be heated inside the machine by electricity at the amount needed. This saves energy compared to heating water previously in large volume. Further, there is a problem that pre-heated hot water supplied by domestic boilers normally becomes cold when it arrives into the machine, and needs to be heated up again.

However, there is potential benefit for customers who have hot water supplied from renewable energy resources which allows hot water supply at a much lower cost [6]. Thus, there is an ongoing debate on using cold water filled washing machine or hot and cold water filled washing machines in the market.

Working Mechanism

Performance

HWC products manage to achieve an accomplishment of hunting two birds with one stone. On one hand, it saves electricity from the heating process water in the machine which is the main part of electricity consumption. Instead, the process water in the machine is heated up by hot water that runs into the machine via a heat exchanger. On the other hand, it enables a system technical advantage by creating a closed hot water loop which keeps temperature constant. It solves the typical problem of hot water fill machine that hot water supply from domestic boiler is energy-intensive. As mentioned before, hot water from a domestic boiler becomes cold when it reaches machine and needs to be heated up again which is inefficient [1].

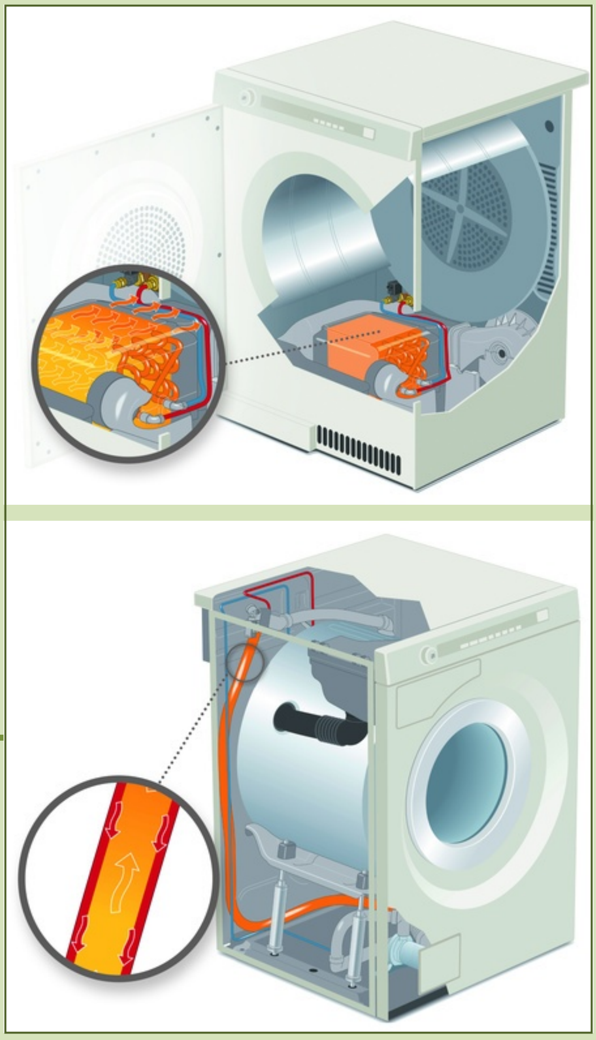
Principle

HWC products could be connected to the hot water circuit from renewable energy heat supply, such as district heating, solar energy and geothermal energy. New components of heat exchangers, new connections, heating water valve, and updated software are added to HWC products and the electricity heating-up system is still retained as backup system [7].

One of the two new connections adds flows of hot water from the hot water supply circuit and the other one leads the water back to the heating plant after the heat exchange. These two new connections substitute the conventional electricity heater.

For dryers, especially, larger condenser and circulation fan engines are needed to ensure working efficacy.

Hot water flowing into the machine to heat up the process water has a minimum temperature requirement of 55°C. Normally, heating hot water should be 10°C higher than process water requirement. For example, if the process water needs to be at a temperature of 60°C,



HWC dryer (above) and HWC washing machine below [7]

Orange: heat exchanger
Red: hot water included
Blue: outgoing hot water
Magnification: Heatwater (red) heats the process water (yellow to orange)

then hot water supply at the temperature of 70°C is required in order to meet the heat demand. HWC washing machine and dish washer have high performance at the temperature of 60°C.

Back-Up System

As the heat exchange happening between hot water and process water, the temperature difference will decrease and the heat exchange efficiency goes down. When higher temperature is required, the electricity system will be switched on automatically to heat up the process water [4]. It could of course also be used in the situation when there is no hot water supply.

Demonstration Projects

Several demonstration projects were implemented in different areas, such as Gothenburg and Västerås, to prove that more could be done to make use of district heating to replace electricity by ensuring energy efficiency and increasing household comfortability. These projects are regarded with high environmental value, because environmental impact is significantly reduced, given the fact that electricity results in large CO_2 emissions [4]. HWC products are equipped in the building connected to a new circuit from a district heating plant in about 200 households with new, non-conventional installations [8]. Sparse heat houses built in Gothenburg in 2006 equipped with HWC products strikes a successful case by demonstrating that HWC products achieved 697 kWh electricity consumption reduction annually. It represents 80-90% of the electrical energy consumption for household appliances [1]. In other words, HWC products could help households save up to 90% of this consumption per year.

Barriers

Even though there are successful cases to demonstrate HWC product efficiency and environmental efficacy, there are several challenges for HWC products to overcome for its commercialisation at large scale based on current market analysis.

Cost of installation

HWC products can only be installed primarily with new construction of a building with new circuit built connected to district heating plant or other renewable energy heat supply. It would be expensive to install HWC products afterwards into single households [9].

Public acceptance

As mentioned in the market analysis sector, hot water-filled washing machines have been on the market for decades but their sales gradually decreased.

The manufacturers are now more focusing on only cold water filled washing machine production with the innovation of detergent technology. More attention is shifting to increase cleaning efficiency of detergents that could be used in cold water. For instance, biological detergents could only be used in water at temperatures below 40°C, otherwise the enzymes contained in the detergent would die off [5]. Thus it makes the hot water filled function unnecessary and connected to additional cost.

In addition, there is an argument that hot water decreases washing efficiency by increasing washing time, and it adds extra wear and tear to the washing machine.

Large-scale commercialisation

Besides ASKO company which is the research leader on HWC products involved in the Remote Viewing Project, no other household appliance manufacturer seems interested in this topic so far. There lies a challenging question how to convince the home appliance industry to make products with consideration of the interest of district heating and thus increase HWC product production and broaden its market?

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Pictures of ASKO products reprinted with permission from the company.

LEGIONELLA IN LOW-TEMPERATURE DISTRICT HEATING

By Charlotte Luka & Veronica Andronache

District heating (DH) refers to a distribution network of heat which is centrally generated and serves the requirements of commercial and residential units both in terms of space and water heating.

DH has the advantage of producing heat in an efficient manner, in particular when waste heat from electricity production or industry is used. An effective DH system is considered to have as low as possible supply temperature and a high difference between supply and return temperatures. Traditional DH systems supply highly pressurised water at temperatures ranging from 80 to 150 °C and return temperatures between 40 and 70 °C [1]. By decreasing the supply temperature in DH the potential performance of combined heat and power stations increases by allowing a higher electricity production, simultaneously with lowering fuel consumption [2]. In addition, heat losses in the piping system are reduced and the possibility to use waste heat from other systems becomes more viable.

Many municipalities are becoming increasingly aware of the benefits of optimising their DH systems. For instance, Danish law requires the energy use in new buildings to be gradually reduced by 25% by 2020. This poses the question whether conventional DH is still suitable for areas consisting predominantly of these new low-energy-buildings or in areas with a low demand density. The problem stems from the reduced heating requirements of such buildings. If a conventional DH system was to supply low-energy-buildings, then a very significant part of the total heat demand of the system would originate from network heat losses in the pipes, rather than heat usefully employed within the houses [3]. Therefore the installation of a low-temperature district heating (LTDH) network would be both sufficient and less wasteful for low-energy buildings. In particular, engineers have identified a system based on high-class insulated twin pipes of small dimensions to be extremely energy efficient [4].

The LTDH concept promises reduced heat losses, heat generation and distribution costs (by allowing the use of low grade heat and plastic pipes instead of copper pipes respectively). It is also more efficient, due to reduced pipe diameters and lower supply and return temperatures of 50 °C and 20 °C respectively [1]. According to Svendsen and Brand [1], the advantages of LTDH include reliable and easy customer operation, the option for sustainable sourcing at community level, which can be argued to apply to conventional DH as well. However, they offer the additional opportunity to use waste heat as a form of renewable energy and the possibility to use solar and geothermal heat with higher efficiency. New LTDH facilities are currently tested in the city of Delft in the Netherlands and in Lystrup, Denmark.

Legionella in Drinking Water Systems

Legionella is a type of bacterium of which more than 50 sub-species exist – a number which is constantly rising [5]. The type that is most dangerous to humans is *Legionella pneumophila*. It triggers infections which can range from mild fever, also known as Pontiac fever, to a potential fatal form of pneumonia - Legionnaires' disease [5].

The bacteria can occur in both fresh and saltwater at temperatures between 25 and 50 °C, with 32-42 °C constituting their ideal multiplying temperature range [6,7]. Legionella can be found in small numbers in natural water bodies, such as lakes, rivers or reservoirs, but prefers warm stagnant waters. This renders installations such as swimming pools, water tanks, cooling towers, air conditioning units and low temperature district heating systems particularly prone to them [8].

In order to prevent infections with Legionella, it is generally recommended that the temperature for storage and distribution of *cold water* remain below 20 °C. However, it is worth noting that Legionella can resist low temperatures for a long period of time and proliferate as the temperature rises [5]. In hot water systems, Legionella was isolated even at temperatures of up to 66 °C. At 70 °C, it is destroyed almost instantly [9]. Besides temperature, other conditions favouring Legionella occurrence and multiplication include the type of piping material, water being stagnant, the presence of a bacterial biofilm and amoebae [5,10].

Human contact with Legionella infested water is not necessarily a health hazard and drinking contaminated water does not usually pose a problem. Only deep inhalation of the water in the form of aerosols, as produced by showers, sprinklers or whirlpools can cause an infection. Contamination from person to person is not possible [11]. Legionella can affect anyone; however, people with other risk factors deriving from age, illnesses, immunosuppression or smoking may be particularly prone to be affected [5]. In the U.S. the number of reported cases of the disease reaches up to 1300 cases per year, with a much higher estimated number of unreported cases [12].

Several studies have shown that the Legionella risk is higher in old buildings with aged installations than in new buildings [13,14,15]. However, new buildings are also exposed to contamination risks, as the time lag between the setup of the water piping system and inhabitation by residents may allow for the development of a Legionella bacterial biofilm in the ambient temperature stagnant water in the pipes [16]. To prevent such risks, standard cleaning procedures of the system are recommended and the use of biocides could be considered [16]. Rubber and plastic components have also been identified as a significant source of Legionella [5]. Therefore the use of such materials should be avoided throughout the piping systems, but especially in the shower heads. A potential solution applicable to the shower outlets can come from a technical fix that can drain the water out after each use. This way the risk coming from stagnant water that can allow the formation of a biofilm that can host Legionella will be eliminated. In conclusion, a LTDH system needs thorough planning, together with continuous monitoring and regular maintenance works (e.g. flushing with hot water in order to avoid stagnant water and low temperature, deposit removal etc).

Legionella and LTDH

LTDH systems will not pose a problem in residential houses where the hot water from the plant is only used to heat the house, while the building's tap water supply is generated completely separately, for instance by a local boiler. However, massive energy savings could be achieved by combining the room and water heating devices when designing new buildings.

Four types of techniques are available to use the heat from the DH plant to heat the drinking water in a building. These include:

1. storage systems;
2. instantaneous heat exchangers – illustrated in Figure 1;
3. storage-loading systems; and
4. direct connection of the DH water to the drinking water supply [17].

These will be dealt with in turn. As we will see, the risk of Legionella renders instantaneous heat exchangers the only suitable device for LTDH systems.

Storage Systems

Storage systems involve big tanks in which large quantities of drinking water are stored. The water in the tank is heated up directly by the DH pipes, which run alongside it. The advantage of storage tanks is the availability of large quantities of hot drinking water all at once.

However, the storage of warm water over potentially long time periods in the tank significantly increases the likelihood of Legionella development [3]. This is the case even for normal temperature DH systems, where the incoming DH water will have a temperature of at least 60 °C. Legionella do not usually survive at this temperature and the water in the storage tank should theoretically reach the same temperature as the DH pipes surrounding it.

However, since the storage tank can be quite large, parts of it might not be fully exposed to heat from the DH pipes. Some of the water in the tank may therefore remain below 50 °C, creating ideal breeding conditions for Legionella. In LTDH systems, the incoming DH temperature will be too low to avoid the procreation of Legionella in household storage tanks altogether. Storage devices are therefore unsuitable for the heating of drinking water in households unless additional disinfecting measures are taken [17].

Heat Exchangers

Instantaneous Heat Exchangers consist of a system of thin metal plates that allow the DH water and the drinking water to run in a counter-current exchange. The DH water therewith heats up the drinking water very quickly and efficiently, allowing hot drinking water to be produced as it is needed.

The advantage of instantaneous heat exchangers is that, because the drinking water is heated only for a brief time period, the water does not remain stagnant in its heated state for as long as it would in a storage tank. The heat exchanger should be located as closely to the tap as possible, in order to avoid stagnant heated water in the pipes and it should not recirculate. This minimises the possibility for Legionella to develop [3].

Additional benefits include the fact that the counter-current heat exchange is so efficient that the water sent back to the LTDH plant is very cool, allowing for better operating conditions at the plant. The average heat exchanger further requires four times less space than an average storage device. However, one limiting factor is that this type of drinking water heating system is mainly suitable for customers with relatively steady consumption habits [17].

Example of an installed household heat exchanger

Storage-loading Systems

Storage-loading systems present a combination of the two devices described above. However, due to the fact that they also store warm water over long time periods, they appear equally unsuitable for LTDH systems.

Direct Connection

This involves a direct connection of the DH water to a building's water supply. While this system is not very common, it is occasionally used in industrial settings where large quantities of warm water are needed. Here again, LTDH seems unsuitable, as the temperature in the pipes of the system may well be low enough to allow for the development of Legionella. This is especially dangerous when the water is needed to produce sprays or other aerosols that may then be breathed in by factory workers and surrounding residents.

Focal & Systemic Disinfection

Focal disinfection methods are directed towards specific parts of the water distribution system, whereas systemic disinfection targets the entire water network, by providing residual disinfectants that can have a bacteriostatic (inhibiting) or bactericidal effect throughout the system [18].

The use of storage tanks may still be needed for those consumers that need large quantities of hot drinking water at once. Here, local disinfection of the storage tanks may provide a viable alternative. Disinfection methods that will destroy the Legionella bacteria include ultrafiltration, UV radiation, chemical disinfection, chlorination and the use of the antimicrobial properties of silver and copper. However, some of these methods are costly, complicated, and have serious limitations. They are therefore only feasible for use in industrial facilities.

According to Lin *et al.* [19], the copper-silver ionisation is the most reliable and convenient method for long-term prevention of Legionella at the moment. This method is also effective in eliminating pre-existing Legionella colonies, even at distal points. The recommended copper and silver ion concentrations for Legionella eradication are 0.2–0.4 mg/l and 0.02–0.04 mg/l respectively, falling within the EU's allowed standards of 2 mg/l for copper. Oral consumption is not a significant issue, as the ions are normally introduced in the hot water recirculation lines.

Despite the benefits rendered by the long-term eradication and recolonisation suppression of the bacteria and low comparative costs and maintenance requirements, this method also has its limitations. High pH values of water (eg. 8.5 pH in hospitals in the U.S.), the addition of anti-corrosives like phosphates, or low ion concentrations may negatively influence the success of the method. Two hospitals in Germany were unable to apply copper-silver ionisation because of the stringent national drinking water requirement of 0.1 mg/l of Cu [19]. It is also important to note that in some cases *L. pneumophilia* gained resistance to copper-silver ions after several years of implementation [20].

Other possible disinfection methods include point-of-use filtres with pore size of 0.2 µm [19]. Alternatively, residential units could theoretically disinfect storage tanks by heating them up to above 70 °C at least once a day [21]. However, this would require a separate boiler and thus defy the energy saving purpose of the LTDH system. However, in the case of an emergency need to disinfect a Legionella cluster, the heat-and-flush treatment is the one that is often recommended [19].

Case Studies

While suspected cases of Legionella have been detected since the early 1900s, it was the famous outbreak in 1976 in Philadelphia which cost 29 American legionnaires their lives that earned the bacterium its name [12]. In Europe, one of the largest outbreaks to date occurred in 2003 in Murcia, Spain with 449 confirmed cases and five fatalities. The outbreak was linked to a cooling tower belonging to a hospital [22].

Mathys, Stanke, Harmuth and Junge-Mathys (2008) [15] investigated the occurrence of Legionella in hot water systems of single-family residences in the suburbs of two German cities, Münster and Bielefeld. They found that private houses that were supplied hot water from instantaneous water heaters were completely free of Legionella. Meanwhile, a prevalence of 12% of Legionella was found in houses with storage tanks and recirculating hot water systems. The volume of the storage tank was found to have no influence on Legionella counts. Interestingly, plumbing systems made of copper pipes were more often contaminated than those consisting of galvanised steel or synthetic materials. Systems constructed less than two years before were not colonised.

What is significant for the present case study is that the type of hot water preparation had a marked influence. More than half of all houses using conventional district heating systems were colonised by Legionella. The key factor leading to intensified growth of Legionella was thought to be a significantly lower hot water temperature. Water with an average temperature below 46 °C was most frequently colonised and contained the highest concentrations of Legionellae. The study concluded water temperature to be "*the most important or perhaps the only determinant factor for multiplication of Legionella*".

This shows that even conventional DH systems carry the risk of Legionella contamination, despite their significantly elevated temperatures. An additional level of care must thus be taken when installing LTDH systems.

One example of a currently existing LTDH system is the testing site in Lystrup, Denmark, which was awarded the International District Energy Climate Award 2011. It tests two types of substations. Firstly, District Heating Storage Units (DHSU) act as buffer tanks, which allow a reduction in the diameter of the DH network. This resembles a traditionally used DH substation with a heat exchanger. The difference to conventional DH storage tanks is that the water is stored in the DH system, rather than in the household. Secondly, Instantaneous Heat Exchanger Units (IHEU) are being tested in some buildings. Due to the reduction in supply temperature to 50 °C, the heat exchanger (Danfoss XB37H) needs to be highly efficient and be able to heat domestic hot water to temperatures over 45 °C while keeping a low return temperature. In the experiment, the DHSU resulted in higher heat losses and costs, while the IHEU needed a by-pass to keep temperatures comfortable during the summer [1].

Importantly, the project developers researched the dangers associated with Legionella and came to the conclusion that, due to the supply temperatures of below 50 °C, it would not be possible to use traditional DH storage tank substations.

Potential Barriers to Implementation

The installation of LTDH systems make sense especially in areas where a lot of new low-energy-houses are built at once. In this case there will be a sufficient number of energy-efficient houses in the region and therefore the municipality will be able to request the installation of instantaneous heat exchangers.

As discussed above, the risk of Legionella means that LTDH systems will be suitable in three situations:

1. Residential houses with separate heating facilities for hot drinking water;
2. Residential houses with Instantaneous Heat Exchangers; and
3. Industrial facilities, hospitals and other large institutions with access to appropriate disinfection measures.

Due to the risks associated with drinking water quality, disinfection technologies supporting the copper-silver ionisation may require approval from relevant bodies before being put on the market [19]. Not only can this delay their application, but also increase costs.

Conclusion & Recommendations

The installation of a LTDH system is a costly and lengthy process, but one that could generate large energy savings if implemented correctly. In order to promote the successful implementation of a low-temperature district heating system, a municipality should take the following recommendations into account:

- Since LTDH is only suitable for new houses of high energy efficiency, the municipality should ensure that such houses are built with the correct internal heating appliances. In other words, regions for which an LTDH system is under serious consideration should create a planning requirement for new houses that renders the installation of instantaneous heat exchangers obligatory. Not only are such heat exchangers more energy-efficient than conventional water storage systems but they further reduce the risk of Legionella infection to a minimum.
- In order to avoid the warming up of the cold water in the drinking water pipes, which can activate the bacteria, good insulation and safe distance between the pipes is recommended for the entire transportation length of the water.
- For industries that require large quantities of hot water, a connection to the LTDH system may be unsuitable, unless appropriate disinfection measures are taken.
- At macro level, it is recommended that water supplies should undergo routine testing for Legionella.
- Because Legionella recolonisation has been associated with periods of flow interruptions due to construction or low usage (for instance in vacation periods), it is important to conduct maintenance flushes in order to make sure the any disinfectant agent reaches all outlets.

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"District heating station" photo taken by Veronica Andronache on December 4, 2011, in Lund, Sweden.

"Heat exchanger" photo taken by Thomas Lindhqvist in Sweden.

LONG-TERM STORAGE OF HOUSEHOLD WASTE:

Enabling Waste-to-Energy Recovery

By Sarah Czunyi

The search for new, clean energy alternatives, in combination with waste reduction targets have led to a favourable environment for the expansion of waste-to-energy recovery schemes, in particular, incineration facilities. However, some practical challenges remain. The Energi Øresund group identified a knowledge gap specifically with respect to the long-term storage of household wastes, and this report identifies existing challenges as well as future potential in this area.

Drivers for Waste-to-Energy Recovery

The current push towards waste-to-energy incineration is driven largely by two European Comission (EC) Directives: Landfill (1999/31/EC) and Renewable Energy (2009/28/EC).

The EC Landfill Directive lays down strict requirements for landfilling, also including an aim to phase out the landfilling of biodegradable wastes. The overall objective of the Directive is to reduce both environmental and human health impacts from landfilling, and encourages a life-cycle perspective of wastes [1]. Resultantly, landfilling is the least desirable option in the European waste hierarchy, but this raises the challenge of how to deal with wastes that are created, even after complying with all prior levels of the hierarchy: reducing/reusing/recycling.

Nations' implementation of the Directive has led to the introduction of landfill taxes. The aim of these taxes in conjunction with other instruments – such as banning landfilling for specific waste streams, and recycling and energy recovery targets – is overall to reduce the amount of waste that goes to landfill and improve environmental performance with respect to wastes. Denmark and Sweden currently have amongst the highest landfill tax rates in Europe, and have concurrently also introduced landfill laws which ban the dumping of organic and combustible materials, which are typically directed towards waste-to-energy recovery schemes [2].

The EC Renewable Energy Directive sets out a vision for 2020 to increase renewable energy by 20% and cut greenhouse gas emissions by 20% [3]. This will require significant changes to be made in the energy mix, creating a high demand for new 'clean' energy sources. From the onset, the use of biomass for energy has been identified as a major component of reaching these energy goals, thus creating high potential for expanding waste-to-energy recovery schemes.

While Denmark and Sweden already have relatively high rates of waste recovery, these two EC Directives in combination with increasingly stringent national legislation for waste and energy performance are significant drivers behind waste-to-energy incineration schemes, and the consequent higher demand for waste storage.

Challenges

While there have been many advances of waste-to-energy incineration facilities, such as efficiency and environmental performance improvements, some challenges still remain. Household wastes are unique in their ability to be stored over long-term periods.

Seasonal Fluctuations

A major challenge faced by waste-to-energy facilities is due to the seasonal fluctuations in energy demand, alongside the relatively constant production of wastes year-round. In many cases, waste-to-energy is used for combined heat and power (CHP) generation, which in the European context faces the highest demand during the winter period. In Denmark and Sweden, these facilities are typically used for district heating [4]. Low demand for heat during the summer periods results in large volumes of waste which do not need to be immediately incinerated – thus creating the need for seasonal storage [5].

Additionally, the aforementioned landfill regulations are expected to increase the total amount of waste to be received by waste incinerators [6]. Changes in the composition of these received wastes, such as increased organic content, alter the way these wastes need to be handled. As such, the need to store wastes over long periods to deal with seasonal fluctuations in energy demand lead to further technical challenges. For household wastes the major challenges are: fire risk; energy content; and space/cost.

Fire Risk

Wastes that are stored for longer periods run the risk of self-ignition, which poses a safety hazard at the storage facility. Spontaneous combustion requires combustible material, an elevated temperature, and oxygen [4]. Due to the relatively high organic content of household wastes (vis a vis industrial wastes), there is a higher risk for spontaneous combustion of the wastes to occur due to the microbiological activity which takes place in the waste [4].

Moreover, fires are not only an immediate safety hazard, but also a long-term health threat as spontaneous fires create much higher emissions of carcinogenic and mutagenic substances, when compared to controlled incineration with flue gas cleaning [4].

Energy Content

The same process of biodegradation that may lead to spontaneous combustion, also reduces the energy content (i.e. calorific value) of the waste over longer time-periods. The initial composition of the waste also determines the waste's calorific value over the short to long terms – higher rates of organic content can lead to greater microbiological activity and thus faster breakdown of calorific value. Water infiltration can also impact upon energy content. Typically, the longer the waste is stored, the more the energy content decreases. For this reason, old waste often needs to be mixed with newer waste to ensure adequate combustion when taken for incineration.

Space/Cost

The storage of wastes generally imposes significant costs – both in terms of space and financially. Thus, facilities are looking at the most cost-effective way to store their wastes over longer time periods, while ensuring the wastes remain of high enough quality to allow appropriate combustion which meets the standards for both energy and environmental requirements.

Waste Storage Techniques

Generally, there are two broad methods for storing wastes for incineration, to avoid spontaneous combustion and preserve energy content over long periods: ventilated storage and compacted storage. In the first, the waste is dried and cooled by free air flow. However, there are practical limitations to this approach as often there is a risk for incomplete drying, leading to zones in the waste which can self-ignite in the presence of oxygen [4]. For this reason, only compacted storage methods will be explored. Within this category there are two major techniques: baling and loose storage.

Baling

The baling technique first requires the compression of the combustible wastes, which are then wrapped in plastic sheeting. The bales can be stored outside without high risk of air or water infiltration/leachate due to the barriers created by the plastic cover [7]. However, the risk of spontaneous combustion is not completely eliminated thus it is recommended to store the bales in sections which can act as fire breaks. Prior to incineration, the bales must be broken up again before feeding into the combustion chamber.

Numerous studies have identified baling as the 'best' method for long-term storage of household wastes [4,5,6]. The primary reasons for this are the features of: little to no environmental contamination; reduced volume through compression; and easier transportation of the baled waste [7]. There is also a growing acceptance that baling is the most appropriate technique to ensure lower biochemical activity of the waste (through minimal air flow through the compressed waste), thus ensuring maintenance of a high energy content and reduction of the risk for spontaneous combustion [6].

While plastic sheeting acts as a barrier to moisture and oxygen infiltration, thus allowing these positive characteristics of baling, it should be noted that this plastic is a fossil-based raw material that is energy- and resource-intensive to produce, as well as potentially harmful to burn. These characteristics may conflict with the overall environmental and human health goals of the EC Landfill and Renewable Energy Directives.

Loose Storage

The second technique also uses compaction prior to storage of the waste. However, in this method the wastes are stored without any further wrapping. The "loose" waste can be kept either in an enclosed facility (e.g. concrete silo), or outdoors in a facility that resembles a landfill – however, the waste is cleared once it is needed for incineration. Typically, the compacted wastes are stored in sections (either outside or indoors) to serve the same purpose as above – as fire breaks. In some cases, an impermeable layer is placed above the waste to reduce water infiltration. However, the primary concern for outdoor storage is fire, thus often there are soil piles placed above the waste piles, which can be spread in the case of spontaneous combustion (water is ineffective in such instances). Once waste is required for incinera-

Waste Storage Techniques: Baling (left) and Loose Storage (right) tion, it is transported directly to the combustion chamber. Typically, loose storage has lower costs than baling as it is less resource-intensive.

The major concerns with this technique, vis a vis baling, are the risks for leachate into the surrounding environment (water, soil) and greater microbiological activity (due to exposure to water and air in the case of outdoor storage), which may lead to fires and greater loss of energy content. However, there are numerous facilities with this type of loose storage that do not suffer from these problems [8, 9]. Appropriate design, monitoring and maintenance of the waste storage system can ensure that loose storage has as high value and is as effective as the baling technique to ensure appropriate combustion once the wastes are incinerated.

Case Studies: SYSAV and BOFA

In mid-November, a site visit was made to SYSAV in Malmö, Sweden. SYSAV is the most efficient waste-to-energy CHP in Sweden [8]. They receive both source-separated and mixed wastes, with the separated wastes from reliable sources going straight for incineration, while mixed wastes are sorted on-site. The sorting ensures that recyclable, compostable, and combustible wastes are all separated and directed towards their respective facilities. A small proportion which cannot be dealt with on-site are directed to landfill. SYSAV has an annual allowance of 550 000 tonnes of waste to use as fuel annually [8].

Due to the characteristic of low energy demands in the summer period, SYSAV has implemented a system for seasonal and longer-term storage of wastes. The facility has undertaken both baled and loose storage of waste. The predominant waste storage technique is loose outdoor storage, where the waste is compacted and then stacked in outdoor sections on-site. The storage area rests upon compacted clay ground (fairly impermeable), which is below sea level. A series of channels ensures that any water leachate is run through a water treatment system before being discharged out of the site, thus combating against potential water or soil contamination. The top of the stacked waste piles are lined with soil (derived from SYSAV's on-site composting facility), which can be easily spread to halt fire in case of spontaneous combustion. The waste piles are monitored regularly, including at night when security personnel conduct regular checks of the waste piles to note for any strange disturbance such as odour or fire. Excess wastes which cannot fit in this outdoor storage area have historically been baled (using an external contractor), and then either stored on-site or transported to another incineration facility.

The primary concern at the SYSAV facility with respect to the storage of household wastes

SYSAV Waste Sorting, Treatment and Storage Site in Malmö, Sweden has been the avoidance of fire. Previously, a differentiated tax system for household and industrial wastes required these wastes to be stored separately. Due to the high organic content of household wastes, this led to high internal temperatures due to enhanced microbiological activity. However, a new tax regime that has the same tax rates for both industrial and household wastes has allowed the SYSAV facility to mix these wastes prior to long-term storage. This enables a lower internal temperature of the waste by prolonging the time it takes for microbiological activity to take place, ensuring that fire is a minimal risk and energy content of the waste remains high [8].

A secondary concern has been how to keep the wastes dry – as this helps to maintain the energy content and enhances the combustion potential of the waste when it is brought for incineration. Some pilot experiments are being carried out at the SYSAV facility, such as simple coverage of the waste with paper sheeting.

Despite the concerns about fire risk and maintenance of energy content of the waste, SYSAV have chosen not to conduct baling as their primary long-term waste storage technique. The main barrier to bailing in this case is cost: SYSAV lacks the in-house expertise and equipment needed, and thus baling needs to be out-sourced, requiring significant costs including labour, raw material and transport. Moreover, the current system of loose outdoor storage has proven to be very successful, with no major incidences of fire reported, and the waste quality has been maintained to ensure enough energy potential for incineration [8]. However, it should be noted that the ability to mix household with industrial wastes seems a key component to ensure loose storage can be an effective mechanism for long-term outdoor storage of household wastes.

A Danish waste-to-energy facility – BOFA – located in Rønne, Bornholm, was also consulted in late November 2011 about their waste storage techniques. BOFA also stores compacted wastes (mixed household and wet industrial waste) without baling, but in this case the waste is stored in concrete silos, then covered with lime and dry wastes to prevent pests such as rats. Fire is not a concern, and baling has not been pursued largely because of high machinery costs [9].

Although BOFA has a different storage mechanism than SYSAV (storing the waste in a silo as opposed to outdoors), both facilities are high performers and have wastes of high calorific value which can be used for incineration after long-term storage.

These examples indicate that loose storage is as viable as the baling technique, although its effectiveness is dependent upon certain factors. These factors include: legislative requirements with respect to waste handling techniques; the ability to mix different waste types; and having an effective monitoring/quality control system in place to ensure early detection of risks such as fire. From a cost perspective, loose storage may also prove cheaper than baling, and a life-cycle perspective of resource use and environmental impact may show baling using plastics as having unforeseen negative environmental and health consequences.

Conclusions

Both baling and loose storage are effective techniques, and have been proven for longer-term storage of household waste in Denmark and Sweden. However, there are differences in terms of both performance and cost which must be taken into consideration when choosing which technique to implement. In-house knowledge and equipment have a role to play, as well as legislative and policy influences. Both techniques are appropriate in reaching final energy goals, the need to reduce landfilling of waste, as well as overall environmental and human health goals which are driving both waste handling and energy changes Europe-wide. Therefore, caution should be taken when advocating one method over another – as is the case with the current push towards baling.

On a more general note, the handling and processing of household wastes may also face changing pressures in the near future. As the demand for alternative energy sources increases, competing uses for different waste streams and types are likely to arise. For example, the organic content of household wastes may be desired for biogas plants – which can direct potential waste sources away from waste-to-energy incineration facilities. This may lead to challenges with acquiring the waste volumes necessary for full production capacity, and also may change the waste handling and storage techniques necessary to deal with differential waste compositions in waste-to-energy incineration facilities.

A final pressure is the changing legislative environment: as requirements for waste handling and energy production become more stringent to reach both national and regional targets, the technical requirements for waste-to-energy facilities may also be altered. Some municipalities have already introduced strict legislation only allowing baling for long-term waste storage, for example [6]. Waste handling and energy recovery facilities must keep abreast of changing regulations, and what this means for their procedural techniques. The waste management sector should also advocate for appropriate information exchange – such as with respect to the benefits of both baling and loose storage techniques – and ensure their experiences and expertise are taken into account within the changing regulatory environment.

It is recommended that further research be carried out, including life cycle analyses of baling and loose storage techniques. Caution should be taken when deriving recommendations from the existing academic literature on the topic, which is fairly limited. Finally, an invaluable information source will come from the facilities that are carrying out long-term waste storage.

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Photos taken by Sarah Czunyi on November 17, 2011.

LARGE BATTERIES FOR ENERGY STORAGE

Possibilities in the Øresund Region

By Stefan Sipka

In this paper an analysis of possible usage of Large batteries for energy storage in the Øresund Region will be conducted. In order to do so a definition of the concept as well as explanation of larger shifts in current electricity systems will be addressed. Furthermore the analysis will follow an analytical division of policy, technology and business sector in order to fully address drivers and barriers in introducing large batteries for energy storage. Finally conclusions with further recommendations will be given regarding application of large battery storage in the Øresund.

Definition

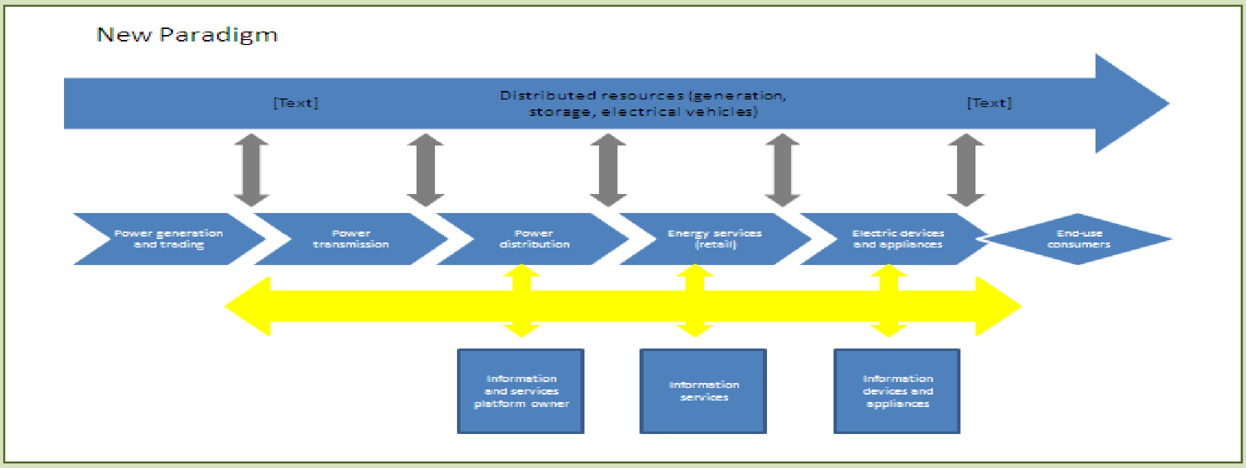
Relevant studies point to a useful definition of electric energy storage:

Electric energy storage (EES) is the capability of storing electricity or energy to produce electricity and releasing it for use during other periods when the use or cost is more beneficial [1].

In addition to the stated definition comes the further clarification of battery storage as a large electrochemical stationary device.

Shift in the System

In order to understand the future capabilities of battery storage, it is important to understand the features of traditional electric systems and the paradigm shift that is currently happening. Modern electricity systems are developing towards a new functional paradigm. Previously the system was one-directional: beginning at electricity generation and ending with final consumers. This direction included generation of energy and information from one source ending with mainly passive end-users (except for some bigger consumers). Moreover, the



A new paradigm in the electricity system. Figure developed based on IBM's model [2].

traditional system was based on a belief that building capacity and consuming more energy was a positive trend due to the logic of economy of scale. Furthermore, it was expected that supply should primarily be adjusted to meet the need of the growing demand. However, recently there has been a trend to change mentioned perceptions (Figure 1). First instead of a one flow activity an interaction was expected to occur between different energy actors regarding both energy and information flows. Second, a new approach envisions saving measures and greater reliance on efficient use of resources instead of constant expansion. Finally a new model includes mutual balance between supply and demand. This is especially important when energy generation varies in time as is the case with some renewable energy (wind and solar). Therefore energy storage can be seen as innovative option that ensures information/energy interaction, energy savings and mutual supply-demand balancing [2].

Analytical Framework

In order to address the emergence of electrical energy storage applications and especially batteries it is important to address different sectors that contain possible drivers and barriers in transition processes. These sectors include policy, business, and technology.

Policy

It is recognised that the influence of storage systems within electricity grids is higher in a deregulated market because different actors in the market have incentives to use resources more rationally instead of relying on centraly (usually state - owned) systems to cover costs. Development of renewable energy production, such as wind and solar, may also be useful for introducing new electrical storage technology since associated daily and seasonal variations stimulate the demand to store surplus energy and provide support when having less energy. Furthermore, there is a space for direct incentives through application of different kinds of administrative, economic and informative instruments (feed-in tariffs, tax breaks etc.) [3].

Technology

There are various storage technologies that are already introduced in the market or in the development process. In general there is a huge tendency towards investing in R&D regarding electrical and battery storage. Except for improving efficiency an important motivation is

Review of relevant battery technologies [4]

CONVENTIONAL BATTERIES	
Sodium-sulfur	Mature, stability concerns (high temperature)
Lead-acid	Mature, lower capacity, environmental concerns
Lithium-ion	Under development, maintenance cost, useless high power density
FLOW BATTERIES	
Vanadium-redox	Immature
Polysulfide-bromine	Immature
Zinc-bromine technologies	Immature

to cut high investment costs. Research shows solid ground for sourcing important electrical energy storage which could be applicable for The Øresund Region. Several relevant technologies are grouped as follows while details are provided in Table 1:

1. Conventional batteries; and
2. Flow Batteries.

Flow batteries are currently considered to be immature technologies. Lithium-ion is more developed but is still under research. Furthermore, such batteries require high maintenance and feature of high energy density which might not be relevant in the case of stationary large battery storage. Lead-acid batteries are the most mature technology, however, with lower capacity when compared to other conventional batteries and with significant environmental concerns. Sodium sulphur (NaS) is also considered to be a mature technology with major concerns being stability due to high temperatures required for this battery to function. However, when compared with other alternatives, NaS seems to be the most applicable battery technology currently available [4].

NaS consists of a positive electrode made of molten sulphur, a negative electrode made of molten sodium and an electrolyte which is solid beta alumina ceramic. Efficiency is estimated to be 70-75%. The lifetime is estimated to be ten years with a maximum storage of eight hours. A high temperature of 300°C is required for electrochemical reaction to occur. Examples of already implemented NaS include a 1.2 MW × 6h NaS installed in US State of New York managed by New York Power Authority and a 6 MW ×4h NaS based in Japan and managed by Tokyo Electric Power Company [5].

Business

There are three primary applications for electrical storage that might be relevant for The Øresund region:

1. Arbitration,
2. Regulation, and
3. Ancillary services.

Arbitration basically means buying and selling surplus energy on the spot market in a certain timeframe. The possibility to acquire profit depends upon the storage capacity, efficiency of transmission and storage cost. Energy is bought during high supply and low demand and afterwards sold at higher price when demand is high. Regulation is a process of adjusting a dynamic energy supply and demand in real time. This process is especially important in shorter timeframes since it is hard to predict electricity oscillations and it is therefore necessary to have a certain amount of energy ready for balancing. Ancillary services rapidly provide needed energy to keep the stability of the grid. Furthermore, these services could be used to provide black start which relates to a capability to restoring a power station in operation without using an external power transmission system. Rapid energy deployment is especially important when introducing wind and solar energy due to daily and seasonal variations of these energy sources [4].

Research shows that in the case of Denmark (with possible general assumptions) battery

Comparative costs of conventional batteries and underground pumped hydro regarding energy storage capacity [4]

TECHNOLOGY	Capacity cost (Euro per kW/h)
Conventional battery	*250-500*
Underground pumped hydro	*25-45*

storage is the most applicable in the case of ancillary services, particularly for rapid deployment of energy. Studies show that the annual cost of having a conventional battery can vary between from EUR 92 to 348 (for 2h storage capacity) while annual revenues could go up to EUR 160 depending on specific circumstances. Alternatively, for arbitration and regulation applications, high storage capacity is required. It can be seen in Table 2 that batteries prove to be very costly regarding energy storage when compared to other technologies such as underground pumped hydro. Furthermore studies show that even in the case of underground pumped hydro there is still no economic argumentation for using it for arbitration and regulation. Alternatively, batteries due to their high speed of energy deployment could be more efficient than underground pumped hydro hence providing a guarantee that neither excess nor lack of wind energy would pose a threat to the stability of the grid. Moreover, batteries can prove to be unacceptable to black start applications due to the higher storage capacity that is required from the black start provider [4].

An issue of lacking business models for battery energy storage deserves attention. It seems that the biggest reliance on further battery implementation lies in further technological advancement. Alternatively, inventions in the business sector are lacking, although they could potentially help to bridge the gap between promising opportunities and high associated costs. Except for usual business models which have limited application capabilities, there is also another business model that deserves attention. This model introduces an aggregated value concept of used storage capacity based on consequential time series of auctioning. In this process a week auction would happen first, followed by day and hour auction. Each new phase would take into account the prices being established in previous phases. The result could be raising the profitability of storage, although case-specific analysis is needed in order to determine the exact size of costs and benefits. In addition, possible storage services would not be artificially separated. The buyer would simply get the right to use auctioned storage capacity for whatever service he intends given the condition that he returns the amount of energy taken by the end of certain time period. Therefore storage may become cost-effective and used more rationally. The analysis of a Belgian electrical storage system using this model gave promising results although each conclusion is case-specific and must take into account the local physical and social environment when drawing conclusions [6].

Conclusions

Battery energy storage could be practically applied to the Øresund region especially on the Danish side. Main function could be rapid energy load into the grid in order to keep its stability. Main mature battery technologies are recognised as lead-acid and sodium sulphur batteries with an emphasis on NaS due to its lower environmental impact and higher life expectancy and capacity. They are concurrently time the only technologies capable of providing cost-effective (ancillary) service due to high or uncertain costs associated with arbitration and regulation. New business models such as the concept of the aggregated value, should be addressed as well in order to bridge the still existing gap between high cost-related risks and technical potential of the batteries. Finally policies have to adjust to the recent shifts in the electricity system through further market deregulation policy incentives and renewable energy development in order to reach the full potential of battery energy storage.

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'Large Battery' photo by Michael Harris on May 10 2011.

WIND CO-OPERATIVES IN THE ØRESUND REGION

By Tom Figel & Ouyang Xin

Wind co-operatives play an important role in wind energy development within the Øresund Region. Co-operatives helped to overcome some of the initial barriers to wind energy development in Sweden and Denmark. In a wind cooperative, all or part of the wind turbine or farm is controlled equally by members of the local community, who share in the profits or electricity produced. The ownership of wind turbines belongs to communities and individuals, instead of large developers or utilities alone. Co-operatives are beneficial for the Øresund region because they tend to increase local acceptance of wind projects, they provide an alternative, more resilient finance strategy, they benefit local communities, contribute to more distributed economies, and empower individuals to invest in their own clean energy.

Today co-operatives own 15% of installed wind capacity in Denmark, and 10% in Sweden. While the fundamentals of wind co-operatives in these two countries are similar, there are significant differences in organisation and policies. This analysis will assess wind co-operatives in Øresund, providing comparative analysis and case studies, with the aim of illustrating the state and significance of wind farms in the region.

Co-operatives in Sweden

Compared with other countries, Sweden has faced relatively high resistance to wind projects [1]. Wind co-operatives have been an important asset in overcoming local resistance to wind development. The first wind co-operatives in Sweden were formed in the early 1990s in Gotland, by a group of environmentally concerned citizens. These individuals advertised shares for sale within their community – and sold them all within two days, demonstrating strong interest of Swedish citizens for renewable energy investment [2].

Presently in Sweden distributed wind ownership is now the norm: individual, community, and other private investors own 72% of installed wind capacity [3]. Co-operatives make up a significant part of this ownership: more than 25 000 Swedes are now members of wind cooperatives. There are currently 86 total co-operatives, which generate around 10% of total wind power in Sweden. There are also two national cooperatives, Swedish Wind Energy Cooperative and O2 Cooperative [2]. While over 80% of wind turbines are locally owned [3], these national co-operatives demonstrate that wind co-operatives can also take on a larger scale. Wind co-operatives are expanding rapidly in Sweden; over the past two years membership has increased by more than 31% [4].

Most co-operatives in Sweden are onshore, and distributed throughout the country. As offshore wind continues to develop, co-operatives could play an important role. Currently, two wind co-operatives have shares in three offshore projects in Vänern, Gässlingen and Kyrkvinden [5].

Organisation & Policy

Sweden's local governance structures are conducive to wind cooperatives, because a great deal of the authority relevant to wind project development, such as siting and permitting, lies with the municipality. Windfarms in Sweden are typically started by developers and municipalities. Co-operatives can then be initiated during the planning phase of projects, by the municipality, or through the expansion of other existing cooperatives. Co-operatives are organized as economic associations, which handle administration and finances, as well as tax and legal requirements. In Sweden, renewables produced for household consumption are not subject to electricity tax. Therefore co-operatives are organized so that members' shares do not exceed their household consumption. Usually, a cooperative's economic association will sell all electricity to a utility company, and members will purchase the electricity at cost from the utility [6]. If there is a surplus in production, proceeds go to the association which then distributes an economic bonus to members once a year. This model incentivizes cooperative members to reduce their electricity consumption because a decrease will lead to higher surpluses, which means higher profits.

Cooperative members usually cover the investment for wind turbines up front. This means that cooperative-financed wind projects are normally independent of financial institutions, making them less exposed to market fluctuations or changes in interest rates that may otherwise jeopardize financing [6]. If enough shares are not sold the remainder may be financed by bank loan, or covered by the utility or developer until the rest of the shares are sold.

Typically, a wind cooperative will sell membership shares, based on a unit of 1000 kWh per of electricity per year [7], to a utility, which then sells it back to members at cost [8]. A share in a cooperative provides about 1000 kWh a year for 20 years, and usually costs between SEK 6000-7000 [6]. Individual profits for wind farms will depend on electricity price fluctuations and the production of the turbine (which determines the price of the shares), as well as whether or not they take a loan. There are some banks, including Swedbank and Nordea, who will offer special loans to people who want to buy shares in cooperatives, with an interest rate of just under 4%. Generally, members can expect to make a profit of around SEK 3000 over 20 years (around 40-50% return on investment); and save between SEK 400-600 on their electricity bills/year (Swedish Wind Energy Cooperative 2011). If there is a rise in electricity rates, they can expect even more savings [6].

The main drivers for wind co-operatives in Sweden are municipal utilities and developers, existing cooperatives, environmental and economic motivation of investors, and policy incentives. Renewable quotas in Sweden require electricity producers to purchase about 18% locally produced renewable energy, which includes energy from cooperatives. Wind co-operatives have been able to maintain an exemption from income tax. However, since 2009, there has been uncertainty from regulators regarding this designation. Officially, the tax authorities state that co-operatives should be subject to taxes on the profit they make (the difference between their prices and the market price of electricity), because the price for electricity they offer is lower than the market price of electricity. The co-operatives contend that the members first have to buy a share to get this lower price. No co-operatives have been taxed with this electricity tax so far, but the subject has been debated, creating uncertainty that has negatively impacted the growth of some co-operatives [9].

Case Study: Lundavind No.1

Lund is home to one of the first co-operatives in Sweden, called Lundavind No.1, which was formed in 1996 [10]. The project was initiated by Lunds Energi, and shares were then sold to its customers [11]. The association has 215 members, owning a total of 900 shares. Most members own 2-3 shares each. The association operates one 600 kW Vestas turbine [10], which is one of the original six wind turbines in Sweden.

Lundavind cooperative is typical of the cooperative model in Sweden, in which a single turbine is initiated by a utility, shares are sold to a cooperative, and electricity is sent back to the utility's costumers.

Wind co-operatives have helped Sweden develop a distributed, more dynamic electricity grid, which incorporates locally produced renewable energy. The Swedish case demonstrates that it is much easier for people to accept windpower plants if they have the possibility to own them [9]. Co-operatives allow a more distributed ownership of power plants, and their development takes place on a wide scale, delivering power where it is needed. They are an effective, and often more resilient way to raise capital for projects. Finally, they represent a movement by the Swedish people to take control over their energy production by making a personal investment in clean energy.

Lundavind Cooperative's turbine.

Co-operatives in Denmark

Danish wind energy has a total installed capacity of 3752 GW as of 2010, comprising more than 22% of the country's electricity consumption. [12] Cooperative wind turbines account for 15% of total installed wind capacity in Denmark, around 560 GW installed capacity.

Co-operatives are highly active in Denmark due to high public awareness of promotion of green energy, profitability of the investment, and historical significance with Danish culture. Co-operatives have existed in Denmark since 1882, when the first was formed in a dairy. In the 1970s, most established co-operatives disappeared or merged into big companies. However the concept of co-operatives survived, and is still widely used to start new businesses in Denmark. Cooperative ownership was essential to the first wind energy projects in Demark. Many of the wind turbines erected in 1980s or 1990s were and still are owned by locals or cooperatives. Turbines owned by wind co-operatives are connected to the grid, providing not only the electricity to the local community, but the whole country. [13]

Big utilities and large energy companies are the main drivers of large-scale wind energy development. By engaging the local communities, public acceptance of wind projects increases greatly, and encourages dialogue with local authorities. There are around 50,000 cooperative owners, down from over 100,000 ten years ago, mainly because utilities tend to buy up shares. In order to encourage community participation, the Danish government issued new legislation in 2009, obligating all new wind energy projects to offer 20 percent ownership to local people, e.g. cooperatives, in order to stimulate local engagement and ownership in new projects [12].

Organisation & Policy

Co-operatives are organized in partnerships with joint liabilities. Often this partnership is also called single purpose vehicle. The reason for forming partnerships instead of cooperative it that according to Danish Law, the interest from loans for wind turbines is tax deductible from the private income of the individuals in a partnership, but not in a cooperative. In the law, the partnership cannot contract debts; which minimizes the risk for cooperative wind projects. Adequate insurances are applied as well.

Normally each share a partner buys corresponds to the yearly production of 1000 kWh from that particular wind turbine or wind farm. Partners can trade their shares, and shares can be mortgaged.

The Danish Promotion of Renewable Energy Act, which entered into force in January 2009, has four schemes to promote local acceptance and involvement of development of wind farms. Two of them focus on promotion of cooperatives, called the 'option-to-purchase' scheme and the 'guarantee scheme'.

The first one regulates: *erectors of wind turbines with a total height of at least 25 metres, including offshore wind turbines erected without a governmental tender, shall offer for sale at least 20% of the wind turbine project to the local population. Anyone over 18 years of age with his/her permanent residence according to the national register of persons at a distance of maximum 4.5 kilometres from the site of installation or in the municipality where the wind turbine is erected has the option to purchase. If there is local interest in purchasing more than 20%, people who live closer than 4.5 kilometres from the project have first priority on a share of ownership, but the distribution of shares should ensure the broadest possible ownership base.* [14]

In practice, if the shares sold are less than 20%, then the utility or energy company is allowed to own the rest shares, may it be 90% or more.

The guarantee scheme offers a total fund of DKK 10 million to co-operatives or associations to initiate preliminary study of wind projects initiate. The fund can keep the initiators financially indemnified if the project cannot be realised. The money for the guarantee fund is recouped from electricity consumers as a contribution. A cooperative can apply for a maximum loan of DKK 500 000.

The two schemes are both administered by transmission system energinet.dk.

Case Study: Middelgrunden Offshore Wind Farm

Co-operatives are often seen in scattered small-scale wind farms or single turbines. However, two offshore projects also show that they can work on large scale. The first is Middelgrunden Offshore Wind Farm (40 MW) and the other is Samsø project (23 MW). Middelgrunden is half owned by a cooperative, and half owned by Dong Energy, and Samsø offshore is 50% owned by the municipality, 30% by individuals from the island and 20% by a cooperative. Outsiders own 15% of the cooperative shares.

In this paper, Middelgrunden as the first and largest offshore large-scale cooperative wind farm, will be studied.

The project was initiated by Copenhagen Electricity Service (KB) and Middelgaden Wind Turbine Co-operatives I/S (MV) in 1997. The application was processed by the Danish Energy Authority. The first round of evaluation was held among interested organisations, and the proposal was modified accordingly. Based on the revised proposal a public hearing was held. Finally the proposal was approved with several conditions, one of which was to consult Swedish Authorities in relation to the Espoo convention, and later authorities also joined the Environment Impact Assessment Procedure (EIA). The revised proposal with EIA were evaluated and published for comments, and final documents were assessed and registered in the Municipality of Copenhagen in September 1999. [15]

In the application and pre-study installed capacity of 20 turbines was 40 MW, with a total output of 85 000 MWh, located between 1.4-3.5 km from the coast of Copenhagen. It also includes the layout of 20 turbines, parameter of turbines, electricity connections, EIA and financial implications. The total investment is about DKK 364 million, of which 334 million was allocated for the farm and 30 million was used for grid connection. Consultancies were formed as well to help to draft the study.

In this application, KB (later merged with Dong Energy) and MV agreed to own ten turbines each, with a flexibility to MV to own less if it failed to sell sufficient shares. KB was responsible for the construction, and each party had financial liability for their own part, while each was held responsible for the operation. After that, the project continued with tender, contracting, construction and commencement.

The cooperative was formed in a partnership called Middelgaden Wind Turbine Cooperatives I/S (MV). MV was responsible for financing, operation, secure insurance, and management of wind turbines. It cannot contract debts, and carries joint liabilities. The Partnership Assembly is the supreme decision body, and is held once a year. It reports on audited accounts, provides recommendation on the use of profit or cover of loss, and budget for the next year. It also decides on issues related to change of bylaws, and sale of shares. Specific rules regarding approval of change are adopted.

The shareowners are all considered partners. Partners are listed in partnership file by name, address, number of shares, and other information demanded by the authorities. The list is updated frequently. The share size is not individual specific, but corresponds to 1000 kWh per year. A share is tradable and the price is set on a free market. The trade is only valid with prior approval from the management. Partners are jointly liable to the partnership's creditor, while the partnership's assets cannot be made the subject of legal proceedings by creditor regarding debts.

The profit (if any after subtraction of partnership's expense, allocations) is equally distributed according to the numbers of shares. It is distributed at least once a year. The financial year follows the calendar year.

Concerning management, a team of five people is elected on a two-year basis. They are responsible for securing adequate liability insurance on turbines and contracting a certified maintenance service company [16].

Discussion & Conclusion

Cooperative windfarms offer many positive benefits to wind development in the Øresund region. Experience in Sweden and Denmark shows that individuals are eager to invest in co-operatives when given the chance, and that co-operatives can be very useful to achieving local acceptance for projects. Co-operatives provide not only an additional source of capital for wind projects, but also support a social investment in wind development. They have many distributed benefits, including keeping revenues in the hands of local communities. Municipalities can continue to encourage co-operatives by including incentives for co-operatives and local energy generation in their energy strategies. As large-scale, offshore wind projects move forward in the Øresund region, local acceptance will be a key issue. Offering cooperative ownership can be one strategy to overcoming this barrier. Large projects like Middelgrunden, and the national co-operatives in Sweden, show that projects can encourage both local and national investment from individuals. By encouraging wind cooperatives, Øresund can support a social movement for renewable, low-carbon energy development that keeps profits in the hands of locals.

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"Lundavind Windmill" photo taken by Lundavind No.1 Cooperative. Permission granted for use. URL: http://lundavind.se/

NORDHAVNEN AND HYLLIE

A Comparative Analysis

By Ian Ross & Allison Witter

Buildings constitute around 40% of energy consumption in Sweden and in Denmark [1,2]. This, in combination with growing urban populations and ambitious national and municipal climate strategies, has led to targeted urban densification projects with strong energy sustainability profiles in both countries. In the Øresund region, two case studies in particular stand out, due to their large scales, ambitious use of cutting edge technologies, and prominent roles in municipal climate and energy planning. These are the Nordhavnen development in Copenhagen and the Hyllie extension area in Malmö. It is useful to analyse these projects, as well as similar developments from abroad, in order to draw lessons on how sustainable urban development may be carried out in order to contribute to minimising energy use and mitigating climate change.

Nordhavnen Phase 1

Nordhavnen is a 200-hectare brownfield site (or underused industrial property available for re-use) in Copenhagen.

Nordhavnen Phase 1.

Presently the location of harbour-related and industrial activities, it is to be converted during a three-phase redevelopment into a carbon-neutral housing and business district.

The first phase of the Nordhavnen project will entail the creation of 2 000 private dwellings out of existing buildings, along with 200 000 m^2 of commercial property [3]. The project is being designed in order to provide the development with a steady supply of renewable energy that is mostly hidden and unobtrusive. Through this renewable energy usage, as well as efficient design, developers estimate that in the period up to 2040, greenhouse gas (GHG) emissions will be 17 000 tonnes less than they would be under minimum standards [4]. These project goals fit within Copenhagen's broader climate and energy goals.

Copenhagen Climate Strategy

Copenhagen identifies itself as a progressive city in terms of sustainable development. Since 1990, the city has restricted its GHG emissions by 20%, meaning that Copenhagen residents emit 30% less than the Danish average per capita. The city plans to reduce emissions another 20% in the period 2005-2015 as part of the Copenhagen Climate Action plan, which seeks to balance mitigation and adaptation by focusing on renewable energy, sustainable transport, building efficiency, and an increase in green spaces. Through this plan, the city intends to become the first carbon-neutral capital by 2025 [5]. Nordhavnen is a perfect example of the city's intentions regarding sustainable urban growth.

Key Project Features

The cityscape will be made up of three- to six-story compact houses mixed with businesses. There will be a large effort to preserve many of the existing historic buildings, creating a blend of modern new buildings and older refitted energy-efficient buildings. In order to implement the EU Directive on Energy Performance of Buildings, Denmark introduced in 2006 more strict building standards along with an energy classification scheme. The scheme includes a Class 1 (50% of minimum requirements) and Class 2 (75% of requirements) rating [5]. All of Nordhavnen's buildings are expected to acquire a Class 1 rating.

So-called "pocket parks", or small parks scattered throughout the development's urban areas, will be introduced along with larger recreational parks and natural habitat reserves. Water is fundamental to project design and is meant to facilitate recreation, good aesthetics, and climate comfort. Excavated channels will be used to bring water closer to urban areas. These "blue areas" will include open-air swimming zones and boat docks [3].

Access to sustainable transport will be another major feature at Nordhavnen. A "green route" traffic artery will eventually contain a metro line and connection to a network of bicycle paths. It is critical that the sale of properties in Nordhavnen is highly profitable, since it is expected that the development shall pay for the metro connection [6].

Energy Technologies

Nordhavnen will have an estimated standard consumption of 22 kWh per m^2 for housing and 48 kWh per m^2 for businesses, equivalent to around 16 000 MWh per year in Phase 1 and expanding to 112 000 MWh per year by 2040. The table below shows how the project developers plan to source this energy.

Four wind turbines will be built on the dike offshore from the harbour and photovoltaic solar panels will be built on the appropriate roofs. It is expected that central solar district heating and storage can provide all of the necessary heating in Phase 1. This will require 115 000 m^2 of space, which will be garnered through utilisation of an undeveloped floating dock and the surrounding land. This will include a 37 000 m^2 heat storage tank, which will be connected to the greater Copenhagen system. This is expected to provide financial gains of DKK 11 million per year, by increasing the city's district heating capacity by 16 000 tonnes and allowing for greater production at times when costs are low. The heating system in Nordhavnen should have a low heat flow of around 55 degrees Celsius so as to provide the greatest potential for recycling cooling water. Instances requiring hot water services, such as sanitation or industrial needs, will be accommodated by heat pumps.

Cooling will be achieved by using a mixture of groundwater, seawater, and absorption cooling. The district cooling system will require six to twelve wells in Phase 1, depending on whether or not absorption cooling is used in the heat storage warehouse. This will entail extracting water from 13 metres below the harbour level, where 10 degrees Celcius water can be removed 200 days a year. Unfortunately, the remaining 165 days are when cooling is at its highest demand [4].

Nordhavnen electricity sources by 2040 [4].

SOURCE	AMOUNT
Solar cells	10%
Micro wind turbines	5%
Onshore wind	33%
Offshore wind	52%

Overall, while the Nordhavnen development has to yet commence construction, detailed plans already exist regarding how specific energy and other sustainability measures are to be integrated into the project.

Hyllie Extension Area

The Hyllie Extension Area is a multi-purpose development in southern Malmö. It aims to offer an urban environment representing sustainable growth – ecologically, economically, and socially. The development is taking place in a primarily unbuilt area of around 200 hectares outside of the city. Being located in such a rural-urban transition area is in fact a central feature of the Hyllie development, which aims to offer both proximity to nature as well as convenient access to both Copenhagen and Malmö through the recently completed City Tunnel, one of Sweden's largest infrastructure projects [7]. Several developers are involved in the project – which aims to build around 8 000 homes plus other types of buildings – under the leadership of the City of Malmö.

Malmö Energy Strategy

Like Copenhagen, Malmö aims to be a world leading climate city. Its long-term energy strategy states that energy shall be safe and efficient and supplied by renewable sources by 2030. The Hyllie project is a targeted expansion meant to densify a specific district of the city, much like the Western Harbour development did, following rapid population growth in Malmö [8]. As the city's largest development area, it is envisioned that Hyllie shall be a leading force in the transition to urban sustainability in Malmö [9]. It is interesting to consider the specific project development measures being taken so that this might occur.

Key Project Features

Numerous buildings with different functions will characterise the Hyllie Extension Area. At the heart of the development lies the Station Square, which links the development to the rest of the Øresund region and beyond by way of the City Tunnel. Completed in 2010, this 17 kilometre long railway cost around SEK 8.5 billion (in 2001 monetary value) to construct and was actually the key justifying factor for going ahead with the broader Hyllie development project. Adjacent to the Station Square lies the Malmö arena. A shopping centre, exhibition facility, four-star hotel, office buildings, and the Point Hyllie project (meant to feature Sweden's second tallest building) are currently under construction nearby. Once fully extended, Hyllie is meant to additionally include around 8 000 residences.

The project is advertised as having a green building profile, which will include energy-efficient lighting and insulation, wastewater heat re-use, green roofs, electricity from wind, and heating from solar. Transportation access via train and new cycle and bus lines, as well as the construction of the Hyllie Water Park and Beech Forest, are additionally highlighted as green features of the development [8].

Energy Objectives

Sweden's energy objective for homes and premises is that energy consumption in 2020 shall be 20 % lower than 1995 levels. Along these lines, the Swedish National Board of Housing, Building, and Planning now requires energy performance certification of most buildings, including those within the Hyllie development [1,7].

Moreover, buildings within the extension area will go beyond these basic requirements by following the Miljöbyggprogram Syd measures for sustainable building. Under this programme, developers demonstrate their level of performance (Class A, B, or C) under four core areas: energy, indoor environment (health and comfort), moisture protection, and urban biodiversity. The Hyllie project intends to perform at a Class A (best option) level for energy and at Class C (the basal level required for building on municipal lands) for the other three areas [10]. Methods for reaching this Class A energy status are laid out in the Hyllie Sustainability Agreement. They include requirements for accurate measurement and communication of overall energy balances and insulation levels (i.e. thermal bridges, U-values for windows, and building envelope air tightness) during the design and construction stages.

Additional energy measures laid out in the Sustainability Agreement include obligations for contractors to investigate opportunities for renewable energies on their properties and to minimise energy use during the construction phase. Measures for the latter include the use of energy efficient building sheds, containers, and lighting; high-grade energy use only where absolutely necessary; eco-driving training requirements for machine and vehicle operators; and 25% environmental car usage. Buildings must also be designed and constructed to fit within Hyllie's eventual smart energy system. In other words, they should strive to provide individual metering for occupants, integrate electric vehicle charging stations, move energy loads from electricity to district heating, produce local energy that is measurable and easily integrated into the grid, and erect information centres on decreasing energy use, among other measures [11].

This smart energy system is the primary objective highlighted by the Hyllie Climate Contract. The contract states that energy at the development is to come from 100% local renewable and reused sources, although it does not explain in detail which steps shall be taken for this to occur, or by which date. A steering group made up of representatives from the City of Malmö and the utility companies E.ON and VA SYD are in charge of implementing the contract's objectives [9,12].

There is little information other than that laid out in the aforementioned agreements regarding energy measures to be taken at Hyllie, given that the project is still in its early stages [12]. It will be interesting to see, then, how the various project partners decide to implement different building strategies and innovative technologies in order to fit within the overarching sustainability visions of the extension area and of the City of Malmö.

Comparative Analysis: Nordhavnen & Hyllie

Both Nordhavnen and Hyllie are being constructed with the targeted aim of populating specific areas – a brownfield site in Copenhagen and a semi-rural location in Malmö. Energy and other sustainability measures taken at each project are meant to not only foster but to also lead the ambitious climate strategies of the two cities. The projects have potential for ample support from municipal, national, and EU level funding. At Hyllie, for example, five projects are already receiving funding from the EU via the BuildSmart project, while the Swedish Energy Agency will help fund development of a large-scale energy system as well as specific energy projects on different properties [12]. At Nordhavnen, funding primarily comes from the developing company made for the project, which is 55% owned by the City and Port of Copenhagen and 45% owned by the Danish state. However, while the City Tunnel in Hyllie was built through ample government funding and was actually an instigator for the project, the construction of a connecting metro line at Nordhavnen will rely upon the development proving itself to be profitable.

Each project should be able to draw on experiences at the pioneering Western Harbour extension project in Malmö. Two key lessons garnered from that development include ensuring that project developers implement uniform energy measurement methodologies and that information on eco-friendly behavioural changes is conveyed to the public in a useful and effective manner [13]. There are virtually no cars present at the Western Harbour, as is to be the case at Nordhavnen. Hyllie, on the other hand, emphasises a good infrastructure for cars as well as a multitude of parking places, marking a key difference in the realm of transportation between it and its Danish counterpart. Other such distinctions are evident in the branding of each project. As an example, while Nordhavnen emphasises small buildings of a few storeys, Hyllie boasts high-rise edifices, one of which will be the second tallest in Sweden once constructed. It will be interesting to see how these distinctions, coupled with a focus during the early stages of development on specific energy measures in Nordhavnen versus more generalised requirements in Hyllie, will influence the profiles and actual impacts of each project.

Lessons from Abroad

Two further examples of sustainable urbanism, which are external to the Øresund region, will be explored here. These are the Dockside Green in Victoria, British Columbia, Canada and Brewer's Block 4 in Portland, Oregon, USA. These cases are useful to explore when deriving lessons on how energy measures can be successfully implemented in development projects. Victoria and Portland are considered to be two of the more sustainable cities in North America, and both have similar climatic conditions to the Øresund region, making consideration of the pioneering green building cases there particularly relevant.

The Dockside Green

In Victoria, the Dockside Green provides an example of a successful brownfield development that has integrated innovative energy measures. The mixed-purpose site comprises 26 buildings and 2 500 residents and is located on an abandoned, brownfield dockyard site. The mixed commercial-residential space features rooftop gardens, on-site renewable energy production (through biomass gasification), improved linkages to bike paths, and a wastewater treatment plant, among other features. In 2008, the site was awarded the highest LEED Platinum ranking in the world. It is also aiming to become one of the first recipients of the LEED for Neighbourhood Development designation.

Dockside Green features an integrated energy system, including on-site biomass gasification utilising waste wood as well as sewage inputs from the project's wastewater treatment plant. A district energy system, run by the development's own energy utility, provides all heat energy and hot water for the site, and there are plans to eventually integrate sewer waste heat recovery technology as well. The system is capable of becoming a net energy provider by supplying thermal energy for clients both on- and off-site. Additional energy saving measures include high performance building insulation (i.e. glazing and shading), exhaust air energy heat recovery, minimized lighting power densities through energy efficient fixtures and occupancy sensors, and individual energy metres that include a calibration of household carbon footprints. Buildings are built 50% more energy efficient than municipal codes require.

Although it has received some federal funding to offset capital costs, this development project has also clearly been able to compete financially with its less innovative condominium neighbours, even in a tough real estate market. Sales were likely boosted for two main reasons. First, the minimised household costs achieved through substantial energy savings at the property were clearly communicated to potential buyers. Second, developers were keenly tuned into local surroundings. Strong commitments were made to community consultation, local partnerships for heating and sewage facilities, First Nations peoples' employment support programmes, and other social measures. These and other facets have helped to create an award-winning climate-friendly community that feels rooted in its context [14].

Portland Brewer's Block 4

The brewery blocks of Portland, Oregon are an interesting example of how industrial buildings can be retrofitted and sold as environmentally friendly business property. The Weinhard brewery district consists of five blocks, located in the most upscale area of the city, and has been redeveloped in a way that combines the preservation of historic buildings with the introduction of modern sustainable design. Block 4 of the development is of particular significance because of its "green" design based on LEED energy efficiency and storm water standards.

A high-efficiency, low-temperature central cooling plant serves all of the brewery block buildings. This is an on-site rooftop plant based on evaporative cooling and featuring outside air economisers and variable speed pumps. This cooling system is calculated to have energy savings of around 540 000 kWh per year when compared to baseline code-compliant buildings, which calculates to savings of USD 37 450 and 242 tonnes in reductions of carbon emitted per year.

The lighting system of Block 4 incorporates a maximisation of natural lighting, daylight dimmers, and improved window glazing, which combined yield 417 000 kWh in energy savings, equalling 189 tonnes of carbon [4]. An innovative garage ventilation system allows for the use of smaller fans and thus runs at half the rate of standard systems. Photovoltaic panels on the roof provide an annual output of 21 600 kWh, yielding USD 1 500 in yearly savings.

All of these technologies have combined to give Block 4 an annual energy savings of 23.5%. This case thereby serves as an interesting example of how efficient design can both save money and make an office building more attractive [15].

Conclusions

It is becoming increasingly clear that energy savings and climate change mitigation will require densified urban living, with access to alternative transportation modes, innovative technologies for energy production, and energy-efficient methods for reducing energy demand [14]. The aforementioned case studies provide examples of how such qualities are being integrated into large-scale urban development projects. Several lessons may be garnered from these experiences.

For example, during the preliminary stages of project design, performance-based measurements regarding energy intensity should be favoured over specific facets of building design. This helps to emphasise energy consumption and building performance, and allows for the most efficient, context-specific combinations of proactive energy saving measures (i.e. passive design) and reactive measures (i.e. mechanical systems) to be designed. While financial support from local municipalities as well as national government bodies is extremely helpful for the success of project development, properties must still be sold in the end. Useful in this regard is the effective communication of energy cost savings to be reaped by potential buyers. Comfort and efficiency can be turned into a marketing advantage in order to create new markets for such large-scale "green" urban projects. Once they buy, residents must subsequently be educated on how their energy consumption behaviour can be shifted in order to add to the efficiency gains fostered by such developments. What is crucial is to strongly integrate a project's energy goals from the designer through to the resident in order to deliver on a development's full potential [16].

One of the largest opportunities for profiting from the energy technologies used in these development projects is through the connection of onsite district heating or cooling plants to larger municipal systems in order to help expand their capacities. The heat storage tank at Nordhavnen and the district cooling plant at Brewery Block 4 are two examples of such potential profitability. At the same time, however, young technologies may take time before living up to this potential: the solar district heating system in Nordhavnen, for example, is not expected to be profitable before 2025 [4].

Overall, while the steps to actually rendering a sustainable city are complex and multidimensional, and while the actual results of the Nordhavnen and Hyllie projects remain to be seen, the development measures presently being undertaken appear to be steps in the right direction towards contributing to the achievement of the climate and energy goals of each respective municipality.

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"Hyllie City Tunnel Photo" taken by Allison Witter on 12/11/2011.

"Nordhavnen phase 1" created by Ian Ross, on 12/8/2012. Created with Google Earth™ mapping service.

ENERGY-EFFICIENT BUILDINGS

Case Studies: Passive Houses & Retrofitting

By Mary Ellen Smith & Jordan Hayes

Around the world buildings use on average between 30-40% of primary energy and are a major contributor to the amount of greenhouse gases being emitted into the atmosphere [1]. Over the past several years, improving the energy-efficiency buildings has been cited as a potentially cost- effective way to create jobs, increase energy security, and reduce carbon emissions [2]. In Europe, the public sector is being called upon to help realise the potential to become a leader in aiding the transformation of existing buildings into more energy-efficient structures [2].

One suggestion that has been put forward to promote public leadership towards energy-efficient buildings is energy performance contracting (EPC). EPC is a performance based purchasing method and financial mechanism for making upgrades to buildings in which the savings from utility bills outweigh the costs of upgrades or equipment installed in an existing building [3].

Building efficiency plays an important role in Europe's most recent version of the Energy Efficiency Action Plan (EEAP) that describes the importance of buildings shifting away from a high carbon economic model. The EEAP further reinforces that Europe's public sector should play a leading role in making energy-efficient improvements to buildings across the EU [2]. It also propositions an obligation for EU member states to double the annual renovation rate of public buildings up to three percent. Under this plan, retrofits to buildings should bring the building within ten percent of comparable buildings in the nation with respect to energy performance [2]. The European Commission also suggests that EPC and energy services companies be integrated as an effort to reach the retrofit target of three percent. Both retrofitting and passive home construction have the potential to aid the EU in reaching its energy efficiency goals for buildings.

Passive Houses

In Germany, roughly one quarter of primary energy consumption is used to heat buildings, and yet 90% of these heat losses could be saved using modern concepts and technology [4]. Passive house building concepts provide a cost-effective and energy-efficient solution to unnecessary energy loss in buildings and homes. According to the Passive House Institute, a passive house "is a building for which thermal comfort can be achieved solely by post heating or post cooling of the fresh air mass, which is required to fulfil sufficient indoor air quality conditions – without a need for recirculated air" [4]. Thus passive house design is a *concept* that can be applied in planning and construction of a building.

The Kronsberg Passive House Estate

The city of Kronsberg, Germany wants to be a model for sustainable development; they have energy efficiency goals to reduce carbon dioxide emissions by at least 60% compared to conventional residential building standards that were benchmarked in 1995. Additionally, the city invested in two wind turbines and promotes solar thermal heating and passive home construction. The Kronsberg Passive House residential estate in Germany is an interesting example of the city's efforts and provides a model of passive house construction and success, with 32 terraced houses with an effectiveness ratio of energy savings of 80% under real working conditions [4]. The number of passive homes constructed in this estate provides a wealth of data and information regarding real electricity and heating efficiency, as well as the cost-benefit and applicability of passive home design in cooler climates.

Construction Details

Each home façade and foundation is built of concrete, a versatile material that reduces air leakage, absorbs sounds, and increases energy savings. The floor and walls were insulated with 60 mm of mineral wool and enclosed with particleboard while the floor was sealed with 300 mm of mineral wool. In order to arrive at air-tightness and a thermal-bridge-free façade envelope, polyethylene foils were used to permanently seal the roof components. The three-paned windows have considerable insulation surrounding the frame and into the floor to arrive at the lowest thermal bridge possible.

Each home has its independent ventilation system, using a heat exchanger to recover heat and the supplied air and exhaust air moves through ducts located in the roof. The ventilation system was designed based on the number of occupants and rooms, with three ventilation flow options to prevent 'dead zones' and allows excellent indoor air quality. Outflow and inflow vents located in the rooms ensure passive airflow when doors are closed.

Hot water and heat is supplied by district heating but also supplemented by a solar thermal system. During summer months, under sufficient solar radiation, a control unit activates the pump allowing district heating to be used only as a supplement. In order to reduce electricity demands, highly energy efficient appliances like dishwashers, washing machine, dryer, refrigerator, freezer, and lighting were installed in the homes.

Cost Savings

Added costs to building passive homes are always a consideration in construction, and without careful planning construction cost can add up quickly. In this case extra insulation costs beyond typical insulation were approximately EUR 69 per m^2, with the actual cost depending on the component being insulated and to what degree. The heating load is only 2.5 kW compared to typical 6 kW. Overall, construction costs of the living area were about EUR 987 per m^2, which is similar to the cost of a typical home of the same size. The table below illustrates energy and cost savings from different infrastructure components, demonstrating the true value of passive house construction added-costs.

COMPONENT	kWh SAVED(Euro/ kWh)	PERCENT ENERGY SAVINGS
Wall insulation	4.6	6%
Roof Insulation	3.5	15%
3-paned Windows	7.6	15%

Energy savings from different forms of insulation at Kronsberg Estate [4].

Efficiency

The total electric energy consumption of the Passive House estate is roughly 33 kWh/m^2a, which is similar to consumption in German homes for supplying only household electricity [4]. The energy consumption of the estate is so small that the remaining energy needs for the estate are generated from renewable wind energy in Kronsberg. Indoor air temperature in the winter averages around 21 °C, with average annual heating energy consumption at 16 kWh/m^2a, meaning that the savings in comparison to a typical German home are over 90% [4]. The 3-paned windows keep heat from being lost during the coldest winter months, with an average indoors window temperature above 17°C, exemplifying stable indoor air temperatures despite reduced heating [4].

The estate was the first to use a fresh air heating system; the high quality ventilation system uses less than 2.3 kWh/m^2a annually and with sufficient heating output, has proven that indoor temperatures are independent of outside temperatures regardless of season. The use of district heating for space heating and hot water for the first year measured 34.6 kWh/m^2a, a savings of 75% compared to average homes.

Electric appliances can offset the indoor temperature balance, thus high quality energy-efficient appliances were installed in all houses of the estate. Total primary energy consumption is 82.6 kWh/m^2a for all energy sources used in the estate, roughly 66% less consumption than similar homes in Germany [4].

Balancing Quality

The case study also highlights the importance of designing a passive house based on occupants, climate, geography and comfort. There is no single model passive house construction plan that can apply to all situations without inadvertently reducing efficiency standards and comfort. Studies have shown that successful passive house projects have special focus on system design, building documents, construction planning, working methods, quality control, leadership, and attitude [5].

Passive houses have efficiency standards composed of lower electricity consumption through building design and energy-efficient appliances, lighting and heat recovery. However, comfort is a key aspect in design thus optimal air quality, humidity, and temperature are important requiring a balance in efficiency measure with comfortability. Indoor air temperatures were measured at a comfortable level most days of the year, and collected data shows there is a strong correlation between occupant activity and indoor air temperature swings. Yet, behaviour does not have the strongest effect on energy savings, it is rather technical and construction standards that have the greatest effect on a home energy profile [4]. The Kronsberg Passive House estate displays the fact that energy consumption can be reduced so much that homes can be powered by renewable energy without compromising comfort or cost, and that passive home design is both environmentally practical and economical.

Retrofitting

The term retrofit refers to the process of modifying something after it has been constructed. For the purpose of building retrofits this means making changes to the systems within the building or the structure after its initial construction and occupancy [6]. The purpose of implementing such measures come with the expectation of improving amenities for building owners and improving the performance of existing buildings to adopt to new efficiency opportunities.

Retrofit Criteria

To date there is no one set of criteria to define a retrofit building. Instead there are several different energy rating procedures to rank performance and efficiency of buildings. The most common building environment assessment schemes to date are Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM) and Green Star schemes [7]. These three schemes are all based on a rating system that applies to both new and existing buildings. All schemes look at a wide range of environmental factors that includes materials, energy, water, pollution, indoor environmental quality and building site [7]. Credits derived from meeting criteria within the schemes determine the level of certification that a building receives. For example the LEED scheme offers four different levels of certification that range from certified, silver, gold, and platinum, while Green Star uses a five star award system which requires more than three stars to have formal certification. Although all these schemes are performance-based credit rating assessment schemes, they vastly differ in assessment method, scope and criteria.

Broadview Avenue Retrofit

Upper Broadview Suites is located in Toronto, Canada and was built in 1930. The building is home to a four story 32 unit rental property. Two locals purchased the building in 2002, aware that there had been no major retrofits done to the property since it was originally constructed. The owners noted that everything was functional but the building itself was not operating efficiently. The building needed a number of improvements to the envelope and the mechanical system. The high maintenance costs and regular breakdowns inspired building owners to make improvements to the property. Since the building was over 70 years old the owners were able to identify a number of areas that would conserve energy and add value to long-term investment. Some of the measures identified included:

- Replace single-glazed metal-framed windows with low emission double-glazed windows.
- Replace boiler controls and steam traps.
- Insulate the attic.
- Replace all toilets with low flush models.
- Replace all faucets and showerheads with low flow aerators.
- Replace common area lighting with compact fluorescents.

Retrofit Details

In the spring of 2003 the boiler and windows were replaced. The single glazed windows were replaced with low emission double glazed windows and took under two weeks to complete. The boiler swap took three weeks to complete. In the summer of 2003 the attic, which previously had no insulation, was insulated and took one week to finish. In November 2006, all toilets were replaced with low flush models while faucets and showerheads were replaced with low flow aerators. This project was completed in within one week. In February 2006, all common area lighting was replaced. This resulted in removing all existing F40-T12 fluorescent bulbs and replacing them with 13W compact fluorescents. This resulted in replacement of 192 existing fixtures.

Cost Savings

The retrofit projects that were carried out on this property resulted in annual savings of CAD 14 000 (EUR 10 288). The total cost of the retrofit was CAD 74 200 (EUR 54 531), which were slightly above the owners estimated costs of CAD 71 500 (EUR 52 544). The payback period for the entire project was just under six years.

The most costly measure was reducing natural gas use. The projects that were completed to reduce natural gas use included replacing boiler controls, replacing all the windows and insulating the attic. The total costs of these measures were CAD 65 000 (EUR 47 775) and had a payback period of six years.

In order to reduce electricity consumption all common area lights were replaced which had a total cost of CAD 3 200 (EUR 2 352). The payback period was just over one year.

Lastly measures to reduce water consumption included replacement of all toilets, showerheads and the addition of aerators. At the time of the retrofit there was an incentive programme for replacement of old toilets, The City of Toronto's Water Saver Program, which provided a rebate of CAD 125 (EUR 92) for each toilet. The total cost was CAD 6 000 (EUR 4 410) with a payback period of just over one and a half years.

Efficiency

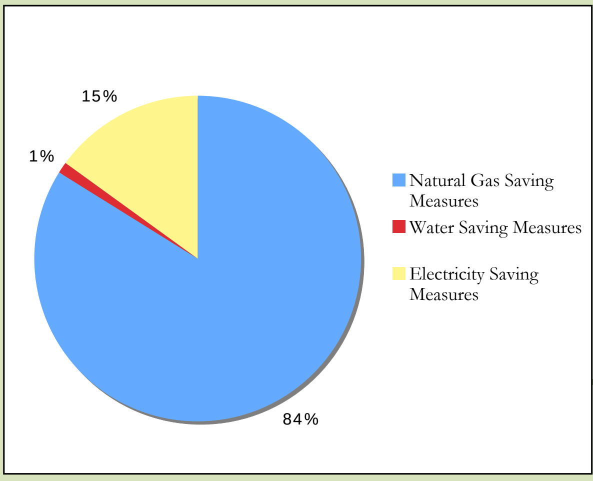
The upgrades to the building essentially covered three areas where performance was lacking which resulted in high utility bills. These areas were natural gas, water and electricity. The process of replacing windows, insulating the attic and replacing boiler controls resulted in a reduction of natural gas use from 50 000 m^3 in 2002 to 30 000 m^3 in 2007. The majority of the 87.5% energy savings came from changing the boiler controls and replacing widows while the remaining savings came from insulating the attic. The replacement of toilets and showerheads with the addition of aerators resulted in a 50% reduction in water use. The retrofit of replacing existing light fixtures in the common areas with compact fluorescents resulted in a 86% reduction in electricity consumption.

In addition to reducing utility bills, reducing number of breakdowns and increasing comfort for tenants, the process of retrofitting this building also helps avoid CO_2 emissions. The total amount of annual CO_2 reduction from this retrofit was estimated to be 48 tonnes. The natural gas savings resulted in a reduction of 40 tonnes of CO_2, water savings resulted in a half tonne reduction and electricity savings resulted in seven tonnes of CO_2 avoidance as seen in the figure below.

Looking Forward

In many countries around the world there are several old buildings that are highly inefficient. There is not a single solution that can be applied to all buildings to make them more efficient as each building is a separate case with unique issues. General barriers that can be associated with old buildings and owners is insufficient capital to implement retrofit projects and extended payback periods.

Upper Broadview Suites is a prime example showing how implementing retrofit projects can greatly reduce costs, reduce CO_2 emissions and add long-term value to an investment. Many of the projects implemented in this retrofit had payback periods within one year that resulted in efficiency gains up to 86%. On top of efficiency gains, owners and tenants noted that the building was much more quiet and comfortable to live in.



Impact of resource saving measures on CO_2 emissions [8].

There are many global companies specialising in retrofitting, providing a vast array of services that can help homeowners decide on implementing retrofit projects to their properties. To begin with, a simple energy audit can help identify problematic areas. Once these areas are identified, owners can discuss with contractors different options that best suit their financial situation.

Conclusion

Both case studies display the energy efficiency potential for buildings and the practicality and applicability of implementing energy-efficient design. The passive housing and retrofit cases prove that proper planning and careful consideration of project details are essential for a successful project. Retrofitting and constructing passive homes are by no means a cheap alternative, yet both are cases where investments do pay off compared to conventional counterparts. As energy prices rise these energy efficient building alternatives will become commonplace, not only due to energy savings, but also for the lasting value of efficiency investments and their ability to connect with infrastructure of the future.

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"Passive House Bornholm" Photo by Jordan Hayes, taken on November 27, 2011 in Bornholm, Denmark.

CLEANTECH CLUSTERS ANALYSIS

Copenhagen Cleantech Cluster and Sustainable Business Hub in Malmö

By Peter Kiryushin

Integration of cleantech companies into the Øresund Energy is beneficial for several reasons. It can contribute to the achievement of better practical outcomes, increase the efficiency of collaborations between project stakeholders and help to include new solutions. To demonstrate these benefits results of two cleantech centres analysis are presented in this paper: Copenhagen Cleantech Cluster (CCC) and Sustainable Business Hub (SBH) in Malmö.

Cleantech is an abbreviation that stands for "clean technologies" and refers to energy and environment-related technologies developed with the objective of reducing harmful effects on the environment. Cleantech also associates with the provision of better performance at lower cost, including promotion of productive and responsible use of natural resources. Many cleantech solutions are energy-related and relevant to energy development of Øresund Region [1].

Cleantech Involvement

One of the purposes of Øresund Energy project is to support achievement of regional and municipal energy goals. Examples of such goals are presented in the table below. Because these goals are quite ambitious, effective cooperation with business will be essential. Cleantech companies possess knowledge, experience

Energy targets in the Øresund region (own compilation).

AREA	2015	2020	2025	2050
Denmark		-30% GHG*		100% RES
Hovedstaden			50% RES	
København			carbon-neutral	
Albertslund	-25% GHG			
Ballerup	25% RES			
Sweden		50% RES,		
Skåne		-30% GHG*		
Malmö			100% RES	
Lund			-50% GHG*	
Kristianstad			-20% GHG*	

XX% GHG refers to XX% decrease greenhouse gases emissions.
YY% RES stands for achieving YY% share of renewables in energy supply.
* Compared to 1990 level.

and technology, which can help. Although different solutions might be already implemented on the local level within the Øresund Region, large-scale implementation can provide region-wide effect.

The integration of cleantech companies from Copenhagen Cleantech Cluster and Sustainable Business Hub in Malmö could as well contribute to the realisation of the Activity Three of the Øresund Energy project: "Idea development and cooperation forum", which has the target of "Strategically energy planning and establishing a cooperation forum to continue the cross border cooperation after Energy Øresund will come to an end". There are several deliverables, which should result from the work connected to Activity 3:

- An established regional forum for analysis, collaboration / coordination and idea development of energy planning;
- A conference that addresses the challenges and opportunities associated with strategic energy planning in the region; and
- A strategy for continued cooperation in each of the thematic areas.

The Clusters

Copenhagen Cleantech Cluster (CCC) was organised by Danish cleantech businesses, research and public organisations with governmental support. The mission of CCC is to create continuous growth for existing cleantech companies, to support and assist development of the new ones and to attract more foreign companies to the region. There are five focus areas, where the cluster carries out its activities: test and demonstration, matchmaking, international outreach, innovation and entrepreneurship and facilitation [2].

Copenhagen Cleantech Cluster is official agent of cleantech development in Denmark. The country has recently adopted the "State of Green" concept with the purpose "to lead the transition and become a green growth economy entirely independent of fossil fuels by 2050" [3]. Cleantech has been the fastest-growing sector of the country exports for the 2008-2010 period and exports of clean technologies are expected to quadruple by the year 2015 [4]. Energy technologies are an important part of the cleantech development in Denmark - its export increased more than three times since 1989.

Many of cleantech initiatives supported by CCC could be relevant to effective energy development for the whole Øresund Region. For example, Denmark is going to be one of the first countries to promote electric vehicles (EV) in a large-scale. There are at least two notable EV-projects, where CCC acts as a partner. The first one is developed by Better Place. The company provides electric car networks for mass adoption of electric vehicles through an innovative battery switch model. The other one is called EDISON, a multilateral initiative that promotes smart integration of electric cars in a power system, with the emphasis on utilisation of renewable energy and wind power in particular.

Sustainable Business Hub (SBH) in Malmö is a non-profit organisation, with the purpose to help companies with products and services with high environmental profile. To achieve this SBH develops networks between businesses, administrations, researchers and NGOs in order to market sustainable products and ideas. SBH is considered to be a key player in environmental business development in southern Sweden [5].

Sweden is prominent for its cleantech export and Skåne is one of the leading regions in this field. In 2009 51% of Swedish cleantech export was accounted for energy-related technology: biofuels, solar, wind, hydro, sustainable buildings and energy efficiency. Denmark is in fact the 5th largest importer of Swedish environmental technologies, with the turnover of SEK 2.12 billion (EUR 230 million) in 2009 [1].

SBH constitutes of companies, including those that could contribute to the energy development of the region. For example, SweHeat & Cooling, the association of Swedish organisations that develop district heating and district cooling products and services. SweHeat & Cooling proved to be effective in Skåne and could help to achieve better results in Øresund region.

Both clusters represent the platforms for communication and integration with business. Its managers are experienced in working with different types of stakeholders, not only cleantech innovation companies, but R&D organisation, consulting, incubators, etc. The clusters have connections and brand-name, so their participation could help for progress of the project. Successful development could make the clusters business gates for the energy development in the Øresund region.

Opportunities for Business

The following three types of opportunities for cleantech businesses were identified to be integrated in the project.

Intraregional Co-operation

Regions and municipalities have ambitious low-carbon development goals that require introduction of high-efficient technologies in order to achieve them. It creates market potential for the companies. At the present many of the cleantech companies are active on the local level and a new market provides opportunities to promote their products in the region. Some of the municipalities plan to increase the share of non-fossil fuel based transport in order to meet low-carbon development requirements.

For example, EDISON cars, a project on Bornholm island, which utilises electricity produced from wind and biomass could be a good solution. Moreover they could be used as energy storage and protect electricity grids from fluctuations.

Multilateral agreements could be one of the instruments for intraregional cooperation. For instance, Malmö, Lund and Kristianstad municipalities, could sign an agreement for bulk buying of EDISON cars with a discount for municipal organisation usage. Additionally, Copenhagen, Albertslund and Ballerup could order products and services of SweHeat & Cooling companies under similar conditions.

Export Opportunities

Business in both Skåne and Sjælland are interested in exporting their clean technologies. Developing mutual cooperation could also be contribute to these activities. International markets for cleantech provides many opportunities, driven by the interests of both developed economies like the United States and developing ones like China. In 2007 overall volume of investments was 2.75 billion US dollars [6]. The Øresund companies could promote themselves under a "Low-Carbon Øresund" umbrella brand.

Clean technologies in Sweden and Denmark are complementary to some degree. Collaboration between specialists from both sides could result in solutions for foreign organisations. The unique situation when two separate states mutually create environment for energy collaboration could be a model for other interregional cooperation within and outside EU. Cleantech tours for foreign investors, administrations or even interested tourists could be organised, so "Low-carbon Øresund" could become an international touristic destination. Or business exhibitions and conferences could be organised abroad for the Øresund Region companies and administrations.

New Markets

Undiscovered market opportunities for cleantech companies are available with collaboration with local NGOs, environmental entrepreneurs and grass-roots initiatives. Nowadays, citizens are becoming more involved in promotion of low-carbon development by realisation of their own projects. Examples of such activities are local wind cooperatives, sustainable university initiatives, urban gardening movements. There are a number of cases from of such collaborations in New-York, for example [7].

Cleantech organisations can establish collaboration with such stakeholders, provide them with technologies and have the opportunities for testing and promotion of the production. These groups could help companies with ideas for innovations, which is known as open innovation approach. According to recent research grassroots activities could be helpful for developing new ideas and promote innovations [7].

Forms of Co-operation

Here are some of the examples of how cleantech companies could cooperate:

1. Develop information package about the Øresund Energy, web-site and newsletters;
2. Select the companies, which are interested and could contribute to the project;
3. Organize seminars for broad audience: municipalities, business, researchers, eco-preneurs;
4. Organize special workshops: best practices on district heating, wind energy solutions, biofuels;
5. Develop cleantech tours, knowhow classes for the broad audience, trainings to promote entrepreneurship;
6. Promote of Øresund Energy. Promotion in the media, on public events, in social networks; and
7. Organize conference and cooperation forum for future development.

Inventory of Cleantech Companies

A screening of the clusters companies show that at least half of the partners of CCC and 25 members of SBH promote energy-related activities. Therefore they potentially could become project participants. Their names with description are presented below where they are grouped under several categories.

Manufacturers and solution providers within SBH consist of three international companies with Swedish origins whereas others are medium and small-sized enterprises solely focused on innovative technologies. ABB is one of the leading in power and automation technologies, with the purpose to improve energy efficiency and lower environmental impact. Vestas provides wind energy systems and complementary services. One of the primary area of Alfa-Laval is heating and cooling processes. A group of smaller companies include Heatex, which deals with air-to-air heat exchangers, AB that manufactures specific groundwater heat pumps and Elgocell AB that developed a heat pipe with extremely thick insulation that has superior properties. Osby Parca produces electric boilers, oil/gas boilers and solid fuel boilers for industrial customers and district heating plants. Multichannel is manufacturers of brazed plate heat exchangers. Ripasso CSP system developed an innovative technology for utilisation of solar energy, combining stirling power converter with a parabolic mirror.

There are three representatives in this category from CCC. First one is Confederation of Danish Industry that is responsible for market-related activities in the cluster, including Export promotion and market fact finding, building knowledge of international markets, fact finding tours, building international partnership. Novozymes is the world leader in bioinnovation organisation, including biofuel productions. Siemens in Denmark is a part of the international Siemens Group.

Service providers in SBH are next. E.ON Sverige, one of the world largest energy services provider, E.ON Sverige has large area of activities including traditional areas as well as climate and renewables. Schneider Electric supplies a wide range of technologies and solutions for energy usage and optimization in energy, infrastructure and industry sectors. Catator develops high-tech catalysis and a customised catalytic process for improvement of emission problems and energy saving. Thermofloc support services for cellulose insulation and complex structures in all buildings insulation attics, sloping ceiling, walls and floors. BioSep provides food waste treatment systems, that allows to convert organic waste into "green energy". Energy Opticon is a software developer for load and optimization forecasting for energy-related organisations. Malmberg develops biogas and geothermal energy solutions. Sysav is a large waste-management company, which also recovers waste in the form of energy. Lunds Energi deals with electricity and district heating in Lund and Lomma. DONG Energy is one representative organisation from CCC in this category. It is the leading energy group in Northern Europe with business is based on procuring, producing, distributing and trading in energy and related products.

Another group consists of technical and business cleantech consultants: The ÅF Group is a leading in technical consulting, BioMil AB is a consultancy company engaged in sustainable solutions for biogas and the environment. EnerChem AB works with biogas and environmental solutions. WSP Consultancy promotes solutions on energy supply, clean energy production and climate change.

SBH is represented in the Research and NGO caterogy by IIIEE, Malmö University, Global Energy Transformation Institute and Sustainable Mobility Skåne. CCC is represented by The Copenhagen Resource Institute, National Laboratory for Sustainable Energy at the Technical University of Denmark, University of Copenhagen and Aalborg University.

Krinova's Science Park is the large venture mutually owned by Municipality of Kristianstad and Kristianstad University. Handelskammaren (Chamber of Commerce) is a private enterprise, which supports business development in the southern Sweden. The mission of the TEM Foundation is to help companies and other organisations develop sustainability issues. Minc promotes entrepreneurship of network-based environment, and developing platform multilateral meetings. Hügoth Business Advisory is focusing on generation of the grounds for successful international business agreements. Information Rapidus is a news service company, which covers the development of industries in Sealand and Scania.

CCC is represented by Scion DTU, providing access to facilities, services, consultancy and networks of the 180 research-based companies, Symbion which consists of four science parks, services facility and hosts more than 90 high tech companies. Business Link Startvækst is a portal for entrepreneurs and growth businesses. Copenhagen Capacity is an official inward investment agency and maintaining foreign companies it promotes the region internationally.

Conclusion

Copenhagen Cleantech Cluster and Sustainable Business Hub can contribute to the energy development of the Øresund region and achievement of the project goals. These clusters have the capacity to become business drivers for the energy development in the region. There is a sufficient number of cleantech companies, which could also benefit from collaboration. This may include benefits from promotion of products within the region and oversees, organising joint ventures and cooperation with grass-roots initiatives.

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THE BORNHOLM EXPERIENCE

A Case Study of the Energy Strategy & Systems on Bornholm Island

By Veronica Andronache, Lea Baumbach, Sarah Czunyi, Tom Figel, Filipe Firpo, Jordan Hayes, Peter Kiryushin, Mauricio Lopez, Adrian Mill, Ian Ross, Stefan Sipka, Charlotte Luka, Mary Ellen Smith, Logan Strenchock, Meiling Su, Allison Witter & Ouyang Xin

Due to its geographic distance from the Danish mainland, the island of Bornholm is easily overlooked. As a major tourist destination during the summer months of July and August, the island's economy relies heavily on the tourism sector, yet historically has lacked other economic sectors that could provide the majority of residents with an income during the rest of the year. As a consequence, the island has faced the challenge of population decline for decades. Many young people have moved to the mainland, while at the same time it has proven difficult to attract new residents to the island. The overall population of Bornholm is predicted to shrink further in the coming years. To counteract these challenges, the Danish government incorporated a Regional Growth Forum on Bornholm in 2006. This Forum employed an enterprise ambassador with the task to develop a growth strategy for the island.

This strategy, named "The Path to an Even More Sustainable Bornholm", has been developed under the EU-financed B7 political-action group, an international collaborative framework involving seven islands in the Baltic Sea, including Bornholm. The strategy followed an assessment of the island, both of its challenges and opportunities, which identified a major untapped resource on Bornholm: wind power. From this discovery, a new branding of the island was conceived: Bornholm – the "Bright Green Island" – is to become a global model in sustainable societies, of which clean energy sources and infrastructure are major components. In order to phase out the use of fossil fuels and achieve a carbon-neutral society, Bornholm aims to make its energy supply independent and more sustainable through the use of local renewable resources [1].

Bornholm is an ideal place to test these innovations because of its capacity to exemplify a closed energy system and its relatively high share of renewables compared with the rest of Denmark [2]. To kick-start the process of changing its energy system, Bornholm conducted an initial assessment of its energy consumption as part of the European project "Transplan" (Transparent Energy Planning and Implementation). This resulted in an energy balance sheet for 2005 that provided an overview of energy potential and demand. Starting from this assessment, two scenarios for the year 2025 were drawn: a "Business-as-Usual" scenario and a "Vision-Achieved" scenario [3]. Bornholm's Energy Strategy 2025 is based on the latter.

The following sections provide more in-depth information on the key aspects and implementation areas of the Bornholm Energy Strategy. The first section highlights some of the key strategic challenges and opportunities in striving for an ambitious green energy future. The second section covers smart grids and how they have been implemented on the island. Following this, the increasing energy efficiency of buildings is addressed. Finally, the use of biomass as an energy source is examined.

Energy Strategy

Bornholm's Energy Strategy aims not only to secure affordable energy for the island's residents in the future, but also to revitalise Bornholm's green image and to contribute to local employment using only economically viable technologies. Its ultimate goal is to render the island carbon-neutral by 2025.

An important challenge in Bornholm's Energy Strategy is to move away from imported fossil fuels, which are currently still used in the Østkraft power utility and indirectly (through purchase of heat) by the Rønne Vand og Varme heat and water utility, as well as by sea, vehicle, and air traffic. Bornholm's energy vision combines plans for reducing energy consumption with measures for rendering energy production more environmentally friendly.

The 2025 Energy Strategy

The vision of the strategy is stated as follows: "Bornholm is a carbon-neutral community based on sustainable and renewable energy by 2025" [1]. This vision aims at the following achievements:

- To improve the security of supply;
- To contribute to local employment and value creation;
- To reduce Bornholm's dependence on fossil fuels;
- To minimise carbon emissions generated by the Bornholm community; and
- To reinforce the island's green image.

Correspondent to this overall vision, the strategy bridges the gap between the island's green growth aspirations and the Danish government's climate change commitments, under the following twelve proposed action areas [1]:

1) More and cleaner district heating in towns and villages;
2) More renewable energy used outside of district heating areas;
3) More electricity from more wind turbines;
4) More biogas;
5) More electric cars;
6) More local biofuel sources (deemed "BornBioFuel");
7) Bioethanol for transport;
8) Electricity savings;
9) Reduced heating bills;
10) Improved information and consultancy; and
11) More co-ordination and co-operation.

Bornholm's energy strategy envisions using the island as an in-site experience field where international enterprises are encouraged to develop new technologies along with leading knowledge institutions. The strategy is used as a branding tool for the island of Bornholm, with a defined target group of new residents, entrepreneurs, tourists, knowledge pioneers, and business tourists [4].

It can be seen from the above that a main way that these goals will be achieved is through the development and use of renewable energy sources. A high share of production and consumption from renewables is already observed on the island. In 2011, more than 60% of power produced and more than 40% of power consumed on Bornholm was sourced from renewables. This is a marked improvement from 2005, when renewables constituted just over 25% of the overall energy production and consumption. For the 2025 vision, the share of renewables in the energy mix is intended to be almost 75%. The biggest contributor to this goal is to be wind power, which is meant to increase from 3% in 2005 to 22% in the envisioned 2025 scenario.

Implementation

Since the publication of the Energy Strategy, numerous projects have been launched. These projects are based on collaborations between local and external companies and the Bornholm Business Centre. To encourage investment in projects, the Centre adopted an approach whereby international companies are invited to try out and showcase their technologies on the island, thus forwarding their technological know-how to the local population while at the same time contributing to the goal of becoming carbon-neutral.

During a study visit to Bornholm, the research team noted several implementation achievements that fit into the aforementioned proposed action areas. For example, the use of biomass from straw and woodchips as a main fuel for Bornholm's district heating systems fits within Action 1 (cleaner district heating).

Work within Action 2 (more renewable energies) and Action 3 (more electricity from wind turbines) is evidenced by Bornholm having successfully increased its share of renewable energy sources during recent years. This includes not only offshore wind power but also photovoltaics and biomass. Bornholm is also conducting drill tests of potential geothermal energy supply. An eco-grid project has been launched, with 2 000 participants developing a new energy trading market.

The import of electric vehicles (EV) from Hong Kong for testing on the island fits within Action 5 (electric cars). Both tourists and residents can use the cars for a limited period of time and provide feedback on the technology. This has created a new business model on Bornholm, while helping the EV manufacturer to collect data and information about its product. A result has been the EDISON project, which combines EVs with smart grids.

The Green Solution House is an important infrastructure project to be realised in the coming years on Bornholm that is relevant to Action 9 (reduced heating bills). It is based on the cradle-to-cradle concept of a closed loop system, as well as adopting new international products and using a decentralized mix of energy from wind, solar, and ground heat sources. Also relevant to Action 9 have been efforts to improve education of and special training for local carpenters with respect to the construction of passive houses.

A focus more co-ordination and co-operation under Action 11 has also been implemented. In 2011 alone, around 40 groups visited the island in order to take part in "energy tours", with the aim of learning more about the comprehensive energy system on Bornholm. These tours intend to create an international communication platform and to attract new business partners. They also help to raise off-season tourist income for local residents. In addition to these tours, the Bornholm Business Centre directly approaches embassies in countries with potential partners who would like to try out new technologies. Engineers from Bornholm also travel regularly to spread and share technology, knowledge, and concepts with the outside world and to bring new business opportunities back to Bornholm [5].

Supporting Structure

A wide range of political and private actors, organisations, and programmes were involved in the development of the Bornholm Energy Strategy. The process was led by the Bornholm Business Centre, which was initially headed by Lene Grønning. The Danish government has offered support by providing EUR 2 million to the Centre through Bornholm's Regional Growth Forum, a guiding council of 20 personalities from politics and business [2].

Projects are only fostered when they can be proven to be economically viable. To date, 18 project managers associated with the Business Centre are financed through the cooperation with private companies [4]. As there is no local university, external research institutions contribute information and knowledge to Bornholm's strategy. An important driving force for the preliminary research and benchmarking of energy consumption in comparison to other islands was the Transplan project (2007-2010) mentioned above [3].

Smart Grids

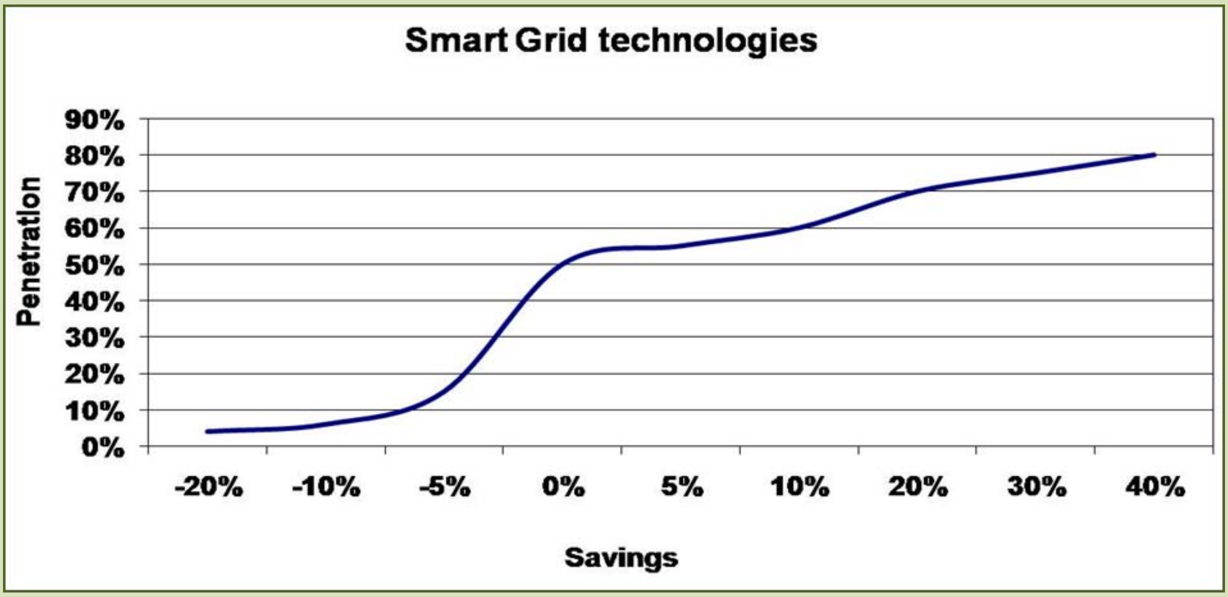
Advancements in renewable energy-based electricity production bring challenges regarding the relationship between energy supply and demand. Renewables are often subject to daily and seasonal variations in energy production, such as occurs with solar and wind energy production. Consequently, there is a risk of divergence between peak rates of supply and demand, potentially resulting in blackouts or simply inefficient use of resources.

In order to respond to this new challenge, the concept of a "smart grid" was introduced. Smart grids aim to connect electricity consumption with production by using information technology systems that automatically balance energy supply and demand. Furthermore, consumers receive price signals based on the prevailing energy conditions. As a result, consumers can time their energy use or program their electrical appliances to use electricity only when the electricity supply is high and prices are low. Adjusting consumption according to price would lead to further balancing of electricity supply and demand. Smart grids are gaining popularity due to the potential cost savings that they offer, as shown in the figure below.

Expansion of wind power is one of the key actions proposed under Bornholm's 2025 Energy Strategy. In 2011, 12 wind turbines were under operation by Østkraft, the local power utility [6]. Total installed wind power capacity on the island is approximately 31 MW from 40 wind turbines [4]. The goal for 2025 is 90 MW (15 MW land-based and 75 MW sea-based), representing a total production of 294 GWh and a saving of 33 000 tonnes of carbon emissions [1]. To achieve this vision, the local transmission grid is to be further developed, while more focus will be placed on implementing policies for land-based wind turbine development and improving dialogues between the key players on the island [1].

Current Smart Grid Projects

There are several projects in Bornholm related to smart grid development [4], some of which are briefly outlined here. Bornholm has accepted to participate as a unique smart grid island laboratory within the EU-funded Eco-Grid Project. The aim is to equip 2 000 small households and businesses with remotely-read



Projected increase of financial savings in Denmark due to improved smart grid penetration [3].

meters that provide information on electricity supply, demand, and price. These advanced meters would enable consumers to regulate their consumption according to price signals, thus adjusting the energy consumption to match production in the grid. Research will also include issues such as data management, reliability, and security. The testing phase of this project is due to end in 2015 [7,8].

In addition, Demand as Frequency Controlled Reserve (DFR) is an ongoing two-year project that aims to test the possibility of automatically switching off electrical appliances when the grid frequency drops, hence allowing for the energy system to recover. This shutdown would last for a short time of a few minutes. Currently, around 200 energy consumers have been involved in the trial. However, further research is needed into how to implement such measures for keeping the grid stable while at the same time meeting consumer needs [7,8].

Lastly, information and education of future power consumers is an ongoing priority for smart grid development. This priority area includes the development of public campaigns to inform consumers about energy market dynamics such as price fluctuations [8].

The EDISON Project

A unique experiment into the use of novel energy storage solutions is embodied in the EDISON (Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks) project. This project involves the testing of EVs, charging stations, and intelligent battery charging controls in Bornholm during 2011, with aim of investigating the possibility of combining these technologies [9]. If successful, such technology could provide a solution to even the imbalances between electricity supply and demand while reducing fossil fuel consumption.

The project involves the integration of strategic partnerships in the development and testing process. Co-operation between partners and the integration of their work has been fundamental for the success of the project. Funding has been allocated by Energinet.dk and other partners include Østkraft, the Technological University of Denmark, Risø National Laboratory, DONG, IBM, Siemens, and the Danish Energy Association [10].

Each partner contributes to a fundamental project component according to its expertise. Siemens, for example, is focusing on the development of battery replacement systems and fast charging technology. Fast charging has been achieved by increasing the voltage and current used during charging via plugs already available in most households in Europe [11].

IBM Denmark and IBM Research-Zurich are responsible for developing synchronization technology for the charge and potential discharge of the vehicles according to the availability of wind-generated electricity [12]. This technology balances electricity supply and demand by distributing car charging times evenly. When available electricity from wind turbines is higher, cars can be charged accordingly, and when available wind energy is low, cars can discharge and contribute to the grid, thereby allowing the customer to be compensated for providing energy to the grid. Although consumers could charge their vehicles at any given time without restrictions, a higher cost would be charged during expensive peak hours [13].

Results from the EDISON testing phase demonstrate the great potential for these technologies as well as the interoperability between EV infrastructures from different operators [14]. Overall, he new identity of Bornholm as a “test island” is embodied in the crosscutting work being conducted on smart grid technologies. With greater experience in this area, it is expected that Bornholm can not only enhance the viability of its renewable energy supply to meet the energy demands of the population, but also export the knowledge gained to help others implement similar smart grid systems.

Energy Efficient Buildings

The proliferation of energy efficiency measures in residential buildings has been prioritised in Denmark's national building standards. 40% of Danish energy demand is for residential heating, and progressive standards encourage a smooth transition to less intensive dwellings [15]. Building codes that regulate energy consumption have been used since the 1960's, with multiple updates occurring per decade [16]. Denmark has created a certification system that classifies buildings based on level of decreased energy demand compared to the minimum requirements for similar structures [17]. This classification system, combined with incentives for improved energy efficiency, has helped Denmark increase efficiency in buildings by 15% in the past two decades [18].

Energy Efficiency in Bornholm

Bornholm made the strategic decision to become a leader in energy efficient housing design. The propagation of homes that require less energy for heating, cooling, and operation is also in line with the island's target of reducing heat consumption by 10% by 2025 [19]. Bornholm has also taken aggressive measures to re-educate construction labourers on the most advanced energy efficiency technologies in construction. They have committed to this knowledge transfer by establishing a construction education centre with the goal of mobilizing a highly skilled working class. Their strategy is to produce an educated workforce well versed in advanced energy efficiency construction, along with the technical knowledge required to retrofit Denmark's existing building footprint, of which 93% has been identified as requiring renovation [19]. Bornholm expects this centre to produce a workforce with a differentiated skill set that would be lucrative in mainland Denmark, where energy efficient building capacity is limited [19].

Remodelling and renovation projects have great potential on the island, where old housing infrastructure would greatly benefit from the reduced utility bills and improved living environment delivered by such updates. The reduction in greenhouse gas emissions from the housing block resulting from widespread retrofitting would bring Bornholm closer to reaching its ambitious environmental targets. Bornholm's construction sector has the capacity to undertake projects at a high rate, as currently, 80 out of 500 domestic construction workers have received the highest level of Green Building supplementary training in Denmark, with more expected in the future [19]. Realistically the widespread instigation of such projects would need to be encouraged with supporting policy in the form of rebates and subsidies for housing updates, along with an aggressive advertising campaign touting the economic and environmental benefits of retrofitting.

Passive Houses

A company in Bornholm supporting energy efficient visions is Steenbergs Tegnestue. Architectural engineers in Steenbergs Tegnestue have focused on energy efficient building design for the past 20 years. Their business model made an aggressive shift in focus to include energy efficiency measures in homes after responding to the sharp increase in fuel prices in Denmark in the 1990s. The company has developed a prefabricated house design that complies with Denmark's 2015 targets for Low Energy Buildings. The design uses principles established in German passive house standards that limit the total input energy required for heating, cooling, and ventilation per area of heated surface [20]. Steenbergs has developed a prefabricated model that delivers superior energy performance, while focusing on aesthetics, functionality, craftsmanship, and economy.

The results of the firm's efforts are exemplified in a house design that exceeds Denmark's standards for building performance, while complying with Bornholm's targets to reduce energy demand from its housing infrastructure. Although this design exists, the company has not yet been able to sell their model to an interested buyer. Their ingenuity has faced the reality of today's housing market, and Bornholm's strategic dilemma: encouraging the purchase of new homes in a stagnated market, while also encouraging a population influx within an isolated island region. This dilemma will continue to challenge the island of Bornholm's ambitious efforts to establish itself as a "Bright Green Island," along with its domestic companies' endeavours to expand their eco-conscious businesses.

An Example: "Green Solutions" Conference Centre

A major example of Bornholm's commitment to resource-efficient buildings is the planned construction of the Green Solutions Conference Centre. Along with a conference centre, the site will include a hotel, science centre and apartments. The construction is being overseen by William McDonough and his design team. McDonough is the creator of the cradle-to-cradle concept, meaning that all aspects of the building are recyclable and do not contribute to negative environmental impacts [15].

The building site of 7 184 square metres plans to be one of the largest structures designed according to cradle-to-cradle principles. The development, located in Rønne, is expected to cost DKK 150 million, not including land acquisition as the property was donated [19]. The site is projected to be energy independent, by utilizing solar panels, windmills, and geothermal energy [15]. Natural lighting will be featured heavily in the design. This concept moves beyond energy efficiency, as it hopes to grow food, treat its own water, and provide a habitat for endangered species [15]. As many of the technologies proposed for this site are not available, the building will be continually updated and not boast full cradle-to-cradle status for decades [15]. This project has been designed as a promotional model of the revolutionary technology that will be featured in energy efficient design in the future.

Smart Grids & Smarter Houses

As already mentioned, Bornholm has placed itself in a position to be a demonstration site for smart grid technology. The isolated test network made possible by Bornholm's unique island setting has made it more attractive as a test ground for state-of-the-art grid technology. The premise behind such systems is to readjust consumption patterns in households to compensate for the fluctuations in energy supply that are a natural occurrence within renewable energy systems. A necessary inclusion in any smart grid system would be a network of living spaces that could "communicate" and "react" to energy delivery systems, by means of intelligent appliances, and heating and cooling systems. This enhanced communication network would be accompanied by a dynamic energy pricing regime that would encourage more balanced and, therefore, more economic consumption of electricity.

To facilitate this process, a shorter time-based regulation of the electricity market is suggested. Within this context, electricity prices would be regulated more frequently (five minutes intervals) and a dynamic grid tariff responding to current load would be established. This would allow smaller renewable energy production units to be able to participate in the greater market (the entire smart grid) directly. As a result, consumer demand would be influenced to produce a balanced load and demand relationship, due to higher consumption costs during peak demand hours. Behavioural change would be probable, made possible by household appliance redesign to acknowledge the changes in energy pricing. A pricing mechanism of this type would direct appliances to participate in the smart grid directly, which would help to save energy, bring balance to the system, and lead to more economical consumption patterns.

The output of this concept is personified in the "Smart Home" model. While the concept is mostly theoretical at present, the technology is developing at a fast enough rate to transfer ideas into functional test implementations within homes. Bornholm has already tested this process with experimental automated houses and businesses. Automated houses are able to adjust the use of energy according to different electricity price signals received.

The buildings are controlled by automated centres in a community or within individual households. The automation centre controls flexible loads in the house by switching off or turning on different appliances when prices are high or low. Automated houses are highly possible with the backbone of a robust grid system. Bornholm will continue to test this experimental system, with the hopes of developing a stable network model that could be transferable to other locations.

Biomass for Energy

As a supplementation to Smart Home technology, the type and form of energy supplied is equally as important. The use of biomass has been identified in the various action areas of Bornholm's Energy Strategy. Presently, biomass on the island is used for the production of biogas to fuel combined heat and power plants, as a feedstock for district heating, and increasingly as a biofuel. The primary sources of biomass on the island are straw, woodchips, agricultural wastes, and animal manure. According to the Energy Strategy, it is envisioned that by 2025 straw, fertiliser, and organic household waste will represent 8%, 6%, and 5% of the island's energy balance, respectively [1]. The two major biomass operations on Bornholm – district heating and biogas electricity generation – are described below.

Woody biomass storage at the Aakirkeby District Heating Plant on Bornholm.

District Heating

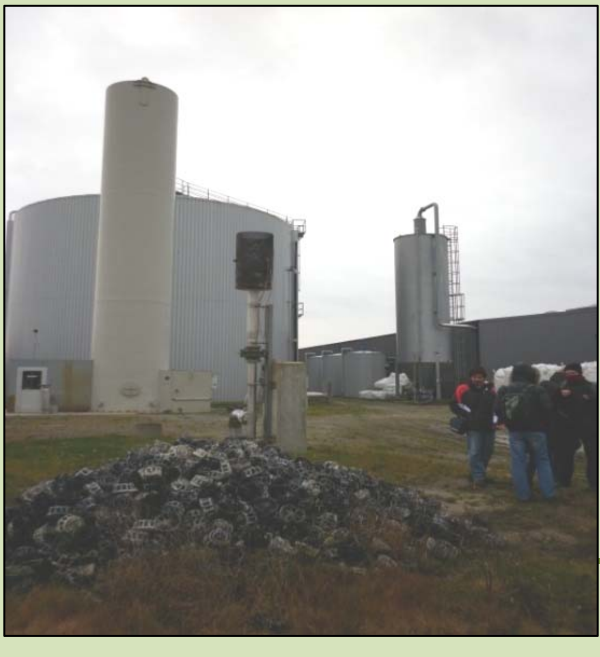
Bornholm's 2007 Heating Plan aims to eventually supply 60% of all houses with district heating generated primarily from local resources, such as straw and wood. Because local sources will be insufficient to cover all villages, additional heat will be gained from solar heating systems and imported wood chips. An example of how Bornholm has approached district heating is embodied in a recently completed plant in Aakirkeby.

The Aakirkeby district heating plant is operated with woodchips derived mainly from surplus wood felled through management of the island's coniferous forests (around 75% of total inputs) as well as surplus sawmill wood (around 25% of inputs). Additional woody mass (e.g. holiday trees) may also be burned at the plant. However, wood scrap such as old furniture is not suitable to be burned at the plant, and is instead incinerated along with other waste.

Having started operations in March 2011, the plant currently provides heating to approximately 1 300 households, as well to schools and small-scale industry in the vicinity, therewith replacing a large number of individual oil burning stoves. Owned by the municipality, the plant is operated in the manner of a private business and was built with special loans under 25 years payback period with a 2.8% fixed interest rate. Construction of the plant and the corresponding distribution system (i.e. pipes and household radiators) took around three years. Each household paid DKK 15 000, approximately Euro 2 000, for the initial connection, which was subsidised by the company, and are to pay another DKK 15 000 in heating costs each year.

The 8 MW plant burns 30 tonnes of wood per day. The ovens are engineered to burn wet woody mass, so no pre-drying is required. According to the operators, the plant was built in order to usefully employ leftovers from forestry operations on the island, and its location selected to serve the approximately 1 300 families in the surrounding area. The plant has no specific sustainability requirements for wood sourcing, and it is uncertain whether or not the operator's suppliers have any either. It would be interesting to see if any efficiency gains could be made by additionally producing electricity, and not just heat, at the plant.

In addition to this plant, three straw-fired district heating plants of a similar scale also exist on Bornholm, with the construction of a fourth one currently in progress. Such plants require more complicated burning procedures, yet straw is cheaper than wood as an input biomass. While it is possible to use the ash produced at straw plants as agricultural fertilizer, disposal in special landfills is necessary when the cadmium content is in excess of permissible levels.



Scrubber and biogas reactors at Biokraft, Aakirkeby.

Biokraft Biogas Plant

Bornholm's Biokraft plant in Aakirkeby is owned by the energy company Østkraft A/S, a part municipal and private owned joint enterprise. The 2 MW plant creates energy from biomass, such as animal manure and organic waste. The biomass is mixed in three reactors, thus generating biogas, which is then converted into electricity and district heating. Farmers may use the degassed slurry as fertiliser.

In full operation, the plant could process over 40% of Bornholm's slurry and could produce 48 MWh of electricity per day. At the moment, however, the operators have trouble sourcing sufficient organic waste and manure, and thus the plant only produces 25-30 MWh/day. Ideally, the fuel input would include a mixture of 25% separated and organic waste, and not exceed 35%. While waste from fishing and chicken slaughter was previously available, the island's fishing industry has largely collapsed and leftovers from local chicken farms are now fed to minks, which are bred on Bornholm for their fur. The waste from local breweries is sold to pig farms, while that from cheese production is fed to cows, creating a fierce competition for organic waste. This sourcing problem is aggravated, in that organic household waste is not collected separately on Bornholm (creating a potential source of future fuel input if legislation changes). In addition, Danish waste regulation has emphasized waste liberalization, making it more profitable for waste to be transported off the island and incinerated elsewhere. As such, corn silage is presently used as the organic addition to the biogas plant. This in itself constitutes a controversial choice, given the potential for corn to be used in food production as a feedstock for cows. Overall, however, a stable supply of a consistent type of organic biomass is required to keep the plant operating efficiently; frequent changes to the type of biomass fed into the reactor can be problematic, as the microorganisms need time to adjust to new types of feeds.

These sourcing deficits, which currently force the plant to run below capacity, were unfortunately not uncovered in the feasibility study for the plant. In fact, some have said that the plant was actually built primarily for political reasons. Biokraft, like many other Danish biogas plants, is now struggling to break even and the Danish government has recently announced subsidies for further operations.

Despite these challenges, the operators at Biokraft do foresee potential opportunities for further biogas development, for example through the construction of a second generation bioethanol plant, as well as via an expansion of production through industrial symbiosis. The latter could be achieved through the use of an ultrafiltration process for digested slurry. This was originally designed and operated at Biokraft's Aakirkeby plant but ceased operation due to technical challenges and input shortages. In such a process, digested slurry is separated through a combination of ultrafiltration and reverse osmosis. The outputs are clean, consisting of ionized water and a concentrate of organic particles and phosphorous. This concentrate can significantly benefit farmers, because it makes an excellent fertilizer. Ultrafiltration renders the nutrients more easily available for the agricultural process and also reduces odour during crop fertilisation [21]. If all farmers were encouraged to put their organic wastes through this process, the biogas and agricultural industries of Bornholm would mutually benefit.

Biomass: A Partial Solution?

Biomass plays an important role in the energy strategy of Bornholm, contributing to the development of district heating, biofuels, a cleaner electricity grid, and opportunities for industrial symbiosis with other sectors on the island. However, Bornholm faces constraints in finding dependable biomass fuel inputs, which will limit the island's biomass capacity in the future.

As a result, the island is taking steps to avoid dependency on any single fuel, and looking for opportunities to increase fuel availability through more advanced processes and collaboration with other sectors on the island. Biomass use on Bornholm demonstrates the importance of planning for a resilient fuel supply chain and the difficulties of achieving cost-effective biomass production, as well as the potential for biomass as a renewable, locally sourced fuel.

Challenges and Lessons

The case studies examined in Bornholm reveal that there are a number of key challenges in implementing new systems, both technically and strategically. As a test island, the improvements and development of technical systems in Bornholm can have great value for future implementations of the same or similar technologies. Beyond technical expertise, however, the Bornholm experience is also a societal experiment: the move towards becoming a sustainable society is no simple feat, and many lessons can be drawn from this experience.

Strategic Challenges

Though Bornholm has chosen an experimental strategy with regard to innovation and energy efficiency, it still faces challenges associated with acceptance and developing a suitable implementation framework. There are three key strategic challenges that Bornholm has needed to take into account, as follows:

1. Public scepticism: In the beginning stages of developing the strategy, the driving actors were confronted with a high degree of scepticism and mistrust from the general public as well as from businesses on the island.

2. High expectations: Parallel to the scepticism, the main strategist had to live up to the high expectations that decision-makers had for the strategy. This meant ensuring financial support and creating employment, while at the same time implementing economically viable projects in the area of renewable energy and energy efficiency.

3. Short vs. long-term challenges: The employment created by short-term projects needs to be channelled into long-term contracts, and this has not happened within all existing projects. In addition, in order to achieve the goal of becoming carbon-neutral, transportation to the island by ferries and airplanes needs to be considered and taken into account within the longer term.

Lessons Learned

There are a number of specific lessons to be drawn from Bornholm's experiences in implementing a green energy framework, as follows:

1. The strategy resulted from the need to develop unique features for a municipality in order to attract new residents, investors, and tourists;
2. The strategy is based on a preliminary assessment of the situation and the identification of the main strengths of the location;
3. In order to reduce costs for such an assessment, municipalities can join forces to develop a common assessment framework;
4. Projects were only implemented when they proved to be economically viable. This reduced financial burdens for the municipalities and helped to overcome public mistrust and scepticism;
5. The coherence of the strategy was achieved through one "central brain" who coordinated and connected political and private actors;
6. The strategy was based on a shared vision, includes measurable objectives, and states responsibilities within a time frame;
7. As local resources were limited, international cooperation was sought by creating an international communication platform; and
8. Enhancing internal communication helped to change attitudes and behaviour.

Conclusions

The "Bright Green Island" is a necessary experiment in moving towards the sustainable society that we require. It is fuelled by clean energy sources that are able to meet demands for energy and the desired quality of life this energy can provide. The fact that Bornholm is a closed system – an island – makes this experimentation more feasible, while also raising the question as to what extent the Bornholm experiences can be transplanted or replicated to other contexts. Hence, while lessons and best practices can (and should) be drawn from Bornholm, the specific context within which these successes have taken place should not be forgotten.

As with any innovative project, unexpected results and negative consequences are never completely avoidable. Bornholm's "Bright Green Island" project has experienced technical, economic, and social hurdles. Though a "closed system", Bornholm can lend itself as an example of energy efficiency and innovation; the challenges faced are sound forewarning to cities or communities wanting to implement a project of similar ambition. The information and knowledge gained from such a project is invaluable to future developers, policy makers, and communities. Thus the outcomes of various project components can be used as supplemental information if not a model for developers. Bornholm's "Bright Green Island" is not representation of perfect sustainable development and energy efficient technological integration; it is a flexible and adaptable project in a constant state of observation, analysis, and improvement, and therefore a valuable centre of knowledge for actors in all sectors of society.

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Photo of lighthouse by Tom Figel, taken November 25, 2011.

Photos of Aakirkeby District Heating Plant and Biokraft Biogas Plant by Charlotte Luka on November 25, 2011.

THE INTERNATIONAL INSTITUTE FOR INDUSTRIAL ENVIRONMENTAL ECONOMICS

The International Institute for Industrial Environmental Economics (IIIEE), part of Lund University, was established in 1994 by the Swedish Parliament. The IIIEE's vision is to transform technical and management structures, as well as public and private sector policies, in such a manner that advances sustainable consumption and production systems. As such, the IIIEE engages in a combination of education and research activities with the aim of bridging academia and practice.

The Institute now operates two international Master's programmes, as well as independent courses, a wide range of pioneering research projects, and numerous outreach activities. Researchers and teachers have backgrounds in natural sciences, technology, law, economics, and other social sciences. The IIIEE cooperates closely in its education and research with other departments at Lund University and with other universities worldwide.

While the debate in society is to a large extent focused on environmental and climate-related problems, the Institute emphasises solutions and pathways towards achieving them. This is exemplified in the IIIEE's motto: "advancing sustainable solutions". Along these lines, the Institute explores and advances knowledge in the design, application, and evaluation of strategies, policies, and tools for a transition towards these sustainable solutions.

Educational effort at the IIIEE is primarily focused on two Masters' level courses: the MSc in Environmental Management and Policy (EMP) and the MSc in Environmental Sciences, Policy, and Management (MESPOM). Students in these programmes have academic backgrounds in subjects relevant for working with sustainable consumption and production issues, such as law, business, and engineering, and frequently have several years of work experience. Many IIIEE staff members have gone through these Master's programmes themselves. The Institute also runs educational programmes at the PhD level, participates in teaching at the undergraduate level, and is involved in executive training.

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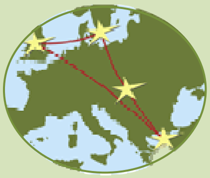
THE AUTHORS



This report was compiled as part of the international Master's degree in Environmental Sciences, Policy and Management (MESPOM). The degree is a two-year Erasmus Mundus course that is supported by the European Commission and is operated by four European and two North American universities. MESPOM students study in at least three out of the following six consortium universities: Lund University in Lund, Sweden; Central European University in Budapest, Hungary; Manchester University in Manchester, UK; the University of the Aegean in Lesvos, Greece; the Monterey Institute for International Studies in Monterey, United States; and the University of Saskatchewan in Saskatoon, Canada.

The authors are presently studying at the International Institute for Industrial Environmental Economics (IIIEE) at Lund University. This publication is part of the IIIEE Strategic Environmental Development (SED) course, which this year analysed the present state of, as well as potential futures for, energy in the Øresund region. **Mikael Backman** and **Thomas Lindhqvist** are IIIEE professors who led the SED course as well as this project. Mikael focuses on sustainable tourism, while Thomas specialises in environmental product policy.

In addition to writing about the energy systems of different sub-regions within Øresund and analysing the energy system of the island of Bornholm's, the authors researched the following specific case studies:

Adrian Mill and **Logan Strenchock** analysed declining heat demand and its effect on the future attractiveness of district heating. Adrian is Australian/British dual national and has worked in environmental management and research. Logan comes from the United States and has a background in civil engineering and historic preservation.

Charlotte Luka and **Veronica Andronache** wrote about the risk of legionella contamination in low temperature district heating systems. Charlotte is a lawyer from Germany and

Veronica previously worked as a project manager for an environmental NGO in her home country of Romania.

Mauricio Lopez and **Lea Baumbach** addressed seasonal heat storage in man-made aquifers for solar district heating. Mauricio is Mexican with a background in economics and Lea comes from Germany, where she studied environmental policy and communication.

Sarah Czunyi investigated storage systems for household waste. She is Tanzanian and British and has a degree in public affairs and policy management.

Meiling Su wrote about hot water circuits in household appliances. She previously studied business in her home country of China.

Stefan Sipka carried out research on large batteries for energy storage. He comes from Serbia, where he studied political science and international relations.

Tom Figel and **Ouyang Xin** looked into co-operative wind farms. Tom has a background in international relations and policy and Ouyang worked in the wind energy sector.

Allison Witter and **Ian Ross** did a comparative analysis of four new energy-saving residential areas in the Øresund region and in their North American hometowns (Victoria, British Columbia and Portland, Oregon). Allison has a background in international development and Ian previously studied sociology.

Mary Ellen Smith and **Jordan Hayes** focused on two energy efficient building cases in Germany and Canada. Mary Ellen comes from the US and has a background in biochemistry. Jordan is Canadian and worked in forestry.

Peter Kiryushin did a comparative study of two cleantech clusters. Originally from Russia, Peter focused on public administration and environmental economics in prior studies.

International Institute for
Industrial Environmental Economics
at Lund University
P.O. Box 196, Tegnersplatsen 4,
SE-221 00 Lund, Sweden
Tel: +46 46 222 0200
iiiee@iiiee.lu.se
www.iiiee.lu.se