Bioenergy for Heat -the Hot Cases

strategic study on renewable heat

IEA Bioenergy

IEA Bioenergy: Task 32:
Biomass Combustion and Co-firing

Bioenergy for Heat–the Hot Cases

Strategic study on renewable heat (D2)

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Case title	**Author(s)**
A cascade of small wood chip boilers	Thomas Nussbaumer
BioSol made small scale wood gasifiers possible	Hans Hartmann, Emanuel Schlosser
Carbon dioxide tax decarbed district heating	Kent Davidsson, Oskar Räftegård
Cooperation made the heating plant successful	Jaap Koppejan
Environmentally friendly fuels	Jens Dall Bentzen, Morten Tony Hansen
Developing advanced control strategies	Christopher Zemann, Markus Gölles,
Forestry wood enables renewable district heat	Thomas Nussbaumer
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Modern pellet-fired biomass heating plant	Arne Michalski, Andreas Wintzer
Pellets move the dairy back to nature	Oskar Räftegård, Jonas Strandlund
Renewable kitchens and coffee systems	Thomas Nussbaumer
Rural biomass-fired district heating	Hans Hartmann
Straw fired district heating in Nexø	Jan Depenau, Allan S. Pedersen, Søren Nielsen, Thorkil F.B. Neergaard, Morten Tony Hansen
The bakery that runs on heat from biomass	Thomas Nussbaumer

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Executive Summary

Heat makes up about half of the global final energy usage, while electric power and transportation fuels together make up the other half of the end use. Fossil fuels are today the predominant source for heating (about 80%), However, in many countries there is enough sustainable biomass available to substitute all fossil fuels that are used for heating today. Switching from fossil fuel fired boilers to biomass fired boilers could - decarbonate 40% of the global energy end use!

This report provides fifteen case studies that show real life examples of modern and sustainable heating as well as co-generation of green power through biomass firing. The transition often goes hand in hand with improved local economy, since added value is derived from the utilisation of local residuals and waste fractions instead of purchasing fossil fuels. Furthermore, new job opportunities are created. It also secures supply of affordable heat resources, now and for generations to come. Biomass is therefore not only CO_2 neutral and renewable, it can also strongly stimulate local socio-economic development.

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Key Findings

All cases show or promote modern sustainable bioenergy to heat solutions, based on solid biomass fractions. Common for many of the cases is utilisation of locally (or regional) available residual biomass resources, which goes hand in hand with creation of local job opportunities. Furthermore, the cases show examples of forest residues fired in district heating boilers, utilisation of agriculture residues as well as generation of industrial process steam.

Many cases come from countries which have or have had strong policies promoting sustainable heating, such as Denmark, Germany, Schweiz and Sweden.

Foreword

In comparison to conventional fossil based alternatives, the design of biomass based heating systems is relatively complex in the sense that an investor not only needs to consider optimal fuel logistics and technical design of the combustion plant. Also the social, environmental and economical aspects related to the fuel supply and operation of the plant can be optimally tuned to a specific situation.

To illustrate how this can be arranged for various market conditions, IEA Bioenergy Task 32 took the initiative to prepare easy to read case studies that highlight the critical success factors for a number of real life projects using biomass for heating. In general, one can observe from these cases that the benefits of biomass based heating systems are not solely defined in terms of cost savings for the investor and CO_2 savings, but also significant socioeconomical benefits may arise such as employment generation or improved landscape maintenance. In order to harvest such benefits, proper project design and cooperation with key stakeholders in a multidisciplinary approach is essential.

We hope that the lessons learned from the case studies presented may be beneficial for implementation of new projects or supporting policies in other areas as well.

Jaap Koppejan
Task leader, IEA Bioenergy Task 32: Biomass Combustion and Cofiring

Background

THE GLOBAL CONSUMPTION OF HEAT

The final global energy consumption for all sectors including transportation and agriculture is shown in Figure 1. About half of the total global final energy consumption is heat, while electricity and transportation fuels make up the other half[1] (OECD/International Energy Agency, 2016). Of this amount, currently about 20% is generated from biofuels. If mobilisation of the available sustainable biomass resources could be organised in an acceptable manner, there would be sufficient biomass available around the globe to cover the complete global heat demand.

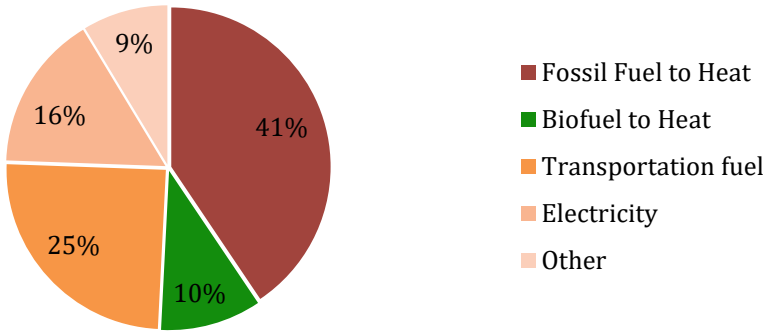

Figure 1 Global energy end use. Source: (OECD/International Energy Agency, 2016).

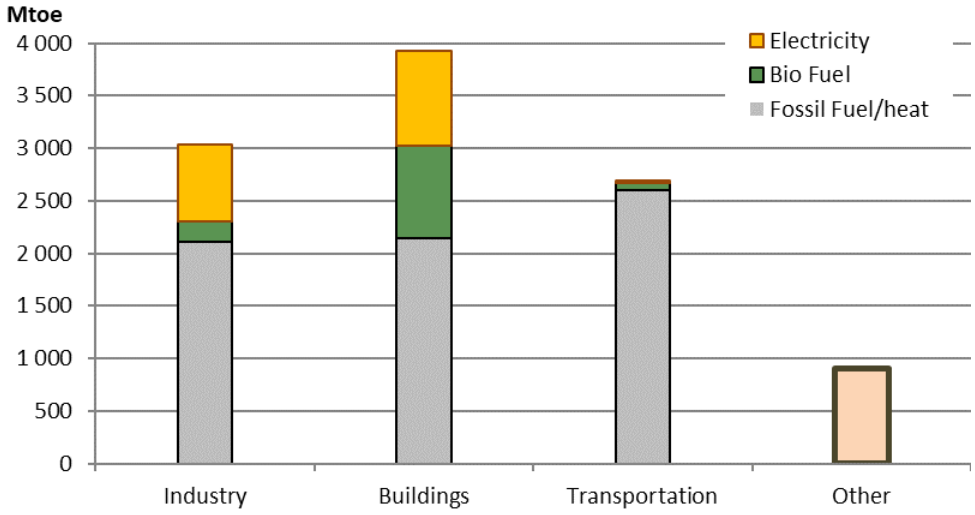

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Figure 2 Global energy end use per sector and energy carrier. "Other" sector is mainly agriculture. Source (OECD/International Energy Agency, 2016)

Most of the final end-use of biofuel goes to building and industry (see Figure 2). Fuel consumption here is mainly for heating, while electricity is mainly for other purposes, some of which are electric heaters, heat pumps and electrical ovens. The building sector (incl. services) is on par with the industry in consumption of fossil fuels, while buildings use more biofuels.

[1] Assuming nearly all final fuel use in building and industry sector is for heating, and little or no electricity is used for heat.

The thirteen investment cases that were prepared in the framework of this study cover both the industrial and the building sectors. All cases show the use of solid fuel fired boilers for heating or for co-generation (combined heat and power), either in district heating systems, or for industrial process heat or for heating of industrial facilities. Eleven of these describe specific projects for biomass combustion based district heating, individual space heating or industrial heat. The two policy cases do not target a specific end-user application. However, both have been applied to (but not limited to) district heating systems.

Industrial and commercial facilities

Five cases cover industrial/commercial operations. Of these, two concern the delivery of process heat (i.e. steam), while the other three cover general heating demand. All industrial cases are relatively small, ranging from 400 kW to 3 MW heat.

District heating is an enabler for biomass heating

While small domestic stoves and open fireplaces are probably the most common household solid biofuel heat source, modern heating solutions have benefits that comes with scale, including cost, fuel handling, maintenance and emissions. For this reason, district heating is an important enabler for expanding the use of biomass in the building sector. Especially thanks to the potential to combust cheap, but somewhat difficult biofuels, such as residues (e.g., wet wood chips or straw).

GOBAL BIOFUEL FEEDSTOCK AND MARKET

The potential global sustainable feedstock from wastes and residues has been estimated in several studies. A review report (Raphael Slade, 2011) comprising multiple studies showed a potential of up to 4,700 Mtoe/a of available biomass residues. To put this in perspective, this exceeds the consumption of fossil fuels for heat. The same review report indicates that the potential for energy crops farmed on degraded land and on rest land is about twice the biomass residues potential.

The overall biofuel feedstock can be divided in four main categories, of which three main categories concern different residues and wastes, while the fourth is energy crops. In Figure 3 below, the four main categories, as well as eleven sub categories are shown. The feedstocks found in the fifteen case studies are indicated in green.

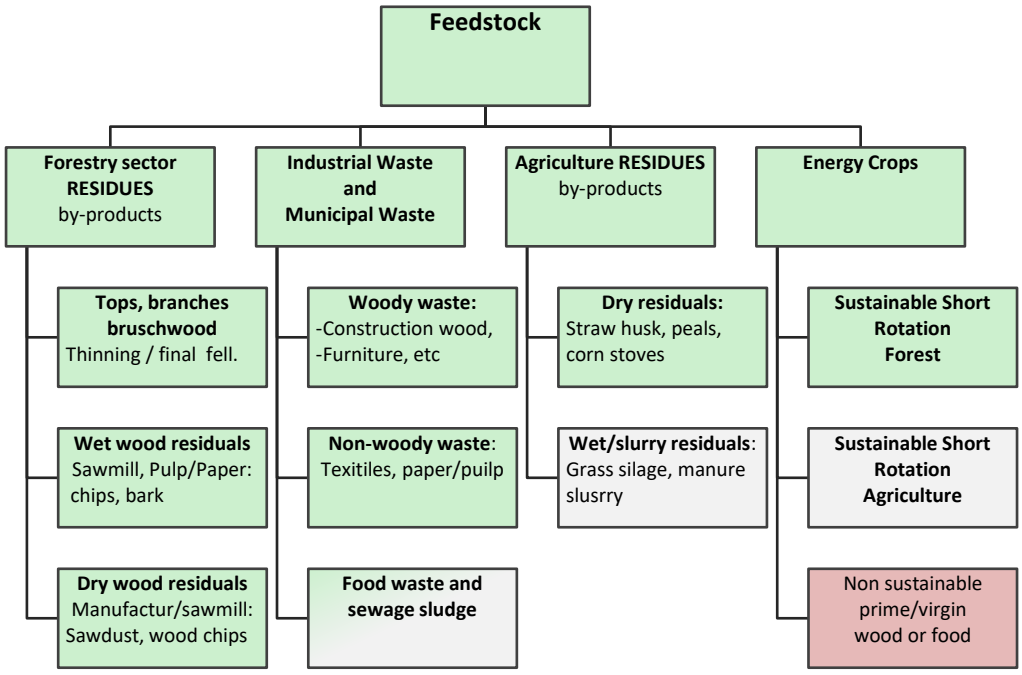

Figure 3 Classification of biomass feedstocks

CASE STUDIES USE LOCALLY AVAILABLE FUELS

For an ideal open market to work, it is often stated that one needs a well-defined fuel that is traded between many suppliers and buyers- which have access to equal information. Currently only wood pellets are seen as a globally traded fuel on an open market, but pyrolysis oils and torrefied fuels are promising candidates (IEA Bioenergy Task 40, 2014). High transportation costs are a limiting factor for long distance transportation of biomass with a low volumetric energy density. Although there are examples of sorted waste and wet forest residues and other non-specified fuels being transported over longer distances by ship and/or train, these cannot be considered as an open market trade.

None of the cases in this study are based on globally traded biomass fuels. Many of them explicitly point out that the availability of local residues was a prerequisite and decisive factor behind the investment decision. In this, close cooperation with the forestry and/or agriculture sector was essential as part of the solution to secure the fuel supply.

UNITED NATIONS' SUSTAINABLE DEVELOPMENT GOALS

UN's Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations General Assembly in 2015. The goals are broad and interdependent, yet each has a separate list of targets to achieve. The SDGs cover social and economic development issues including poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanization, environment and social justice. (Wikipedia, 2018)

Biomass for heating can have a positive impact on several of these targets. The case studies indicate a positive impact on no less than nine of the 17 main goals. Biomass can hoverer also have a negative impact if not deployed correctly. There are especially three key concerns: food security, land use (or change on land use), and on economic competition/providing affordable heat (IEA/IRENA, 2017). None of these three key-concerns or any other negative impact is associated with the case studies, on the contrary several of them have a positive impact on the key-concern areas.

All fifteen case studies have indicated a positive impact on two of the SDGs: "Ensure sustainable consumption and production patterns" and "Take urgent action to combat climate change and its impacts". Other frequently indicated positive impacts are (in falling order): "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation", "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all", "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" and finally "Ensure access to affordable, reliable, sustainable and modern energy for all".

Positive contribution of bioenergy to sustainable development

Bioenergy typically enhances regional energy access and reduces reliance on fossil fuels. It can vitalize the forestry and agriculture sectors and support increased use of renewable resources as feedstocks for a range of industrial processes. It can contribute to our global climate change mitigation goals as well as other social and environmental objectives. However, bioenergy can also have negative impacts if not developed and deployed properly. Three key concerns are food security, risks that land use and land use change from bioenergy expansion may increase carbon emissions or reduce biodiversity, and challenges in achieving economic competitiveness and providing high quality and affordable energy services. Bioenergy is multifaceted. Specific bioenergy options (such as biofuels produced from edible vs. non-edible feedstocks) are not good or bad per say; sustainability impacts are context specific and depend on the location and management of feedstock production systems. Fortunately, significant knowledge and competence are available to govern bioenergy expansion so as to harness opportunities and minimize risks of negative impacts.

Source: (IEA/IRENA, 2017)

Introduction to the Case Studies

This study covers fifteen case studies. These case studies not only concern real investment cases, but also illustrate how conducive bioenergy policies can have a great impact. The investment cases show a broad diversity, although the majority concerns boilers in district heating systems, fired with forestry residues. Other cases show the delivery of industrial process heat or heating of industrial/commercial facilities. The cases show that these relatively small systems can strengthen the local economy by creating local job opportunities and utilizing locally available biomass residues.

The table below show an overview of all cases, with respect to type of feedstock, type of application (end user: industry or district heating) and type of case (investment or policy).

Table 1: Biomass feedstock type, end-user and case type (investment or policy)

	Forestry Sector Residues			Waste Sector		Agric. Sector Residu.	Energy crops	End-user	Case
Case title	Silviculture: (branches)	Wet residues (chips, bark)	Dry residues (saw dust)	Woody waste	Non-woody waste (incl. food waste)	Dry residuals (straw, peals)	Sust. short rotation forest	Industry/DH.	Type
A cascade of small wood chip boilers		x	X					DH	I
BioSol made small scale wood gasifiers possible	X	X					X	all	P
Carbon dioxide tax decarbed district heating	X	X	X	X	X			DH	P
Cooperation made the heating plant successful	X	X						DH	I
Environmentally friendly fuels	X	X	X	X				DH	I
Developing advanced control strategies	X	X						I	I
Forestry wood enables renewable district heat		X						DH	I
Fossil free heating from a new biomass plant	X	X	X				X	DH	I
Heating with the power of sun and earth	X	X						DH	I
Modern pellet-fired biomass heating plant			X					I	I
Pellets move the dairy back to nature	X	X	X					I	I
Renewable kitchens and coffee systems		X						I/DH	I
Rural biomass-fired district heating	X	X	X				X	DH	I
Straw fired district heating in Nexø						X		DH	I
The bakery that runs on heat from biomass		X				X		I	I

End-user: I=Industry or DH= District Heating **Case**: I=investment case, P=policy case

In the table below are the case studies impact on the United Nations' Sustainable Development Goals indicated.

Table 2: Indicated impact on Sustainability Development Goals

Case title	End poverty in all its forms everywhere	Ensure healthy lives and promote well-being for all at all ages	Ensure access to affordable, reliable, sustainable and modern energy for all	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Build resilient infrastructure, pro-mote inclusive and sustainable industrialization and foster innovation	Make cities and human settlements inclusive, safe, resilient and sustainable	Ensure sustainable consumption and production patterns	Take urgent action to combat climate change and its impacts	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
A cascade of small wood chip boilers				X	X	X	X	X	
BioSol made small scale wood gasifiers possible				X	X		X	X	
Carbon dioxide tax decarbed district heating			X			X	X	X	X
Cooperation made the heating plant successful			X		X		X	X	X
Environmentally friendly fuels	X	X	X	X	X	X	X	X	X
Developing advanced control strategies			X		X		X	X	X
Forestry wood enables renewable district heat				X	X	X	X	X	X
Fossil free heating from a new biomass plant	X	X	X	X	X	X	X	X	X
Heating with the power from the sun and the earth		X	X				X	X	
Modern pellet-fired biomass heating plant			X	X	X	X	X	X	X
Pellets move the dairy back to nature					X		X	X	X
Renewable kitchens and coffee systems				X	X	X	X	X	
Rural biomass-fired district heating			X	X	X	X	X	X	
Straw fired district heating in Nexø	X	X		X	X	X	X	X	X
The bakery that runs on heat from biomass				X	X	X	X	X	

Lessons learned

Although it should not be concluded that the fifteen cases described are representative for all market conditions prevailing, several lessons can be learned.

Cooperation between stakeholders is essential as an enabler for the transition to fossil fuel-free heating. Utilizing local biomass residues instead of fossil fuels for heating helps to strengthen local economies (e.g., job creation opportunities) as well as in fighting climate change. Municipalities and local stakeholders should therefore be mobilised in the transition towards biofuels.

Solid biomass fired boiler systems (in general) have a higher investment cost and require more maintenance than equivalent oil or gas fired boiler systems. As the relative investment cost drops with the boiler size, larger boilers applied in district heating systems can act as an enabler.

Secure access to cheap fuel is a prerequisite to minimize operational costs, and also to be assured of reliable and affordable heat. Many cases show how cooperation between local actors can lead to the building up of a local trustworthy and supply-secured biofuel trade based on locally available (cheap) residues from the forestry and agriculture sectors. Example of this can explicitly be found in "Forestry wood enables renewable district heat".

Policy towards sustainable heating is another recurrent factor. Almost all cases come with a history of a strong national or regional policy. In the case "How Carbon Dioxide Tax Decarbed District Heating", it is shown how a national tax on fossil carbon dioxide in heating fuels made biofuels competitive in district heating systems and makes biofuels the dominant fuel within 5 years.

A more subtle policy is found in the investment case "Straw fired district heating in Nexø", where the municipality guarantees the investment, and by this facilitates financing as well as lowers the financial cost for the transition to biomass heating.

National and regional subsidies can also be used to open up the market for a (new) technology or drive the development of new technology. The case "BioSol made small scale wood gasifiers possible" shows an example of a subsidy to make small scale combined heat and power "market ready", and in "Rural biomass-fired district heating", one can read of an investment enabled by this subsidy.

In the case "Pellets move the dairy back to nature", the company's environmental policy as well it's slogan "Closer to Nature", was important when the decision was made to invest in biofuels was made.

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Case Studies

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