SUSTAINABLE CITIES IN A BACKCASTING PERSPECTIVE

FJÄRRSYN

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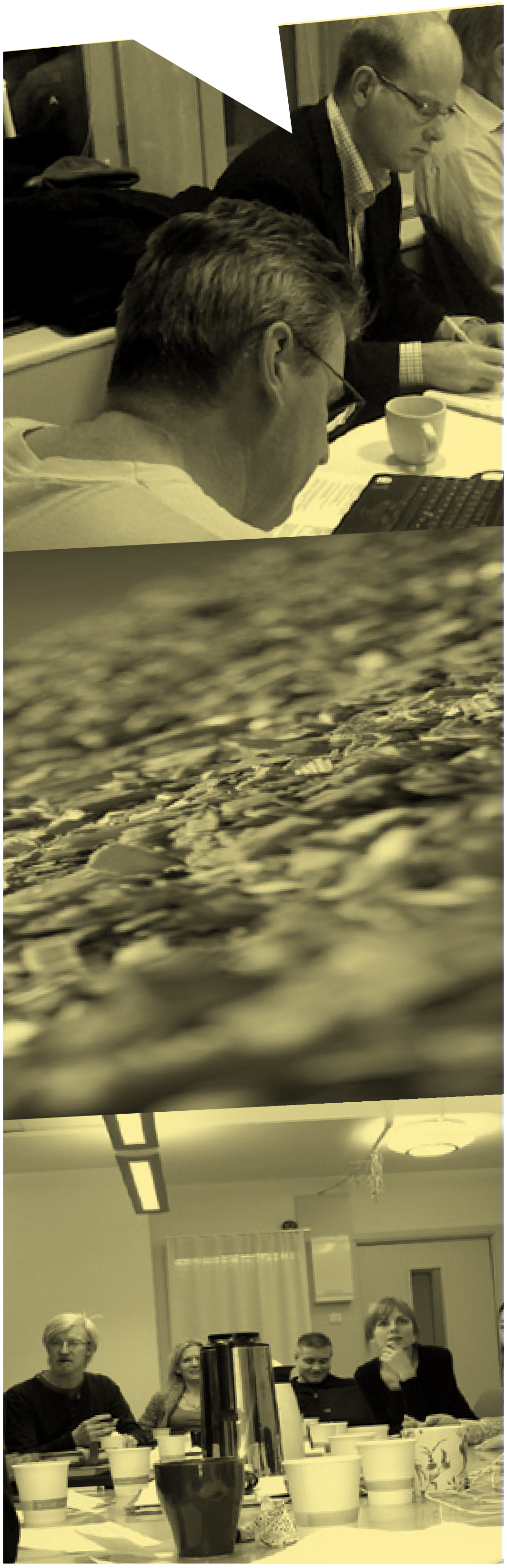

Sustainable cities in a backcasting perspective

Hållbara städer i ett backcastingperspektiv

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FÖRORD

Genom integrering av kunskap och kompetens inom strategisk hållbar utveckling och kunskap och kompetens inom energisystemanalys så har forskarna i detta projekt utvecklat en prototyp av ett metodologiskt stöd för hållbar fjärrvärmeutveckling. För att utveckla detta stöd och för att exemplifiera hur stödet kan användas har fallstudier genomförts. Här har fjärrvärmens utmaningar och möjligheter i Blekinge och Stockholm studerats med en kombination av backcasting och forecasting.

Backcasting används främst för att klargöra det övergripande långsiktiga målbilden inom ramen för en principiell definition av hållbarhet, för en analys av dagens situation i förhållande till denna målbild och för att stimulera generering av tänkbara åtgärder för att överbrygga gapet. Forecasting, i det här fallet genom energisystemanalys, används främst för att pröva olika tänkbara lösningar och handlingsvägar och därigenom stödja beslut om i vilken ordning åtgärderna som genererats bör göras i en strategisk plan.

Projektet har genomförts av Louise Trygg, Linköpings Universitet samt Göran Broman och Cesar Levy Franca vid Blekinge tekniska Högskola. Projektet har följts av en referensgrupp med Åke Axenbom (Energimyndigheten), Peter Dahlström (E.ON Värme), Erik Dotzauer (Fortum Värme), Fridolf Eskilsson (Jönköping Energi), Hans Gulliksson (Energikontor Sydost), Anita Gustafsson (Aura Light International), Bo Johansson (Karlshamn Energi), Erik Larsson (Svensk Fjärrvärme), Johnny Lilja (Karlskrona kommun) och Erik Thornström (Svensk Fjärrvärme).

Projektet ingår i forskningsprogrammet Fjärrsyn som finansieras gemensamt av fjärrvärmebranschen och Energimyndigheten. Fjärrsyn ska stärka möjligheterna för fjärrvärme och fjärrkyla genom ökad kunskap om fjärrvärmens roll i klimatarbetet och för det hållbara samhället till exempel genom att bana väg för affärsmässiga lösningar och framtidens teknik.

Christian Schwartz
Ordförande i Svensk Fjärrvärmes Omvärldsråd

SAMMANFATTNING

Hållbara städer i ett backcastingperspektiv

Mänskligheten står inför en stor utmaning – att ställa om till hållbarhet. Det finns många historiska exempel på lokala samhällen som gått under p.g.a. misskötsel av de ekologiska och/eller sociala system som de var beroende av. Nu är hela den globala mänskliga civilisationen hotad. Samtidigt innefattar denna utmaning strategiska möjligheter för proaktiva företag, kommuner och regioner. Genom att systematiskt minska sitt bidrag till problemet och genom att istället tidigt börja bli en del av lösningen till problemet så påskyndar man omställningen. Man blir då även mer attraktiv på den alltmer hållbarhetsdrivna marknaden och som ett sådant föregångsexempel stimulerar man också andra till proaktivt och strategiskt hållbarhetsarbete.

Vår nuvarande användning av energi utgör en stor del av hållbarhetsproblemet. Att skyndsamt utveckla hållbara energisystem är av avgörande betydelse för hela samhällets omställning till hållbarhet. Ökad systemeffektivitet och minskad klimatpåverkan är viktiga delar i detta. Svenska fjärrvärmesystem har haft stor betydelse för ökad systemeffektivitet och minskad klimatpåverkan och kan fortsatt spela en viktig roll i samhällets omställning till hållbarhet. Att göra miljömässiga och affärsmässiga bedömningar av ytterligare investeringar i fjärrvärmesystem har dock blivit mer komplext. Exempelvis så bygger den stora fördel ur klimatsynpunkt som fjärrvärmesystem kopplat till kraftvärmeproduktion ofta tillgodoräknas idag till stor del på att det övriga energisystemet är ohållbart (med kolkondensproducerad el på marginalen). Men när nu hela energisystemet, och hela samhället, kommer att genomgå ett paradigmskifte; hur kan man då resonera kring och bedöma investeringar i fjärrvärme? Hur försäkrar man sig om att ha ett tillräckligt stort perspektiv i både rum och tid och beträffande samhällssektorer? Hur kan åtgärder inom olika delar av energisystemet och samhället genereras och samordnas så att de ömsesidigt stödjer varandra, eller i varje fall inte utgör hinder för kommande nödvändiga åtgärder inom delsystemen? Hur skulle ny kompetens som kombinerar strategiskt hållbarhetssänkande och energisystemanalys kunna byggas upp och hur skulle ett metodologiskt stöd kunna se ut som hjälper företag, kommuner och regioner att hantera den ökade komplexiteten inom energiområdet? Dessa frågeställningar, med ett speciellt fokus på fjärrvärme, utgjorde en bakgrund till detta projekt.

Baserat på denna bakgrund så formulerades projektets syfte till att: applicera energisystemanalyser och marknadsanalyser inom ramen för ett backcastingtänkande på studier av fjärrvärmesystem, där en övergripande strategisk ”masterplan”, samt metodik för dess uppföljning, revidering och kommunikation, samt för utveckling av fjärrvärmesystem, som stöd för utveckling till ett hållbart samhälle, är målet.

Exempel på frågeställningar som ansågs intressanta var:

- Vilka åtgärder för fjärrvärmeleverantörer och för användarsidan inom dagens fjärrvärmesystem leder till, och påskyndar, utvecklingen till ett hållbart samhälle?
- Hur marknadsintroduceras ny fjärrvärmerelaterad energiteknik och relaterade affärsmodeller och hur ökas marknaden för detta?
- Hur kan fördelar ur hållbarhetssynpunkt med fjärrvärmesystem kommuniceras till kunder och andra intressenter på ett attraktivt sätt?

Det ansågs intressant att studera både tätortsregioner och glesbygdsregioner med jämförande analyser av regioner med olika förutsättningar.

Arbetet med ovanstående har inneburit (1) ett korslärande mellan områdena *strategisk hållbar utveckling* och *energisystemanalys* vid de involverade universitets-avdelningarna och byggande av en tvärveteskaplig kompetensgrund för framtida integrerad forskning och utbildning inom hållbar fjärrvärmeutveckling, samt (2) att den under projektet successivt förstärkta tvärvetenskapliga kompetensgrunden för att studera regionala energisystem, med fokus på fjärrvärmens roll, och baserat på lärandet från dessa fallstudier har använts för att utveckla en prototyp av ett metodologiskt stöd för hållbar fjärrvärmeutveckling.

Genom integrering av kunskap och kompetens inom strategisk hållbar utveckling som finns vid Blekinge Tekniska Högskola (BTH) och den kunskap och kompetens inom energisystemanalys som finns vid Linköpings universitet (LiU) har en prototyp av ett metodologiskt stöd utvecklats för hållbar fjärrvärmeutveckling (Resource Kit). Både som ett sätt att utveckla detta stöd och för att exemplifiera hur stödet kan användas så har fallstudier genomförts. Några sådana exempel på fallstudier har beskrivits i stödet i pedagogiskt syfte och resultat från samtliga fallstudier är redovisade i ett flertal vetenskapliga publikationer.

Aktionsforskning och fallstudier har alltså varit framträdande vetenskapliga metoder i projektet. Med en kombination av backcasting och forecasting har vi studerat fjärrvärmens utmaningar och möjligheter i Blekinge och Stockholm. Backcasting används främst för att klargöra den övergripande långsiktiga målbilden, för en analys av dagens situation i förhållande till denna målbild och för generering av tänkbara åtgärder för att överbrygga gapet. Forecasting används främst för ”what-if-simuleringar” för att pröva olika handlingsvägar och stödja beslut om i vilken ordning åtgärder bör tas. De två geografiska områden som studerats inom projektet utgör två ganska olika fall, vilket bidrar till ökad generaliserbarhet. Det har också lett till insikten att generellt giltiga utvecklingsplaner är svårt att ge. Med olika förut-sättningar för olika fjärrvärmeföretag och för olika regioner fann vi och referens-gruppen det viktigt att de aktuella aktörerna får stöd att bygga upp sin kunskap och kompetens och att de får tillgång till ett metodologiskt stöd för att själva kunna tydliggöra grunderna för, och de sannolika implikationerna av, sina beslut utifrån de rådande villkoren i respektive fall.

I de workshopar och övriga dialoger vi haft med fjärrvärmeintressenter har vi sett hur tidiga versioner av Resource Kit har gett stöd åt t.ex. nulägesanalyser av lokala och regionala energisystem i förhållande till hållbarhet, självvärdering av mognadsgrad med avseende på strategiskt hållbarhetsarbete, kartläggning av nuvarande intressentnätverk, klarläggande av styrkor och svagheter med nuvarande affärsmodeller samt hur det stimulerat generering av lösningsidéer och nya affärsmodeller. Genom att utgå både från dagens system och trender å ena sidan, och från en framtida situation där samhället uppnått hållbarhet å andra sidan, och genom att fundera kring hur fjärrvärmeinvesteringar skulle kunna bidra till att överbrygga detta gap på ett ekonomiskt bärkraftigt sätt, så vidgades perspektiven och kreativiteten stimulerades.

Åtgärder som vid workshopar och referensgruppsmöten inom projektet har identifierats som intressanta har vi gått vidare med och studerat mer ingående med metoder och verktyg för energisystemanalys. Resultat från dessa analyser visar att samarbete kring fjärrvärmeleverans, introduktion av kraftvärme, absorptionskyla och produktion av biobränsle är exempel åtgärder inom dagens fjärrvärmesystem som kan leda till, och påskynda, utvecklingen till ett hållbart samhälle. I de fall vi studerat har investeringar i t.ex. samarbete kring värmeleveranser och kraftvärme visat sig speciellt intressanta att prioritera som tidiga åtgärder. T.ex. skulle ett värmesamarbete mellan ett regionalt energibolag och en industri tillsammans med investeringar i ny biobaserad kraftvärmeanläggning leda till ca 100 % lägre globala CO2-utsläpp jämfört dagens situation (med antagande av kolbaserad el på marginalen). Men fördelarna med värmesamarbete och ny kraftvärme är mindre tydliga när man utgår från ett framtida hållbart samhälle där all el produceras av förnybara och hållbara energikällor – och då vi alltså inte har marginalel från kolkondenskraftverk. Under vissa förutsättningar kan dessa åtgärder ändå spela en avgörande roll för utvecklingen till ett hållbart samhälle. Generellt giltiga standardåtgärder är som sagt dock svårt att ge, eftersom förutsättningarna är olika för varje fjärrvärmeföretag och för varje region, och därför är det viktigt att de aktuella aktörerna bygger upp sin kunskap och kompetens och får tillgång till ett metodologiskt stöd för att samskapa lämpliga utvecklingsplaner utifrån de rådande villkoren i respektive fall.

Den främsta målgruppen för Resource Kit är energibolag, men även konsultbolag, myndigheter, kommuner och universitet kan ha nytta av stödet. Resource Kit lämpar sig i första hand för något större organisationer. Användaren bör vara så stor att den har en enhet för strategisk planering och utveckling, vilket brukar finnas på fjärrvärmeföretag med fler än omkring 20 anställda. Även mindre organisationer kan ha glädje av Resource Kit men då med ett mer omfattande expertstöd utifrån. Första gången det används, och om det inte redan finns kompetens inom organisationen i strategiskt hållbarhetstänkande och energisystemanalys, så rekommenderas hursomhelst ett externt stöd.

För att bygga på med fler exempel på hur Resource Kit kan användas och för att med hjälp av dessa förfina stödet så gör vi för närvarande också studier där vi antar att både biobränsle och avfall sannolikt kommer att vara en begränsad resurs i ett framtida hållbart samhälle (studier där enbart biobränsle antagits vara en begränsad resurs har redan utförts). Vi vill visa hur riskerna med att okritiskt anta en ökande tillgång till dessa bränsletyper kan tydliggöras och hanteras. Detta är påkallat av backcastingperspektivet. Vi vill också gå vidare med analyser av några av de mer radikala idéer som har kommit fram under våra workshopar med fjärrvärme-intressenter. Ett exempel är idén att byta värdeerbjudande från ”värme” till ”inomhusklimat” och att bygga upp intressentsamverkan och affärsmodeller kring det. Generellt vill vi, för att vidareutveckla prototypen av Resource Kit till ett mer komplett och användarvänligt stöd, i kommande arbete genomföra ytterligare iterationer mellan utveckling och användning, gärna i fler regioner och kommuner för att testa och säkra en hög generaliseringsgrad.

Att projektet skapat ett långsiktigt värde visar sig också i den kompetens-uppbyggnad som skett bland utförarna, bland medlemmar i referensgruppen och bland övriga som interagerat med projektet. Projektets doktorander har tagit del av kurser inom båda kompetensområdena och vi har genomfört flera seminarier och workshopar med kolleger vid respektive universitet. För att trygga återväxten av personer med denna kompetens har vi även integrerat nyvunna kunskaper och erfarenheter från projektet i kurser samt samverkat med examensarbetare vid både BTH och LiU. Vid LiU har projektet dessutom resulterat i en ny kurs inom civil-ingenjörsprogrammet *energi-miljö-management* i vilken metodik för strategisk hållbar utveckling och energisystemanalys appliceras på regionala fjärrvärmesystem och vid BTH startas till hösten ett högskoleingenjörsprogram inom *energisystem för hållbar utveckling* som inspirerats av och stärks av detta projekt. Vi och referens-gruppen ser det korsvisa lärandet för oss själva och bland kolleger, liksom bidraget till kurser och utbildningsprogram, som ett viktigt resultat av projektet.

Projektets resultat kan således sammanfattas i följande punkter:

- För att bygga upp och förmedla kunskap kring, och för att ge stöd åt branschen att arbeta med, hur fjärrvärmesystem och affärsmodeller kring sådana på bästa sätt skulle kunna utgöra en strategisk plattform för att uppnå det hållbara samhället, hur ny fjärrvärmerelaterad energiteknik och relaterade affärsmodeller skulle kunna marknadsintroduceras, hur marknaden skulle kunna ökas för detta samt hur detta förhållande i så fall skulle kunna kommuniceras till kunder och andra intressenter på ett attraktivt sätt så har en prototyp av ett metodologiskt stöd för hållbar fjärrvärmeutveckling tagits fram; Resource Kit.
- Som ett sätt att utveckla det metodologiska stödet, och för att exemplifiera hur stödet kan användas, så har fallstudier på fjärrvärmesystem i tätorts-regioner och glesbygdsregioner (Stockholm respektive Blekinge) genomförts. Dessa har gjorts med, och exemplifierar en kombination av, forecasting och backcasting, d.v.s. energisystemanalyser och marknads-analyser inom ramen för ett backcastingtänkande. Sammantaget visas hur backcasting främst används för att klargöra den övergripande långsiktiga målbilden, för en analys av dagens situation i förhållande till denna målbild och för generering av tänkbara åtgärder för att överbrygga gapet, och hur forecasting främst

används för ”what-if-simuleringar” för att pröva olika handlingsvägar och stödja beslut om i vilken ordning åtgärder bör tas, d.v.s. hur energisystemanalyser och forecasting kommer in för att studera delsteg.

- Dessa fallstudier, som utförts med forecasting inom ramen för ett backcastingtänkande, visar hur t.ex. ökat samarbete mellan industrier och energileverantörer, konverteringsmöjligheter, samproduktion av biodrivmedel samt introduktion av kraftvärme och absorptionskyla kan vara åtgärder inom dagens fjärrvärmesystem som leder till, och påskyndar, utvecklingen till ett hållbart samhälle, och att samarbete kring värmeleveranser och kraftvärme visat sig speciellt intressanta att prioritera som tidiga åtgärder under de gällande förutsättningarna i de studerade fallen. Samtidigt har vi insett att generellt giltiga utvecklingsplaner är svårt att ge p.g.a. olika förutsättningar för olika fjärrvärmeföretag och olika regioner.
- Det korslärande mellan områdena *strategisk hållbar utveckling* och *energisystemanalys* som projektet resulterat i bidrar till en långsiktig kompetensuppbyggnad för fortsatt utveckling av hållbara fjärrvärmesystem. Integrationen av den uppbyggda kunskapen i kurser och utbildningsprogram vid BTH och LiU har bidragit till, och bidrar fortsatt till, att öka intresset för fjärrvärme inom högskoleutbildningen.

SUMMARY

Humanity is facing a great challenge – to transition society towards sustainability. There are many historical examples of local communities that perished due mismanagement of the ecological and/or social systems that they depended upon. Now the entire global human civilization is threatened. At the same time this challenge holds strategic opportunities for proactive companies, municipalities and regions. By systematically reducing their contribution to the problem and by early on start to instead become part of the solution to the problem, they accelerate the transition, become more attractive in the increasingly sustainability-driven market and as such good examples they also encourage others to be proactive and strategic about sustainability.

Our current use of energy is a major part of the sustainability problem. To rapidly develop sustainable energy systems is crucial for the whole society's transition towards sustainability. Increased system efficiency and reduced climate impact are important parts of this. Swedish district heating systems have been very important for increased system efficiency and reduced climate impact and can continue to play an important role in society's transition towards sustainability. However, making environmental and economic assessments of additional investments in district heating systems have become more complex. For example, the great benefit from a climate perspective that district heating linked to combined heat and power generation (CHP) is often credited for today, is to a large extent based on the fact that the rest of the energy system is unsustainable (with coal based electricity generation at the margin). But when the entire energy system, and the entire society, will undergo a paradigm shift, how can we then discuss and assess investments in district heating? How can we ensure that we have a wide enough perspective in both space and time and as regards societal sectors? How can actions in different parts of the energy system and society be generated and coordinated so that they mutually support each other, or at least do not preclude future necessary steps within the subsystems? How could new competence that combines strategic sustainable development and energy system analysis be built and how could a methodological support look like that helps businesses, municipalities and regions to manage the increased complexity in the energy sector? These issues, with a special focus on district heating, formed a background to this project.

Based on this background, the following project aim was formed: to apply energy systems analysis and market analysis within a backcasting perspective to the study of district heating systems, where an overall strategic "master plan", and methodology for its follow-up, revision and communication, and for development of district heating systems that support the development of a sustainable society, is the goal.

Examples of issues that were considered interesting were:

- What measures for district heating suppliers and for the user in today's district heating systems leads to, and accelerates, the development of a sustainable society?
- How are new heating-related energy technologies and related business models introduced in the market and how can the market for this be increased?
- How can sustainability advantages of district heating systems be communicated to customers and other stakeholders in an attractive way?

It was also considered interesting to study both urban areas and rural areas with comparative analyses of regions and conditions.

The work with the above has implied (1) cross-learning between the areas *strategic sustainable development* and *energy system analysis* at the involved university departments and building of a cross-disciplinary competence foundation for future integrated research and education on sustainable district heating development, and (2) that this (during the project successively strengthened) cross-disciplinary competence foundation to study regional energy systems with a focus on the role of district heating and, based on the learning from these case studies, has been used to develop a prototype for a methodological support for sustainable district heating development.

By integrating Blekinge Institute of Technology's (BTH) knowledge and competence in the field of strategic sustainable development and Linköping University's knowledge and competence in the field of energy systems analysis, a prototype of a methodological support for sustainable district heating was developed. Both as a way of developing this support and to provide examples of how the support can be used, some case studies have been performed. Some of these examples are included in the support for pedagogical purposes and the results from all case studies have been presented in several scientific publications.

Action research and case studies have thus been prominent scientific methods in the project. We have studied the challenges and opportunities of district heating in Blekinge and Stockholm with a combination of backcasting and forecasting. Backcasting is primarily used for clarification of the overall long-term goal, for an analysis of the current situation in relation to this goal and for the generation of possible measures to close the gap. Forecasting is primarily used for “what-if simulations” in order to test different development paths and support decisions regarding in which order measures should be taken. The two rather different geographic areas that have been studied lead to greater generalization. It has also led to the understanding that generally valid development plans are difficult to give. With different conditions for different heating utilities and for different regions, we and the reference group found it important that stakeholders are supported in building their knowledge and competence and that they get access to a methodological support to clarify the grounds for, and the likely implications of, their decisions based on the prevailing conditions in each case.

In the workshops and other dialogues we have had with district heating stakeholders, we have seen how early versions of the Resource Kit have provided support for, e.g., analyses of the current situation of local and regional energy systems in relation to sustainability, self-assessment of maturity in terms of strategic sustainability work, clarification of the strengths and weaknesses of current business models and how this has stimulated the generation of solutions and new business models. By on the one hand using today's systems and trends as one bridge head, and on the other hand using a vision of a future situation in which society has achieved sustainability as a second bridge head, and by thinking about how investments in district heating could contribute to bridging this gap in an economically viable manner, the perspective was broadened and creativity stimulated.

Measures identified as interesting in workshops and reference group meetings during the project have been studied in greater depth with methods and tools for energy system analysis. Results from these analyses shows that cooperation on the supply of district heating, the introduction of CHP, absorption cooling and the production of biofuel are measures that within the district heating system of today, will accelerate the development towards a sustainable society. In the cases we have studied, investments in, e.g., cooperation on the supply of district heating and CHP have proven to be of particular interest as prioritized early measures. For example, heat cooperation between a regional energy utility and an industry, combined with investments in new bio-based CHP, could lead to approximately 100 % reduction in global CO2 emissions when compared to the current situation (assuming coal-based power as marginal electricity production). But the advantages of heat cooperation and new CHP are less clear in a sustainable society in which all electricity is produced by renewable and sustainable energy sources – where we thus have no marginal electricity production in coal-fired condensing power plants. Under certain conditions, these measures can still play a crucial role in the development towards a sustainable society. As said, it is however difficult to give any generally applicable or standard measures, as the conditions vary for each district heating company and region, and it is therefore important that the stakeholders in question build up their knowledge and competence and get access to a methodological support, enabling them to co-create appropriate development plans based on the prevailing conditions in the specific cases.

The primary target group for the Resource Kit is energy utilities, but consultancies, authorities, municipalities and universities can also benefit from the support. The Resource Kit is primarily intended for larger organizations. The user should have a unit for strategic planning and development, which tends to be the case for district heating companies with over 20 employees. Smaller organizations may also benefit from the Resource Kit, but with more support of external expertise.
In any case, the first time it is used, and if the organization does not already have expertise in strategic sustainable development and energy system analysis, external support is recommended.

In order to provide more examples of how the Resource Kit can be used and in order to use these to refine the support, we are currently also conducting studies based on the notion that both biofuel and waste will likely be a limited resource in a future sustainable society (studies where only biofuel is assumed to be a limited resource is already performed). We want to show how the risks of uncritically assuming increasing access to these fuel types can be clarified and managed. This is prompted by the backcasting perspective. We also wish to work more with analyses of some of the more radical ideas that have come up during our workshops with district heating stakeholders. One example is the idea of changing the value proposition from ”heat” to ”indoor climate” and building up stakeholder collaboration and business models around it. In general, in order to further develop the prototype for the Resource Kit into a more complete and user-friendly support, we wish in our future work to do additional iterations between development and usage, preferably in more regions and municipalities in order to test and secure a high degree of generalization.

The long-term value of the project is also evident from the development of competence that has taken place among the researchers, among members of the reference group and among other stakeholders that have interacted with the project. The project's PhD students have taken courses in both competence areas and we have conducted a number of seminars and workshops with colleagues at the respective universities. To ensure the regrowth of people with this competence we have also integrated the new knowledge and experience gained from the project into courses and collaborated with thesis project students at both BTH and LiU. Furthermore, the project has resulted in a new course in LiU's Master's Program in Engineering *energy-environment-management* in which methods for strategic sustainable development and energy system analysis are applied to district heating systems, and at BTH a Bachelor of Science Program inspired and reinforced by the project, *energy systems for sustainable development*, will start in the fall. We and the reference group see the cross-learning achieved by ourselves and our colleagues, as well as the contribution to courses and educational programs, as an important result of the project.

The result of the project can be summarized in the following points:

- To build up and disseminate knowledge about, and to provide support for the industry to work with, how district heating and related business models could best provide a platform for reaching the sustainable society, how new district heating related energy technologies and related business models could be introduced on the market, how the market could be increased for this and how this relationship could then be communicated to customers and other stakeholders in an attractive way, a prototype of a methodological support for sustainable district heating development have been developed; Resource Kit
- As a way to develop the methodological support, and to exemplify how the support can be used, case studies of district heating systems in urban areas and rural areas (Stockholm and Blekinge) have been performed. These have been made with, and exemplify a combination of, forecasting and back-

casting, i.e., energy systems analysis and market analysis within a backcasting perspective. Overall it is shown how backcasting mainly is used to clarify the overall long-term vision, for an analysis of the current situation in relation to this vision and to generate actions to bridge the gap, and how forecasting is mainly used for "what-if simulations" to help prioritize early smart actions and onwards support successive re-designs of the plan, i.e., how energy systems analysis and forecasting are used to study sub-steps.

- These case studies, performed with forecasting within a backcasting perspective, show, e.g., how increased cooperation between industries and energy suppliers, conversion possibilities, co-production of biofuels and the introduction of, e.g., CHP and absorption cooling are examples of actions within today's district heating systems that can accelerate the development towards a sustainable society, and that cooperation on heat supply and cogeneration are proved particularly interesting to prioritize as early action under the existing prerequisites of the studied cases. At the same time we have realized that generally valid development plans are hard to prescribe, because of different prerequisites for different utilities and different regions.
- The cross-learning between the areas of *strategic sustainable development* and *energy systems analysis* that this project has resulted in, contributes to a long-term capacity building for continued development of sustainable district heating systems. The integration of the generated knowledge into courses and programs at BTH and LiU has contributed, and continue to contribute, to an increased interest in district heating within higher education.

CONTENT

1 INTRODUCTION

This report describes the background ideas, activities and results of the project "Sustainable Cities in a Backcasting Perspective". It has been a joint project between Blekinge Institute of Technology (BTH) and Linköping University (LiU). The project started in February 2010 and ended in February 2013. Besides this report, the learning and outcome of the project has also been captured in a Resource Kit and in case study descriptions. The Resource Kit is briefly described in section 5.1 and some explorative case studies are briefly described in section 5.2.

1.1 BACKGROUND

Humanity is facing a great challenge – to transition society towards sustainability. There are many historical examples of local communities that perished due mismanagement of the ecological and/or social systems that they depended upon. Now the entire global human civilization is threatened. At the same time this challenge holds strategic opportunities for proactive companies, municipalities and regions. By systematically reducing their contribution to the problem and by early on start to instead become part of the solution to the problem, they accelerate the transition, become more attractive in the increasingly sustainability-driven market and as such good examples they also encourage others to be proactive and strategic about sustainability.

Our current use of energy is a major part of the sustainability problem. To rapidly develop sustainable energy systems is crucial for the whole society's transition towards sustainability. Increased system efficiency and reduced climate impact are important parts of this. Swedish district heating systems have been very important for increased system efficiency and reduced climate impact and can continue to play an important role in society's transition towards sustainability. However, making environmental and economic assessments of additional investments in district heating systems have become more complex. For example, the great benefit from a climate perspective that district heating linked to CHP is often credited for today, is to a large extent based on the fact that the rest of the energy system is unsustainable (with coal based electricity generation at the margin). But when the entire energy system, and the entire society, will undergo a paradigm shift, how can we then discuss and assess investments in district heating? How can we ensure that we have a wide enough perspective in both space and time and as regards societal sectors? How can actions in different parts of the energy system and society be generated and coordinated so that they mutually support each other, or at least do not preclude future necessary steps within the subsystems? How could new competence that combines strategic sustainable development and energy system analysis be built and how could a methodological support look like that helps businesses, municipalities and regions to manage the increased complexity in the energy sector? These issues, with a special focus on district heating, formed a background to this project.

Previous studies have shown how a methodology for strategic sustainable development – based on backcasting from sustainability principles – can stimulate generation of innovative ideas and guide strategic planning and decision making for viable transitions towards sustainability within companies, municipalities and regions (e.g., Broman et al., 2000). It has also been shown how this basic methodology can be used to assess the strengths and weaknesses of other methods and tools for sustainable development and to coordinate the use and maximize the benefits of such methods and tools (e.g. Robèrt et al., 2002). Other previous studies have shown the power of using energy system analysis tools for a more detailed investigation of various alternative measures and energy systems investments (e.g., Trygg, 2004; Bohlin et al., 2004; Henning et al., 2004; Trygg et al, 2009). The basic idea of this project was to combine these competence areas, as an attempt to address the above issues. Potential benefits of such a combined approach would thus include stimulation of district heating stakeholders to co-create innovative solutions, new business models and attractive early steps for viable transition paths towards sustainability, i.e. transition paths that minimize the risks of sub-optimization due to a too narrow perspective in space or time or as regards societal sectors.

1.2 AIM

Specifically, the aim of this project was to:

- Promote cross-learning between the areas *strategic sustainable development* and *energy system analysis* at the involved university departments and build a cross-disciplinary competence foundation for future integrated research and education on sustainable district heating development.
- Use this (during the project successively strengthened) cross-disciplinary competence foundation to study regional energy systems with a focus on the role of district heating and, based on the learning from these case studies, develop a prototype for a methodological support for sustainable district heating development.

2 PROJECT ORGANISATION

The project has included researchers from Blekinge Institute of Technology (BTH) and Linköping University (LiU) and a reference group with representatives from industry, consultancy, utilities and municipalities. The project was conducted in close collaboration between researchers and the reference group, with an ongoing dialogue throughout the whole project, and in close cooperation with other district heating stakeholders in Blekinge and Stockholm.

2.1 PROJECT GROUP

The persons presented in table 1have been active within the project.

Table 1. Project group members.

Name	Function
Louise Trygg, LiU	Project Leader
Göran Broman, BTH	Asst. Project Leader
Danica Djuric Ilic*, LiU	Ph.D. Student
Cesar Levy Franca, BTH	Ph.D. Student

* Participated in the project until July 2011.

2.2 REFERENCE GROUP

The persons presented in table 2 have been active within the reference group.

Table 2. Reference group members.

Name	Organization
Åke Axenbom	Energimyndigheten
Erik Dotzauer	Fortum Värme
Fridolf Eskilsson	Jönköping Energi
Hans Gulliksson	Energikontor Sydost
Anita Gustafsson	Aura Light International
Bo Johansson	Karlshamn Energi
Erik Larsson	Svensk Fjärrvärme
Johnny Lilja	Karlskrona kommun
Erik Thornström	Svensk Fjärrvärme

Charlotte Reidhav, Göteborg Energi; Anders Möller, Lund Energi; Michael Erman, Regionplanekontoret samt Peter Dalström, E.ON Värme have been members of the reference group for part of the project period. They left the reference group at various points in time due to changes in their work situation.

The reference group's mission was to be an enhancement to the project and to monitor the work throughout the project. According to the Swedish District Heating Association, the reference group members have an advisory role and are responsible for:

- Specifying the work of the project and ensure that the focus remains in line with the priorities of the Swedish District Heating Association’s council and in line with the program Fjärrsyn’s vision and goals.
- Following the project and to oversee the implementation of the approved project plan. If abnormalities are detected, this shall be promptly reported to the contact person at the Swedish District Heating Association.
- Contributing with knowledge from their perspective by providing advice and guidance for the benefit of the project and thus the industry.
- Calling attention to the need for reorientation or other changes in the project. Decisions on changes are made by the Research Board.
- Providing support and ideas for the project and facilitating contact and communication with the industry.
- Contributing with input on how the results will be implemented or what is required for the results to be used.
- Reviewing interim reports and the final report both regarding of the content and against the project plan and the Swedish District Heating determinations for reports. The report shall always be finally approved by at least one of the councils and of the Research Board.

At the reference group meetings, the importance of having a strong peer group has been stressed, especially given that some of the reference group's main tasks are to follow the work of the project, provide expertise and discuss the progression of the project together with the project members.

The composition of the reference group assured a broad expertise and experience, particularly as regards regional conditions. This has been of great value to the project.

Seven reference group meetings have been held during the project, April 16, 2010 in Stockholm, August 26, 2010 in Karlskrona, November 29, 2010 in Linköping, May 20, 2011 in Karlskrona, November 29, 2011 in Stockholm, October 26, 2012 in Karlskrona and February 25, 2013 in Linköping.

3 METHODS

In this project, backcasting from sustainability principles has been combined with forecasting. A generic and unifying framework for planning and decision making towards sustainability (Framework for Strategic Sustainable Development; FSSD) has been used as the overall methodology. This has been integrated with methods and tools for modeling, simulation and optimization in the energy system field. Below we describe the core methodologies and how they have been integrated through action research and case studies.

3.1 FRAMEWORK FOR SSD

The Framework for Strategic Sustainable Development (FSSD) is designed to give guidance in how to develop any region, organization, project or planning endeavor towards social and ecological sustainability in an economically viable way. The FSSD provides a generic support for backcasting planning in any field at any scale by applying generic sustainability principles as boundary conditions and basic strategic guidelines for a stepwise change process. It has been under continuous development in a 20-year scientific consensus process including theoretical exploration, refinement and testing in iterative learning loops between scientists and practitioners from business and society.

3.1.1 BACKCASTING IN COMBINATION WITH FORECASTING

An approach that is often used in planning is forecasting. This is an approach used to project from current situations and trends in an attempt to predict the future. This is often useful when studying a relatively small subsystem within a superordinate system for which the overall trends are generally desirable and can be assumed to be relatively stable. However, when the current dominant trends of the whole system represent undesirable (unsustainable) development and need to change, when the change is expected to take considerable time (a long planning horizon) and when the system to be changed is complex, forecasting is not useful as the <u>only</u> approach. This would risk continuing the current undesirable trends of the overall system (e.g., society within the biosphere). Forecasting should then be combined with backcasting. Backcasting means agreeing on a desirable vision of a future situation and then asking “what do we need to today and onwards in smart step-by-step action plans to maximize our chances of reaching this vision?” As the development unfolds, the plan needs to be continuously re-assessed, taking into account changing conditions (that could not be predicted in detail upfront) for the optimal path ahead. Backcasting can be done from a vision described as a scenario or by basic success principles. In the sustainability context it is more helpful to backcast from a principled definition of success or from scenarios framed by such principles (Ny et al. 2006). When evaluating the backcasting question “what do we need to today…”, and when continuously re-assessing the development plan, forecasting is a useful approach. By doing forecasting in this way, within a backcasting perspective, alternative solutions and paths can be tested in “what-if-simulations” to help prioritize early smart actions and onwards support successive re-designs of the plan. A methodological support for doing this as regards district heating system development has been developed, and some case studies have been undertaken, in this project (see section 5).

3.1.2 THE FIVE LEVEL MODEL OF THE FSSD

To solve complicated problems in complex systems, a clear intellectual differentiation between five different (but interacting) levels is helpful. Those five levels focus on the *system* in which the planning takes place, the definition of *success*, the *guidelines* that are used to ensure a strategic process, and the *actions* and *tools* that are used in planning and implementation (Robért et al., 2012). These five levels are further described below:

1. The system level. This level describes the overall major functions of the system, i.e. the biosphere with its human society, organizations, value-networks, etc., our knowledge on stocks, flows, biogeochemical cycles, biodiversity and resilience, human needs, and the basic relationships between human practices and their impacts. The current systematic degradation of this system (unsustainability of the global human society) is the rational for the coming levels. In order to plan and act strategically, more and more detailed knowledge about the system is not necessarily helpful in itself. It is essential to also have a robust definition of “purpose/success” or “overall objective”. Such a robust definition of the objective can then provide a basis for backcasting planning and provide a lens for the further study of the system, i.e. identification of the relevant and essential aspects of the system that need to be further studied with regard to reaching the defined objective.

2. The purpose/success level. This level specifies the definition of the objective – success of the region, organization or other subject of the planning within the constraints of a sustainable society. Basic principles are used to define (frame) a sustainable society. In the sustainability context it is more helpful to backcast from a principled definition of success than a fixed detailed scenario, for several reasons. For example, it is often difficult for many stakeholders to agree on a detailed objective that is far into the future. Also, since, e.g., technical and cultural evolution continuously change the conditions for the planning endeavor in a way that cannot be predicted in detail it is best to avoid overly specific assumptions of the future too early in the transition process. A principled vision offers more flexibility than a detailed scenario because success can be achieved in a variety of ways (as long as the principles are met). Organizational learning experts have observed that these types of constraints *stimulate* creativity. For example, Senge

(2003) states “understanding your constraints frees you to create”. Applying an analogy; to checkmate one’s opponent is the purpose/success in chess, which can happen in almost uncountable combinations all complying with the same basic principles of checkmate. To be functional for strategic sustainable development, the set of principles must be *necessary* (but not more) to avoid unnecessary restrictions and to reduce distraction over elements that may be debatable and *sufficient* (and not less) to cover all aspects of sustainability. In addition, the set of principles should be *general* to make sense for all stakeholders and thus allow for cross-disciplinary and cross-sector cooperation, *concrete* to inspire and guide innovation, problem solving and actions, and *distinct* (non-overlapping) to enable comprehension and facilitate development of indicators for monitoring. The next level requires this key second level.

3. The strategic guidelines level. This level specifies the guidelines for how to approach the objective strategically. This implies a step-by-step approach towards the objective in a way that ensures that financial, social, and ecological resources continue to feed the process. In chess, moves serve as strategic steps to checkmate. Trade-offs, in chess or in the “game of sustainable development”, are selected from their capacity to serve as platforms towards complying with principles of success (level 2), rather than as choices between inherent evils.

4. The actions level. This level is about putting concrete measures (e.g. investments) into stepwise action programs in line with the strategic guidelines at level 3.

5. The tools level. Concepts, methods and tools are often required for decision support, monitoring and disclosures of the actions (4) to ensure they are chosen strategically (3) to arrive stepwise at the objective (2) in the system (1). Examples in sustainable development are modeling and simulation tools, management systems, indicators, life cycle assessments, etc. The FSSD is designed to not compete with any other concept, method or tool, but to be structuring and unifying to aid people in making the best use of any other concept, method or tool, depending on purpose and context.

It is the rigor by which levels (1)-(3) are described and allowed to inform each other that determines how confident users can be when developing/choosing appropriate actions (4) and appropriate complementary concepts, methods and tools (5).

The FSSD uses an application procedure with four general steps. In the first step, (A) participants learn and apply the FSSD to share and discuss the topic or planning endeavor and agree on a preliminary principle vision of success, framed by sustainability principles (SPs). In the second step, (B) participants explore the current situation in this context. They list the main current challenges in relation to the objective they want to reach, informed by the SPs applied as boundary conditions, as well as current assets to deal with those challenges. Thereafter, (C) participants turn to brainstorming, whereby they suggest possible future solutions to the challenges and scrutinize them only with respect to the vision within the SPs, temporarily disregarding constraints related to the current situation, e.g., constraints related to the current infrastructure, the current energy system, the current financial capacity, etc. In the final step, (D) the strategic dimension comes to the fore when participants prioritize solutions, e.g., investment decisions from the previous step. In this D-step, priorities are set with an intuitive logic. It means a stepwise approach, ensuring that early steps are designed to serve as (1) flexible platforms for forthcoming steps that, taken together, are likely to bring society, the organization and the planning endeavor to the defined success, by striking a good balance between (2) direction and advancement speed with respect to the defined success and (3) return on investment to sustain the transition process. The logic creates the opportunity for pragmatic leadership, not only looking at the promise for an improved bottom-line in the future, but also considering short-term profits designed in a way that opens up the potential for the longer-term profits. The FSSD allows for a self-benefit of sustainability proactivity to be captured by, e.g., companies.

3.2 MODELLING – SIMULATION – OPTIMIZATION AS A TOOL WITHIN THE FSSD

In this project, energy systems modelling, simulation and optimization have been used as a “tool” within the FSSD. The energy systems analyses have been performed with a combination of backcasting and forecasting, as described above. To combine backcasting and forecasting is valuable when identifying the best stepping stones to the desired goal, especially for the stepping stones closets in time, where predications are the most reliable (Robért et al., 2012).

An advantage of using models is to be able to answer questions about the studied system without performing any real experiments. Those are sometimes impossible to perform, too expensive, or ethically doubtful. Working with models is especially advantageous when there are several factors to consider. The effects of all the factors one by one may be clear but the totality is not. However, it is important to remember that any model is only an approximation of the real system. Practically all technical analyses and design work is dependent on models. Models’ usefulness depends on how well the model describes the real system. It is important to clarify a model’s range of validity and to verify the model (Wallén, 1996; Ingelstam, 2002).

A number of modeling and simulation tools have been developed for analyzing energy systems. Examples include MODEST (e.g. Henning, 1999), MARKAL (e.g. Unger and Ekvall, 2003), EFOM (e.g. Holttinen and Tuhkanen, 2004), MESSAGE (e.g. Messner and Schrattenholzer, 2000) and TIMES (e.g. Remme et al., 2001). According to Wallén (1996), a model should fulfill the following requirements: systematic, efficiency, validation, model conditions and generalization. A model for analyzing energy systems should also be able to represent (e.g. Henning, 1999): many energy forms, investment costs and fixed and variable operation costs, demand-side measures, flexible, seasonal, monthly, weekly and diurnal time division, optimal operation and marginal costs.

In this project, mainly the MODEST tool has been used. The reason for choosing MODEST was, above all, the possibility to model a flexible time division. The MODEST model (short for Model for Optimisation of Dynamic Energy System with Time-dependent components and boundary conditions) was developed to fulfill the above-mentioned fundamental criteria as well as other criteria, see (Henning, 1999). The MODEST model is briefly described below.

3.2.1 MODEST

MODEST is used for minimizing the cost of existing and potential new plants (Henning, 1999; Gebremedhin, 2003). It is a model framework developed for simulation of municipal, regional and national energy systems and is based on linear programming. The aim of the optimization is to minimize the total cost of supplying the demand for heat and steam by finding the best types and sizes of new investments and the best operation of existing and potential plants. The total system cost is calculated as the present value of all capital costs of new installations, operation and maintenance costs, fuel costs, taxes and fees. The system is optimized over a given period of time. Each year in the optimization model is divided into seasons, which are then divided into daily periods.

The method assumes that the demand for district heating and electricity is known and the capacity of the plants is available. MODEST is not primarily a model for operational optimization, even if such optimization can be made in an approximate manner. MODEST has no other objective than total cost minimization, i.e. it has no objective of minimization, e.g., emissions or the use of certain energy forms.

As pointed out above, the validation of a model is important since the validation will indicate how well the model describes reality. Comparing the model with the real system’s behavior can validate a model. MODEST has been tested for modeling electricity and district heating supply for approximately 50 local utilities, for biomass use in three regions and for the Swedish power supply (Sjödin and Henning, 2004; Gebremedhin and Zinko, 2003).

For the studies in this project, the results of the optimizations have been thoroughly checked by analyzing the reasonability of both input and output data and by communicating and checking those data with local energy utilities.

3.3 ACTION RESEARCH FOR INTEGRATION

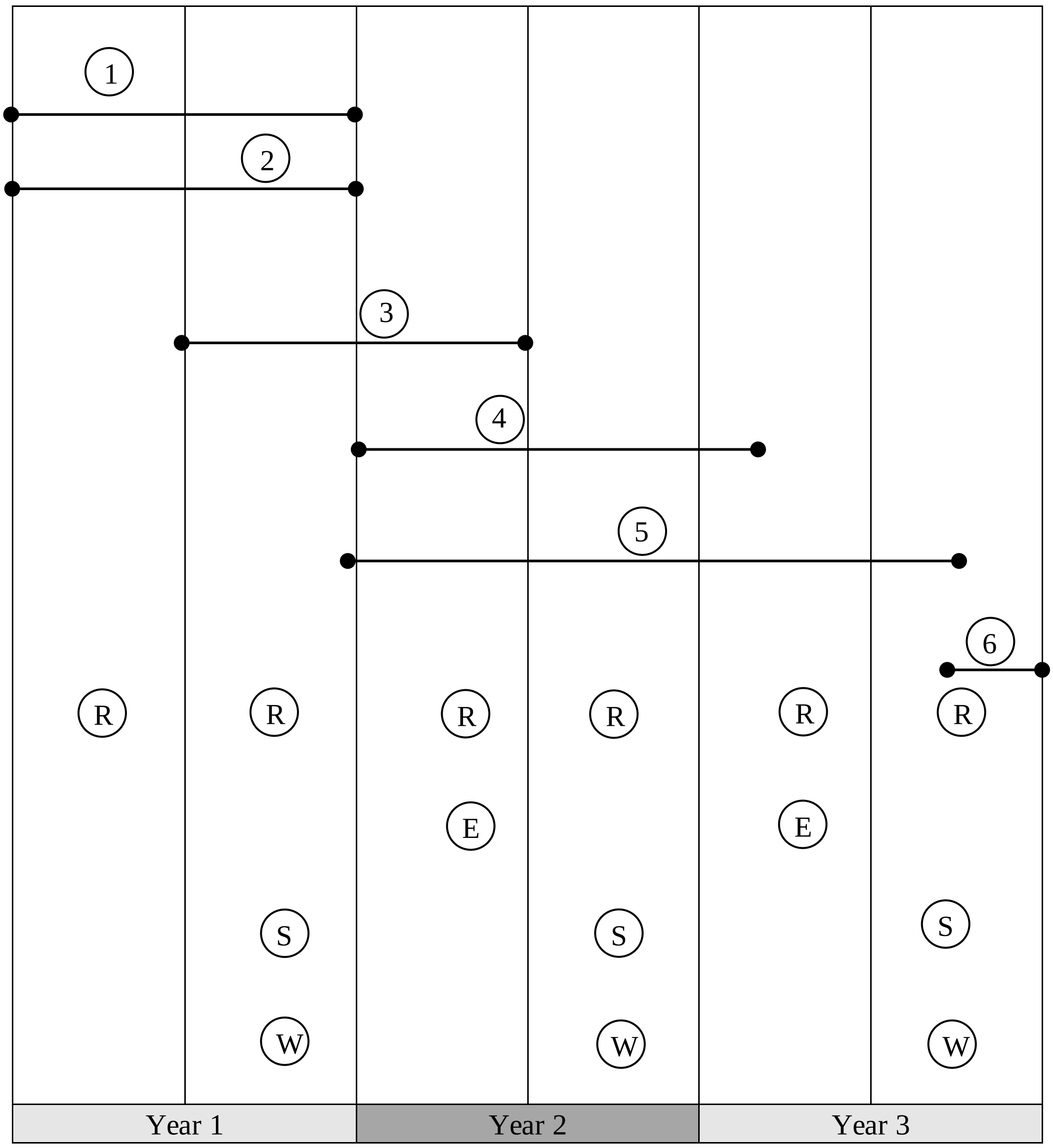
Action research and case studies have been prominent scientific methods in the project. We have studied the challenges and opportunities of district heating in Blekinge and Stockholm with a combination of backcasting and forecasting. These are two rather different cases, which leads to greater generalization. The integration of the competence areas described above has largely taken place through the case studies and the development of an integrated methodological support (Resource Kit; see the section on results). These case studies have also provided examples of how the support can be used, some of which have been included in the support for pedagogical purposes. As part of the action research, several workshops have been arranged with district heating actors and with researchers from both technical and social sciences disciplines. The workshops have served as a foundation for the development of the Resource Kit and also for the prioritization of areas for case studies.

We have also conducted a number of seminars and workshops with colleagues at the respective universities and the project's PhD students have taken courses in both competence areas. In order to achieve a long-term development of competence, we have also integrated the new knowledge and experience gained from the project into courses and educational programs and collaborated with thesis project students at both BTH and LiU.

4 PROJECT ACTIVITIES

4.1 TIME SCHEDULE WITH ACTIVITIES

At the first reference group meeting a schedule for the project activities was established (see figure 3). The activities are briefly described below.



Main activities and events according to the above schedule	
1.	Cross-learning between the departments at BTH and LiU
2.	Inventory of scientific literature and reports, industry reports and promotional materials to get an overview of existing technology, existing business models and communication methods, and an overview of the relationship between district heating systems and sustainable development.
3.	Analysis and description of the above from a full sustainability perspective.
4.	Exploration of possible visions of how district heating systems can be part of a future sustainable energy system within an entirely sustainable society (e.g. when the energy use is no longer contributing to increasing global atmospheric CO2), and related business models. Case studies of district heating systems in Blekinge and Stockholm.
5.	Investigation of some early steps in the development of district heating systems which are flexible with respect to possible future scenarios. Attractive business models associated with these steps. Modeling and simulation of the effects of various alternative paths of district heating system development. Explore if expansion of district heating can possibly accelerate/be a prerequisite for the development of a sustainable society, even if it turns out to have a possibly minor role in this future society.
6.	Compilation of final report.
R	Reference group meeting.
E	Presentations.
S	Public seminaries at BTH/LiU.
W	Workshop.

Step 1
The first year of the project was a characterized by an intense exchange of knowledge and experiences between BTH and LiU, by, e.g., seminars, meetings, e-mails and telephone conversations. Cesar took part in the course "*Modeling Energy Systems*" given by LiU. Danica took part in the course "*Introduction to Sustainable Engineering*" given by BTH.

Step 2
Parallel to step 1, step 2 focused on literature reviews in order to obtain an insight into the existing district heating system technology and design, business models and communication methods related to district heating systems and sustainable development. Many reports and scientific articles were studied.

Step 3
In step 3, a full sustainability perspective was applied to the analyses. This has continued throughout the whole project.

Step 4 and 5

Within steps 4 and 5 we have explored possible visions of how district heating systems can be part of a future sustainable energy system within an entirely sustainable society. We have done this in relation to, e.g., the Greenpeace Energy [R]evolution Scenario and the IPCC Scenario. We have worked with case studies of district heating systems in Blekinge and Stockholm and investigated some early steps in the development of district heating systems which are flexible with respect to possible future scenarios and related business models. We have modeled and simulated the effects of various alternative paths of district heating system development. The case studies have been used as a support for the continued cross-learning and the development of the Resource Kit (see the results section).

Step 6

In step 6, the project documentation is prepared and compiled. Besides this project report, a major deliverable is the Resource Kit and the scientific publications (see the results section).

4.2 WORKSHOPS

In order to identify visions and early measures that are flexible with respect to possible future energy solutions, workshops have been organized where researchers from the social sciences and technical disciplines have participated as well as students, representatives from industries, municipalities, authorities and consultancies. For example, a large workshop was arranged for actors within the Karlshamn municipality in 2011, gathering about 30 persons.

All workshops have been very useful and popular, both for us in the project and for the other participants. The interdisciplinary approach in several workshops brought many interesting ideas to the project. These ideas have formed the basis for the different case studies carried out within the project.

See also section 7 – COMMUNICATION.

5 RESULTS

This project has resulted in a methodological support (so far a first prototype) for sustainable district heating development (Resource Kit). As examples of how the methodological support developed in this project can be used in practice, and as a way of developing the methodological support, different case studies have been performed with a combination of backcasting and forecasting. The project has also resulted in cross-learning between the areas *strategic sustainable development* and *energy system analysis* at the involved university departments and a cross-disciplinary competence foundation for future integrated research and education on sustainable district heating development. These results are briefly described below.

5.1 THE RESOURCE KIT

5.1.1 INNOVATION AND BUSINESS MODELS

The Resource Kit is a methodological support for sustainable district heating development. Transformation of society towards sustainability both demands, and brings great opportunity for innovation. Since there is no attractive alternative to sustainable development, organizations that learn to innovate for sustainability will have great opportunities for economic success while serving a higher purpose. One important, and sometimes neglected, aspect of innovation for sustainability is the redesign of business models to support the realization of sustainability promoting technical solutions. The benefits of business model changes for the realization of strategies that adequately and effectively respond to challenges and opportunities related to sustainability have been argued for and demonstrated by both researchers and business leaders. The majority of managers who say that their company´s sustainability activities have added to profits also say that these activities have led to business model changes.

However, in general, there is a quite poor understanding among business leaders of the business risks of not heading towards sustainability and of the business opportunities of heading pro-actively towards sustainability. And even among those who have such an understanding on an overall level, many do not know how to concretely plan an act pro-actively and strategically towards sustainability and therefore fall short on execution. The usual absence (unawareness) of an operational definition of sustainability and of basic guidelines for how the organization can support sustainable development while strengthen its own competitiveness in the increasingly sustainability-driven market is a major barrier to innovation for sustainability.

Furthermore, it is well-known that support for generation and selection of ideas and for formulating goals and strategies is especially important to have during the early phases of the innovation process. The purpose of the Resource Kit is to provide an enhanced support for district heating innovation for sustainability in those early phases.

A sustainability definition that can guide assessment of the current situation and stimulate generation of ideas for upstream solutions and strategic guidelines that can aid prioritization of early smart actions are among the most promising leverage points. These are key features of the FSSD, which, together with methods and tools for energy systems modeling and simulation, is used as the basis for the Resource Kit.

5.1.2 TESTING AND DEVELOPMENT

The development and initial testing of this prototype version of the Resource Kit has been supported by case studies with district heating stakeholders in the region of Blekinge and in the city of Stockholm. We have in particular studied whether the Resource Kit is perceived to be: (i) easy to comprehend, (ii) relevant, (iii) capable of differentiating the organizations in a comprehensive way, (iv) helpful for discovering insufficiencies that the organizations are not already aware of and (v) helpful for generation and selection of ideas for upstream solutions, business model innovation and for formulation of goals and strategies.

In the workshops and other dialogues we have had with district heating stakeholders, we have seen that already this early version of the Resource Kit exhibits the above qualities to a high degree, by providing support for, e.g., analyses of the current situation of local and regional energy systems in relation to sustainability, self-assessment of maturity in terms of strategic sustainability work, clarification of the strengths and weaknesses of current business models and stimulation of the generation of solutions and new business models. By on the one hand using today's systems and trends as a point of departure, and on the other hand using a vision of a future situation in which society has achieved sustainability, and by thinking about how investments in district heating could contribute to bridging this gap in an economically viable manner, the perspective was broadened and creativity stimulated.

5.1.3 HOW TO USE THE RESUORCE KIT

The use of the Resource Kit is, as described earlier, guided by the FSSD and its ABCD operational process (see section 3.1.2). The ABCD process on its own can generate great solutions. However, it is also flexible and can guide the use of various complementary methods and tools.

In the Resource Kit, a stepwise approach is designed to guide the use of other methods and tools such as: context mapping, business model canvas, value network analysis, life cycle assessment, scenarios, energy systems analysis, modeling, simulation and sustainability indicators.

An ABCD approach is designed as a chain of exercises to be completed from start to finish. This will guide the users through the integration of sustainability-driven strategies and business models design. The steps are simple, inspiring and creates space for innovation through idea generation for upstream solutions. In the beginning of each stage: i.e. A, B, C and D there are short instructions for users on how to move the team forward through the ABCD process. The CD included in the Resource Kit also contains a set of supplementary resources such as tools and guidance to support the realization of each step. Additional tools can be also added here if relevant. For the initial process of learning and using the Resource Kit in organizations, an external facilitator is recommended. Mixing different disciplinary and educational and professional backgrounds helps to approach challenges from different points of view and to increase the chances to come up with better solutions.

The Resource Kit can be used at different ambition levels, e.g.:

1. An introductory two day workshop
This option provides an introduction to core concepts of sustainability, the business model perspective and initial steps for a preliminary vision for the organization. The process for how to use the Resource Kit is also introduced. Previous case studies are used as basis for understanding and developing problem solving and decision making skills. All steps are presented in sequence with examples based on case studies and quick practical exercises. This also provides motivation and helps teams identify concrete goals and a path towards a long term process within the organization.

2. A one week workshop
This way of engagement includes all activities from option 1 and support teams to quickly gather, analyse data and focus on solutions, prototypes and plans. This provides a deeper understanding of the Resource Kit and triggers new thinking. The outcome should also be a plan for iterating early prototypes in future refinement.

3. A two months study period
This mode enables a deeper and more detailed understanding of the complexities related to sustainable innovation and to the business model design challenge. With a longer time frame, more aspects can be examined and more stakeholders in the value chain can become participants in the process.

4. Integrating support methods and tools to already existing FSSD knowledge
This option considers that the FSSD and the ABCD process have been applied before by the organization to integrate sustainability into the organization´s day to day activities. Here methods related to, e.g., sustainable business models design and energy systems analysis can be used to help complement previous work.

5. Integrating FSSD knowledge to already existing support methods and tools knowledge
Distance learning is here an easy option and covers the ABCD process from Awareness to Action. Participants gain initial knowledge in the FSSD. The courses included in the distance learning (e-learning) are designed to help learners understand

basic sustainability concepts and apply them to day-to-day business, community and personal decision-making and includes:

- A structured overview of key sustainability concepts including systems thinking and backcasting; sustainability principles; and a step-by-step process for strategic planning and decision-making in complex systems (business, government, etc.).
- Real-life case studies and interactive activities that present current social, ecological and economic issues and help learners apply theoretical knowledge to practical business and community situations.

The Resource Kit includes instructions for how to identify and invite key stakeholders to workshops or seminars, suggested agendas, support materials (such as the Sustainability Handbook, the Business Model Canvas, etc.) and examples of expected outcomes of the different steps of the design process of strategic development plans.

For further details see:

- Franca C-L., Broman G and Trygg L., *Resource Kit - District Heating Innovation for Sustainability*, manuscript/prototype of main document, Blekinge Institute of Technology, Karlskrona Sweden.

5.2 CASE STUDIES IN RELATIONS TO THE RESOURCE KIT

The overall purpose of energy systems analysis in relation to the Resource Kit is to quantify the implications of technologies and other solutions that are assessed or generated while using the FSSD and other complementary methods and tools.

Energy modeling, simulation and optimization tools can be useful in all steps of the ABCD procedure of the FSSD. In the A-step they can be used to facilitate learning, in the B-step they can support the analysis of the current situation, .e.g., by clarifying orders of magnitude of various contributions to societal violations of the sustainability principles and in the C-step they can aid stimulation of creativity for the generation of possible solutions.

However, the main utility of those tools is in the D-step. Here the solutions from the C-step need to be prioritized into a strategic plan, with some early steps that are designed to serve as (1) flexible platforms for forthcoming steps that, taken together, are likely to bring society, the organization and the planning endeavor to the defined success, by striking a good balance between (2) direction and advancement speed with respect to the defined success and (3) return on investment to sustain the transition process. This involves many “what-if-simulations” to compare alternatives with respect to their performance in relation to these prioritization questions.

In workshops and reference group meetings during the project, examples of measures have been identified as interesting to study in greater depth with methods and tools for energy system analysis. The case studies have been performed with the overall methodology FSSD and in a combined perspective of backcasting and forecasting. The measures include cooperation on the supply of district heating, the introduction of CHP, absorption cooling and the production of biofuel. In the cases we have studied, investments in, e.g., cooperation on the supply of district heating and CHP have proven to be of particular interest as prioritized early measures towards a more sustainable future. For example, heat cooperation between a regional energy utility and an industry, combined with investments in new bio-based CHP, could lead to approximately 100 % reduction in global CO2 emissions when compared to the current situation (assuming coal-based power as marginal electricity production). Several examples of specific results are provided in the next section. We have also seen how the methodological support has stimulated more radical ideas during our workshops with district heating stakeholders. One example is how to build up stakeholder collaboration and business models around the idea of changing the value proposition from ”heat” to ”indoor climate” .

A summary of the performed case studies within the project are presented below.

5.2.1 MODELING DISTRICT HEATING SYSTEMS IN BLEKINGE

The study is motivated by a backcasting perspective based on the shared vision of a sustainable district heating system in Blekinge with, among other things, zero global CO2 emissions in the end and reduced CO2 emissions on the way. Early measures that are anlyzed are (1) cooperation of four separate district heating systems, (2) investment in a biomass fuelled CHP plant, and (3) introduction of solar collectors in the district heating system. The implications of current energy policy measures are studied using a forecasting approach. The measures are studied in order to analyze if and how they can be used as a driver for a sufficiently swift development towards a sustainable society.

Presently, the district heating in Blekinge is mostly produced by biomass based heating plants and waste heat. One of the plants utilizes waste heat from the local pulp industry and there is one recently started biomass based CHP plant in Karlskrona.

The research is carried out by using computer programs and literature study. Two computer programs are used in the thesis. PVSYST is used to estimate the effective solar irradiation and MODEST is used to model the local district heating system. Six scenarios have been analyzed based on the district heating situation for today and for the future.

The results show that connections between the networks would give more economic benefit when there are more imbalanced fuels input or production facilities. If the connections were introduced into the existing district heating system, the heat flows through them would be low and the economic profitability would not be significant. However, with the new CHP plant in the system, the introduction of the connections would reduce the system cost by about 50 % and the global CO2 emission of the system would be reduced by 93,440 tons annually.

The new installed solar collectors with an area of 10,000 m^2 in Olofström's district heating network would produce 3,7 GWh, corresponding to 29 % of the total district heating supply in Olofström. Moreover, if the biomass prices would increase in the future, the solar district heating production would become even more interesting.

For further details see:

- Zhan H., *Modeling District Heating Systems in Blekinge County*, Master Thesis, LIU-IEI-TEK-A--11/01240-SE, 2010.

5.2.2 ABSORPTION COOLING IN CHP SYSTEMS

Electricity generated in coal-fired condensing power plants that today cover about 45 % of the electricity production in Europe, release approximately one ton of CO2 emissions per MWh. With the assumption that this electricity can be replaced by new electricity generated in CHP plants, there is a potential of CO2 emission reduction by increasing power generation in district heating systems.

Stockholm's district heating system delivers more than 12 TWh heat annually. The total installed electricity capacity in the system is about 600 MW, which makes it possible to produce over 3.5 TWh of electricity annually. However, since the heat demand during the summer is low the power generation is significantly reduced and the total electricity production is about 2 TWh/year.

The study is performed in a backcasting perspective with the vision of a sustainable future energy system with zero global emissions of CO2. Early measures that are analysed are the possibility to increase the production of electricity in CHP district heating systems during the summer by introducing heat-driven absorption cooling.

The system has been modelled with MODEST.

The results show that more than 95 % of the cooling demand that is currently met by compression chillers during the months from April to October should be produced by district heat driven absorption cooling chillers in order to lower global emissions of CO2. As a consequence of this conversion, the utilization time of the CHP plants in Stockholm's district heating system would be prolonged and at the same time the electricity used for compression cooling production would be reduced. Considering both the increase in electricity production and the reduction in electricity used, the potential for the reduction of global emission of CO2 would be about 0.15 million tonnes annually. Rising cooling demand would make the introduction of absorption technology in the system even more cost-effective. If the comfort cooling demand in the region increases by 30 %, electricity production in the system during the summer would be about 70 % higher, which would lead to a reduction of global emission of CO2 by 0.2 million tonnes annually, compared with the level of today. These measures will not give the same advantages when considering a future sustainable society, where the marginal production of electricity is not fossil fuel based but in instead based on renewable energy sources. But the measures are examples of important flexible platforms in a backcasting perspective that will support a faster transition to that desirable future situation.

For further details see

- Djuric Ilic D. and Trygg L., Introduction of Absorption Cooling Process in CHP Systems – An Opportunity for Reduction of Global CO2 Emissions, *Proceedings of the 4th International Conference on Efficiency, Cost, Optimizations, Simulation and Environmental Impact of Energy*, Serbia, 2011.

5.2.3 SUSTAINABILITY SELF-ASSESSMENT AND BUSINESS MODEL DESIGN

The business case of sustainability has been argued for by many authors (Willard, 2005; McNall et al., 2011). There is a large degree of consensus regarding the potential business impact of sustainability. However, most companies either are not acting or are falling short on execution (MIT Sloan, 2009). Relatively few companies consider innovation for sustainability substantially rewarding. Suggested solution for this includes better access to frameworks for understanding sustainability and value creation and the business cases thereof (MIT Sloan, 2009). Furthermore, it is well-known that support for generation and selection of ideas and for formulating goals and strategies is especially important to have during the early phases of the innovation process (Roozenburg & Eekels, 1995).

The usual absence of an operational definition of sustainability is still a major barrier to corporate strategic sustainable development (Holmberg & Robèrt, 2000). A sustainability definition that can guide assessment of the current situation and stimulate generation of ideas for upstream solutions and strategic guidelines that can aid prioritization of early smart actions are among the most promising leverage points. A framework including those features is being developed in an international consensus process since twenty years. Among other things, this framework for strategic sustainable development (FSSD), clarifies the self-interest in sustainability work and thus supports more widespread and proactive sustainable innovation.

In this study, the FSSD is used as the main basis for a new tool to be used in early phases of the innovation process for self-assessment of an organization's current maturity and performance from an overall strategic sustainability point of view and for stimulating generation of ideas for business models design. We present a prototype version of such a tool and results from initial tests of this tool performed in four organizations. We study in particular whether the outlined tool is perceived by the organizations to be: (i) easy to comprehend, (ii) relevant, (iii) capable of differentiating the organizations in a comprehensive way, (iv) helpful for discovering insufficiencies that the organizations are not already aware of and (v) helpful for generation and selection of ideas for upstream solutions, business model innovation and for formulation of goals and strategies.

For further details see:

- Franca C-L., Broman G., Robèrt K-H. and Trygg L., Sustainability Self-Assessment and Business Model Design, *Proceedings of the 17th Sustainable Innovation Conference*, Germany, 2012.

5.2.4 THE ROLE OF DISTRICT HEATING FOR SUSTAINABLE DEVELOPMENT

In Sweden, district heating is quite well developed and is already mainly based on non-fossil fuels. Increased use of district heating is therefore considered as a way of phasing out fossil energy for heating purposes. Furthermore, increased use of district heating provides an increased basis for CHP.

Considering that coal condensing is the marginal production of electricity in Europe, increased use of bio-fueled CHP leads to even greater reductions of global CO_2 emissions. However, in a sustainable society, where there is no longer a systematic increase of CO2 (and no other sustainability problems), the benefits of district heating are less obvious.

The aim of this work is to explore in a backcasting perspective the impact of district heating and CHP in the development towards such a sustainable society. A local energy system is studied for five different time periods from 2010 to 2060 with different marginal technologies for electricity production. Results show that when the local energy utility cooperate with a local industry plant and invests in a new CHP plant for waste incineration the global CO2 emissions for the whole studied time period will be reduced with about 48 000 tons, which corresponds to over 100 % of the emissions from today's system for the same time period. The energy systems modeling has been performed with forecasting, but when considering the overall backcasting perspective in the study, analyzing waste a scare resource is vital when studying a future sustainable society. These studies are underway.

When considering that biofuel is a scarce resource, and that the amount of CO2 emission linked to waste probably will be lower in sustainable society, the global CO2 emissions will be about 250 % lower compared to the system of today (assuming coal-based power as marginal electricity production). The studied district heating related cooperation and introduction of CHP will reduce the system cost for the whole studied energy system with 2 500 MSEK for the studied period. In general, the results indicate that the modeled measures will not have any major sustainability advantages over other heating technologies in a sustainable society but that it can play a vital role for the development towards such a society.

For further details see:

- Nordén E., Strand B. and Wennergren E. *Förnybar energitillförsel i Blekinge* (Renewable energy supply in Blekinge – in Swedish), Report LiU, 2011.
- Isaksson R. and Karlsson O., *Utbyggnad av fjärrvärmenätet i Karlshamn* (Expansion of the District Heating Network in Karlshamn) , Report LiU, 2011.
- Trygg L., Broman G. and Franca C-L., District Heating and CHP – a vital role for the development towards a sustainable society? *Proceedings of the 3rd Urban Sustainability, Cultural Sustainability, Green Development and Clean Cars Conference* (USCUDAR 12), Spain, 2012.

5.2.5 BIOFUEL PRODUCTION IN A DISTRICT HEATING SYSTEM

In this study, cooperation between Stockholm's transport and district heating sectors is analysed. The study is motivated from a backcasting perspective, with the vision of a sustainable future district heating system and transportation system, and to find out if and how a combination of those systems could support a faster transition to that desirable future situation. The cooperation concerns the integrating of biofuel polygeneration production. The optimisation framework MODEST is used, assuming various energy market and transport sector scenarios for the year 2030. The scenarios with the biofuel production and increased biofuel use in the region are compared to reference scenarios where all new plants introduced in the district heating sector are combined heat and power plants and the share of the biofuel used in the transport sector is same as today.

The results show that the cooperation implies an opportunity to reduce fossil fuel consumption in the sectors by between 20 % and 65 %, depending on the energy market conditions and assumed transport sector scenarios. If we consider biomass as an unlimited resource, the potential for greenhouse gas emissions reduction is significant. However, considering that biomass is a limited resource, the increase of biomass use in the district heating system may lead to a decrease of the biomass use in other energy systems.

The potential for reduction of global greenhouse gas emissions is thus highly dependent on the alternative use of biomass. If this alternative is used for co-firing in coal condensing power plants, biomass use in combined heat and power plants would be more desirable than biofuel production through polygeneration. On the other hand if this alternative is used for traditional biofuel production (without co-production of heat and electricity), the benefits of biofuel production through polygeneration from a greenhouse gas emissions perspective is superior. However, if carbon capture and storage technology is applied on the biofuel polygeneration plants, the introduction of large-scale biofuel production into the district heating system would result in a reduction of global greenhouse gas emissions independent of the assumed alternative use of biomass.

Biofuel production through polygeneration requires significant investments but could also result in significant revenues from the biofuel produced. Based on three future transport scenarios in combination with five future general energy market scenarios, different business strategies for district heating producers in Stockholm's region are analysed.

The profitability turns out to be highly dependent on the energy market scenarios, especially on the ratio between biofuel and electricity sales prices. Large-scale biogas and ethanol production may lead to a significant reduction of the district heating production cost. This combination is a strong alternative in most scenarios and the profitability is especially high if the biofuel sales prices are higher than the electricity sales price.

The profitability is shown to be much lower if the biogas produced is used for combined heat and power production instead of being used for transportation. Investments in Fischer-Tropsch diesel and Dimethyl Ether production are not profitable for district heating producers even if the biofuel sales prices are 20 % higher than the electricity sales price.

For further details see

- Djuric Ilic D., Dotzauer E., Trygg L. and Broman G., Introduction of large-scale biofuel production in a district heating system – an opportunity for reduction of global greenhouse gas emissions, Submitted to the *Journal of Cleaner Production*.

- Djuric Ilic D., Dotzauer E., Trygg L., Broman G and Amiri S., Integration of a large-scale biofuel production into district heating– an economic evaluation, Submitted to the *Journal of Cleaner Production.*

5.3 CROSS-LEARNING

Beside the Reourse Kit and the performed case studies we and the reference group see the cross-learning achieved by ourselves and our colleagues, as well as the contribution to courses and educational programs, as an important result of the project (long-term development of competence). Via the seminars and workshops that we have carried out with colleagues at each university, via workshops with many different district heating stakeholders and via the project's PhD students taking courses within both competence areas, we have achieved a solid foundation of interdisciplinary competence for future integrated research and education in the field of sustainable energy system development. The long-term development is also secured via our integration of the new knowledge and experience gained from the project into courses and through our collaboration with thesis project students at both BTH and LiU. Furthermore, the project has resulted in a new course in LiU's Master's

Program in Engineering *energy-environment-management* in which methods for strategic sustainable development and energy system analysis are applied to district heating systems, and at BTH a Bachelor of Science Program inspired and reinforced by the project, *energy systems for sustainable development*, will start in the fall.

6 DISCUSSION

The importance of integrating strategic sustainability thinking into the core business of companies is becoming more and more pronounced around the world. The systematic guidance for how to do this by using a framework for strategic sustainable development (FSSD), could therefore be of significant value for business and society. Using this together with methods and tools for energy system analysis – as presented in this project – will assist district heating stakeholders to decide on actions that support sustainable development of the whole society and at the same time strengthen their own organizations.

We have concluded that energy modeling, simulation and optimization tools can be useful in all steps of the ABCD procedure of the FSSD. In the A-step they can be used to facilitate learning, in the B-step they can support the analysis of the current situation, .e.g., by clarifying orders of magnitude of various contributions to societal violations of the sustainability principles of the FSSD and in the C-step they can aid stimulation of creativity for the generation of possible solutions. However, the main utility of those tools is in the D-step. Here the solutions from the C-step need to prioritized into a strategic plan, with some early steps that are designed to serve as (1) flexible platforms for forthcoming steps that, taken together, are likely to bring society, the organization and the planning endeavor to the defined success, by striking a good balance between (2) direction and advancement speed with respect to the defined success and (3) return on investment to sustain the transition process. This involves many “what-if-simulations” to compare alternatives with respect to their performance in relation to these prioritization questions.

The Resource Kit prototype that has been developed in this project is an attempt to guide this integration of competence areas, to support sustainable district heating development. The main target group is energy utilities, but also consulting companies, authorities, municipalities and universities can benefit from this methodological support. The Resource Kit is suited primarily for somewhat larger organizations. The user should preferably have a unit for strategic planning and development, which is usually the case for district heating companies with more than about 20 employees. With a more comprehensive external expert assistance, also smaller organizations can benefit from Resource Kit. The first time it is used, and if there is not already competence within the organization in strategic sustainability thinking and energy system analysis, it is recommended that external support is used.

In the workshops and other dialogues we have had with district heating stakeholders, we have seen how early versions of the Resource Kit have provided support for, e.g., analyses of the current situation of local and regional energy systems in relation to sustainability, self-assessment of maturity in terms of strategic sustainability work, clarification of the strengths and weaknesses of current business models and how this has stimulated the generation of solutions and new business models. By on the one hand using today's systems and trends as one bridge head, and on the other hand using a vision of a future situation in which society has achieved sustainability as a second bridge head, and by thinking about how investments in district heating could contribute to bridging this gap in an economically viable manner, the perspective is broadened and creativity is stimulated.

Examples of measures identified as interesting in workshops and reference group meetings during the project which we have studied in greater depth with methods and tools for energy system analysis include cooperation on the supply of district heating, the introduction of CHP, absorption cooling and the production of biofuel. In the cases we have studied, investments in, e.g., cooperation on the supply of district heating and CHP have proven to be of particular interest as prioritized early measures. For example, heat cooperation between a regional energy utility and an industry, combined with investments in new bio-based CHP, could lead to approximately 100 % reduction in global CO2 emissions when compared to the current situation (assuming coal-based power as marginal electricity production). But the advantages of heat cooperation and new CHP are less clear in a sustainable society in which all electricity is produced by renewable and sustainable energy sources – where we thus have no marginal electricity production in coal-fired condensing power plants. Under certain conditions, these measures can still play a crucial role in the development towards a sustainable society, by supporting a faster transition to that desirable future situation.

It is however difficult to give any generally applicable or standard measures, as the conditions vary for each district heating company and region. It is therefore important that the stakeholders in question build up their knowledge and competence and get access to a methodological support, enabling them to clarify the grounds for – and likely implications of – their decisions, based on the prevailing conditions in the specific cases.

To build up more examples of how the Resource Kit can be used, we currently do studies where we assume that both biomass and waste are likely limited resources in a future sustainable society (studies where only biofuel is assumed to be a limited resource is already performed). With these studies we want to show how the risks of uncritically assuming an increasing access to these types of fuel can be clarified and handled. This is prompted by the backcasting perspective.

We also want to do further analyses of some of the more radical ideas that came up during our workshops with district heating stakeholders. One example is the idea to change value proposition from “heat” to “indoor climate” and to build stakeholder cooperation and business models around it.

In general, in order to further develop the prototype for the Resource Kit into a more complete and user-friendly support, we wish in our future work to do additional iterations between development and usage, preferably in more regions and municipalities in order to test and secure a high degree of generalization.

7 COMMUNICATION

The project has been communicated at several seminars and meetings, e.g., at Energiting Southeast, at a seminar organized by Energiledargruppen, at a Roundtable meeting organized by the Delegation for Sustainable Cities, the DHC+ Annual Conference, at the Euroheat & Power Conference and at a number of workshops were students, researchers and district heating actors from different sectors have participated.

Results from the project have been presented at the following scientific conferences:

- The 12th International Symposium on District Heating and Cooling, Estonia.
- The 3rd International Conference on Urban Sustainability, Cultural Sustainability, Green Development and Clean Cars, Spain.
- The 17th Sustainable Innovation Conference, Germany.

The project has also been presented at Fjärrvärmedagarna 2010, 2012 and 2013 and abstracts were submitted to Energiutblick 2011 and 2012.

8 PUBLICATIONS

The following publications are based on this project:

1. Zhan H., *Modeling District Heating Systems in Blekinge County*, Master Thesis, LIU-IEI-TEK-A--11/01240-SE, 2010.

2. Djuric Ilic D. and Trygg L., Introduction of Absorption Cooling Process in CHP Systems – An Opportunity for Reduction of Global CO2 Emissions, *Proceedings of the 4th International Conference on Efficiency, Cost, Optimizations, Simulation and Environmental Impact of Energy*, Serbia, 2011.

3. Franca C-L., Broman G., Robèrt K-H. and Trygg L., Sustainability Self-Assessment and Business Model Design, *Proceedings of the 17th Sustainable Innovation Conference*, Germany, 2012.

4. Trygg L., Broman G. and Franca C-L., District Heating and CHP – a vital role for the development towards a sustainable society? *Proceedings of the 3rd Urban Sustainability, Cultural Sustainability, Green Development and Clean Cars Conference* (USCUDAR 12), Spain, 2012.

5. Nordén E., Strand B. and Wennergren E. *Förnybar energitillförsel i Blekinge* (Renewable energy supply in Blekinge – in Swedish), Report LiU, 2011.

6. Isaksson R. and Karlsson O., *Utbyggnad av fjärrvärmenätet i Karlshamn* (Expansion of the District Heating Network in Karlshamn) , Report LiU, 2011.

7. Djuric Ilic D., Dotzauer E., Trygg L. and Broman G., Introduction of large-scale biofuel production in a district heating system – an opportunity for reduction of global greenhouse gas emissions, Submitted to the *Journal of Cleaner Production*.

8. Djuric Ilic D., Dotzauer E., Trygg L., Broman G and Amiri S., Integration of a large-scale biofuel production into district heating– an economic evaluation, Submitted to the *Journal of Cleaner Production.*

9. Franca C-L., Broman G and Trygg L., *Resource Kit - District Heating Innovation for Sustainability*, manuscript/prototype of main document, Blekinge Institute of Technology, Karlskrona Sweden.

10. Franca C-L., Broman G. and Trygg L., Business model design for realization of sustainability-driven strategies – case study of district heating, manuscript for journal publication (under preparation).

11. Franca C-L., *Business Model Design for Realization of Sustainability-Driven Strategies*, manuscript for licentiate thesis (under preparation).

12. Djuric Ilic D., *Stockholm a sustainable region – cooperation between district heating systems*, manuscript for doctoral thesis (under preparation).

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FJÄRRSYN

Forskning som stärker fjärrvärme och fjärrkyla, uppmuntrar konkurrenskraftig affärs- och teknikutveckling och skapar resurseffektiva lösningar för framtidens hållbara energisystem. Kunskap från Fjärrsyn är till nytta för fjärrvärmebranschen, kunderna, miljön och samhället i stort. Programmet finansieras av Energimyndigheten tillsammans med fjärrvärmebranschen och omsätter cirka 19 miljoner kronor om året. Mer information finns på www.fjarrsyn.se

HÅLLBARA STÄDER I ETT BACKCASTINGPERSPEKTIV

Hur kan insatser i olika delar av samhället och energisystemet samordnas så att de stödjer varandra? Och hur kan ny kompetens som kombinerar strategiskt hållbarhets-sänkande och energisystemanalys byggas upp? Kan man kanske utveckla ett stöd för företag, kommuner och regioner så att de lättare kan hantera den ökade komplexiteten inom energiområdet?

Här har forskarna gjort en kombination av backcasting och forecasting för att besvara de här frågorna och för att studera fjärrvärmens utmaningar och möjligheter i ett hållbart samhälle. Genom backcasting visar man en övergripande och långsiktig målbild för att kunna göra en analys av dagens situation och för att kunna hitta åtgärder och lösningar för att nå det målet. Forecasting används främst för att pröva olika handlingsvägar och för att stödja beslut om i vilken ordning olika åtgärder bör genomföras.

Resultaten visar att ett ökat samarbete mellan industrier och energileverantörer, samproduktion av biodrivmedel och introduktion av kraftvärme och absorptionskyla kan vara åtgärder som påskyndar utvecklingen mot ett hållbart samhälle. Men det är svårt att ta fram generella utvecklingsplaner för olika geografiska områden eftersom alla regioner och fjärrvärmeföretag har olika förutsättningar.

För att lösa detta har ett så kallat Resource Kit tagits fram så att företag och kommuner själva kan bygga upp kompetens genom att till exempel göra lokala nulägesanalyser, kartlägga intressentnätverk och få fram styrkor och svagheter med sina nuvarande affärsmodeller. Det här är ett sätt att tydliggöra grunderna för och de sannolika konsekvenserna av olika investeringsbeslut. Rapporten är skriven på engelska men har en svensk sammanfattning.

Svensk Fjärrvärme

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