Chapter

Investment Costs and Profitability of Biomass Heating Plants

4

4.1. Austria

The energetic utilisation of solid biomass has a long tradition in Austria and is still a very important factor within the renewable energy sector. The consumption of final energy from sold biofuels increased from 142 PJ for 2007 to 164 PJ for 2010. The consumption of wood chips has increased steadily since the beginning of the 1980s. In 2010 wood chip consumption was 74 PJ and thus exceeds the consumption of wood logs, at 68 PJ. The very well documented wood pellet market developed at an annual growth rate between 30 and 40% until 2006. This development was then stopped 2006 due to a supply shortage which resulted in a substantive price rise. The production capacity of 21 Austria pellet manufacturers was extended to 1.2 million tons a year and this resulted in a market recovery. Fuels from solid biomass contributed to a CO_2 reduction of almost 9.4 million tons for 2010. The whole sector of solid biofuels accounted for a total turnover of 1.306 billion Euros and 13,302 jobs.

The success of bioenergy depends highly on the availability of suitable biomasses in sufficient volumes and at competitive prices. Short rotation forestry is therefore seen as having good potential for the future extension of the biomass base. This development is determined by regulative policy measures such as the Common Agricultural Policy. Furthermore, the development of bioenergy has to be coordinated with other biomass-based branches and stakeholders. Together new synergies should be established to maximise added value from (especially regional) biomass. Technological research and development is required in order to further exploit new resources and to reduce costs along the supply chain with consideration for sustainability.

The market for biomass boilers increased steadily from 2000 until 2006. A market break of more than 60% occurred in 2007, with low prices for heating oil and the mentioned supply shortage of pellets. For 2008 the sales figures again reached the level of 2006. For 2010 a slight reduction of about 4% in the sales of pellets boilers was documented. In 2010 the wood log boiler sector suffered a substantial market break. There were several reasons for this break, such as delayed impacts of the economic crisis, reduction of subsidies for biomass boilers and subsidies still being given by the Austrian mineral oil industry for new oil boilers. In 2010 the Austrian market comprises of 8,131 pellet boilers, 6,211 wood log boilers and of 4,219 wood chip boilers, concerning the whole range of power. Furthermore 3,273 pellet stoves, 8,210 cooking stoves and 26,100 wood log stoves were sold. Austrian biomass boiler manufactures typically export approximately 70% of their production. In Germany, for instance, two out of three installed biomass boilers are of Austrian origin. Germany and Italy are the biggest export markets for Austrian companies. The biomass boiler and stoves sector reached a turnover of 867 M€ in 2010. This resulted in a total number of 4,097 jobs. Research efforts are currently focused on the extension of the power range, further reduction of emissions, optimisation of systems and combined systems, and the development of a market for ready small-scale and micro CHP systems.

4.1.1. Investment, Operating Costs and Profitability

The following performance figures are average values of newly installed heat plants in Austria in the years 2007 and 2008 (ÖKL 2009). These figures should give guidance to those preparing a feasibility study for a biomass heating plant.

4.1.1.1. Specific Investment Costs for Heating Plants

The specific investment costs for heating plants include the overall investment costs of the heating plant (boiler house and storage with all installations without land and development costs) referred to as the sum of nominal power [kW] of all heat generators.

$$\textit{specific investment costs}_{\textit{(heat plant)}} = \frac{\textit{investment costs}}{\textit{overall nominal power}}$$

An average value for the specific investment costs of new plant installations in Austria is 519 €/kW.

4.1.1.2. Specific Investment Costs for Heat Distribution Network

The specific investment costs of heat plants consist of the overall investment costs [€] of heat plants without transmission stations, referred to the annual heat amount, which is consumed through the network [MWh/a] without losses in the distribution network.

$$specific\ investment\ costs_{(heat\ distribution\ network)} = \frac{investment\ costs_{(heat\ distribution\ network)}}{annual\ heat\ consumption}$$

An average value for the specific investment costs of new distribution network installations in Austria is 214 €/MWh/a.

4.1.1.3. Electric Auxiliary Energy Demand of Biomass Boilers

The specific electricity demand of biomass boilers is the electricity demand for all electric auxiliary aggregates [kWhel], including those for biofuel feeding, ash and flue gas transport (hydraulic, pneumatic, blowers and grill, area, pumps) referred to the heat amount [MWh_{th}] generated in the same time period at nominal power. The specific electricity demand of measured biomass boilers is between 7 and 20 kWhel/MWh_{th}. Even apparently identical plants can demonstrate big differences, i.e. having different components (blowers and pumps). Guaranteed upper limits should be fixed in the boiler delivery contract.

$$specific\ electricity\ demand_{\ (biomass\ boiler)} = \frac{electricity\ demand}{nominal\ power}$$

The optimum value for the specific electricity demand of a biomass boiler should be below 10 [kWhel/ MWh_{th}].

4.1.1.4. Profitability Calculation

Because of the high investment costs for a biomass district heating plant, a profitability analysis is absolutely required. A dynamic profitability analysis is recommended for a period of 20 years. The critical influencing factors for economic operation should be determined in a sensitivity analysis ("what if" calculation). For secure operation and supply of the heat plant, the following costs should be assumed:

- Fuel costs: min. 22 € MWh raw energy regarding the lower heat value

- Personnel expenditure: at least 2–4 € per sold MWh heat
- Electricity demand: min. 15kWh per generated MWh heat, or 20kWh/MWh for plants with heat recovery and measures to avoid the generation of water steam swath or electric filters
- Annual maintenance costs: biomass boilers 3%, technical facilities 2%, buildings and distribution network 1% of investment costs (VDI 2067)
- Equity ratio of the company: at least 20% in order to avoid liquidity problems if unexpected economic occasions occur

4.1.1.5. Heat Demand Density (q_{area})

The parameter of heat demand density gives information about the suitability of a region/zone for district heating. The heat demand density is the ratio of the total annual heat demand of buildings in a discrete area ($Q_{buildings}$) to the extending areas.

$$(q_{area})\left[kWh/am^2\right] = \frac{\sum Q_{buildings}[kWh/a]}{A_{area}[m^2]}$$

$Q_{buildings}$ [kWh/a] total annual heat demand of buildings in a discrete area

A_{area} [m²] extent of the discrete area

Application of the benchmarks listed in Table 4 is recommended for evaluation of an area

Table 4. Recommended heat demand density for service areas (QM Holzheizwerke 2008)

Suitability	heat demand density [kWh/m²]
not suitable	< 50
limited suitability	50–70
optimal	> 70

Summary and recommendation:

- single-household settlements are normally critical (10–30 kWh/m²)
- areas of interest are: centres of villages, multi-family households, areas with dense construction

- the involvement of an large customer ensures better economy

For an economic operation of the biomass DH plant compliance with a minimal heat demand density of areas of > 50 kWh/m² is recommended.

4.1.1.6. Transport Performance ($p_{network}$)

Thermal transport performance is calculated by dividing the total heat capacity demand of the connected buildings with the total length of the pipe network.

$$(P_{network})\left[kW/m\right]=\frac{\sum P_{buildings}\left[kW\right]}{l_{network}\left[m\right]}$$

$P_{buildings}$ [kW] total heat capacity demand of buildings in a discrete area
l_{area} [m] total length of the pipe network

To ensure economic operation of the DH plant a minimal thermal transport performance of 1 kW/m should be reached. The optimal thermal transport performance amounts to 2°kW/m. The thermal transport performance of existing plants averages from 1 up to 6 MW/km. The minimal thermal transport performance should be 0.5 kW/m for buildings with heat loads lower than 100 kW and 0.75 kW/m for buildings with heat loads from 100 to 200 kW.

4.1.1.7. Connection Density ($q_{network}$)

Thermal connection density is the coefficient of the total annual amount of sold thermal energy and the total length of the district heating network. It is defined as follows:

$$(q_{network})\left[kWh/am\right]=\frac{\sum Q_{buildings}(\text{"sold thermal energy"})\left[kWh/a\right]}{l_{network}\left[m\right]}$$

$Q_{buildings}$ [kWh/a] total annual heat demand of buildings in a discrete area
I_{area} [m] total length of the pipe network

The thermal connection density is an essential economical parameter for estimating the investment costs and the energy losses of the DH network. In general the heating plant should be located as close as possible to industrial/bulk consumers. After the completion of the DH network a continuous densification should be aimed for, resulting in an increasing connection density and higher economical operation of the plant. Subsequent extension of the DH network will lower the connection density.

At the end of the first stage of completion of the DH network the specific investment costs shouldn't exceed 470 €/(MWh/a) and after completion 330 €/(MWh/a). In Table 8 the required thermal connection densities as a function of local conditions are listed, to assure the economical benchmarks.

Table 5. Required thermal connection density of DH network (QM Holzheizwerke 2008)

Status of network extension	Favourable conditions [MWh/a m]	Unfavourable conditions [MWh/a m]
at the beginning	> 0.7	> 1.4
after completion	> 1.2	> 2.0

In rural areas the construction costs for the installation of the DH network are usually lower than in cities (unfavourable conditions). In urban areas higher investment costs are caused by different ground conditions, difficult traffic situations, and existing networks for water supply or electricity.

The maximal distance of the network between the heating plant and the furthest connected building in DH networks with average size (1–5 MW) shouldn't exceed 1.5 km to restrain additional auxiliary power demand and the delivery height of distribution pumps.

4.1.1.8. Thermal Losses from Heat Distribution

The thermal heat losses due to heat distribution of the DH network are an essential parameter with respect to the economy of the plant. The thermal heat losses of the heat distribution depend, among other things, on:

- thermal connection density
- duration of plant operation: whole year operation or only seasonal operation
- temperature level of heat distribution
- insulation of distribution pipelines

The maximal thermal heat loss due to heat distribution shouldn't exceed 10%

of the thermal heat demand of buildings in the area considered. That amount of heat loss corresponds to approximately 9% of the total heat supply of the DH network. To observe the target value of 10% heat distribution losses, the connection densities listed in Table 6 have to be reached.

Table 6. Minimal connection densities to assure a maximum of 10% heat loss from heat distribution (QM Holzheizwerke 2008)

Working temperature [°C]	Mode of operation	Connection density [MWh/a m]
70–90	whole year operation including warm-water	> 1,8
70–90	seasonal operation including warm-water	> 1,3
40–70	seasonal operation without warm-water	> 0,8

Thermal heat distribution loss should amount to 15% of the total thermal energy demand of buildings, which represents an average value for new biomass DH plants.

4.1.1.9. Annual Efficiency

The majority of the investment costs involve the biomass boiler, therefore a maximal annual efficiency of the boiler has to be assured in order to guarantee economic plant operation. An annual efficiency for the biomass boiler of >85% can be reached by ensuring ideal localisation of the biomass plant, a high connection density and a high degree of capacity utilisation (full load hours). Table 7 lists the required annual full load hours of operation for biomass DH boilers as a function of operation mode (whole year or seasonal) and boiler design (mono-, bivalent).

Table 7. Target values for hours of full load operation for biomass boilers (QM Holzheizwerke 2008)

Plant type and operation	Hours of full load operation
1 biomass boiler–seasonal operation	> 1500
1 biomass boiler + hot water accumulator - whole year operation	> 2000
1 biomass boiler (basic load) + 1 oil boiler (peak load)	> 3000
2 biomass boilers–whole year operation	boiler 1 base load: > 4000 boiler 2 peak load: > 2000

4.1.2. Funding Possibilities

4.1.2.1. Feed-in-tariffs

The Eco-Electricity Act supports the production of electricity from photovoltaic, wind power, geothermic, solid and liquid biomass, biogas and landfill gas. This includes the fixed feed-in tariffs for all these renewable energy sources. This regulation refers to new plants, which are licensed by authority after 31.12.2004. The budget for the period from 2012–2015 amounts to 500 M€. The objective is to achieve 34% eco electricity. The feed-in tariffs for solid biomass are given in Table 8.

Table 8. Feed-in tariffs for solid biomass

Raw Material	Scale	Cent/kWh
Solid biomass such as woody biomass and straw	<500kW	14.98
	500kW–1MW	13.54
	1–5 MW	13.10–2.26
	5–10 MW	12.06
	>10MW	10.00

4.1.2.2. Federal Funding

Table 9. Federal funding for biomass applications (KPC 2013)

	2010		2011		2012	
	Number	Funding [Million €]	Number	Funding [Million €]	Number	Funding [Million €]
Single plants	501	12,208,959	532	5,104,216	550	4,576,907
District heating	134	18,264,155	127	13,722,683	129	13,943,211
CHP	7	2,533,831	2	46,461	3	3,757,228
Total	723	35,696,317	809	24,060,629	787	25,929,902

The subsidies for commercial and industrial applications, as well as biomass district heating plants (biomass heating), usually fall within the remit of the Kommunalkredit Public Consulting (KPC). The funding rate amounts to 25% of the eligible investment costs. Table 9 presents the number of funded heat plants and the sum of the paid-out funding.

4.1.2.3. Provincial Funding

Private individuals receive funding from their respective province. In Austria, there are nine provinces and each province has specific requirements for the funding of biomass heating systems. For farmers, there is a separate funding framework. For plants greater than 100 kW, such as small district heating systems and micro-grids, the province of Lower Austria spent € 1.3 Million for 5,076 plants in 2010.

In Lower Austria, the current funding rate amounts to 30% of the investment costs for wood chips and pellet boilers with an automatic fuel supply. The province also pays a maximum of 750€ for single ovens such as pellet stoves and fireplaces. These funding rates are limited to 2012.

4.1.3. Sample Calculation for Realised Investment Example

In Table 10, there is a sample calculation of the investments and prime costs of heat. This calculation was made for a 2.1MW heating plant, primarily operated on wood chips. All investments were made by the contractor who sells the heat to a nearby school and residential buildings. This heating plant, located in Lower Austria, was built in 2006. This heating plant represents a typical solution for such medium scale biomass heating plants. The boiler house includes 2,500 m^3 wood chip storage.

Table 10. Investment calculation for district heating systems–Example FJ Wieselburg

Costs of the heating system	Heating system
Nominal capacity [kW]	2,100
Service life [years]	15
Annual fuel demand [kg/a]	1,200,000
Annual heat demand of consumers [kWh/a]	2,900,000
Annual energy production [kWh/a]	3,600,000
With heat supplied area [m²]	20,000
Length of pipe network [m]	1,500
Heat capacity demand of the buildings [kW]	2,275
Investment costs:	
Boiler [€]	580,000
Storage room, Building [€]	610,000
Construction, initial operation and component parts [€]	100,000
Flue gas treatment system [€]	85,000
Heating grid [€]	510,000
Total Investment costs [€]	1,885,000
Capital consumptions:	
Boiler [€/a]	38,667
Storage room [€/a]	40,667
Construction, initial operation and component parts [€/a]	6,667
Flue gas treatment system [€/a]	5,667
Heating grid [€/a]	34,000
Total capital consumptions [€/a]	125,667
Operating costs:	
Fuel costs [€/a]	84,000
Auxiliary energy costs [€/a]	4,500
Chimney sweeper costs [€/a]	300
Maintenance and repair [€/a]	1,500
Total operating costs [€/a]	90,300
Total annual cost [€/a]	215,967
Total costs over service life [€]	3,239,500
Heat production costs [€/kWh]	0.060

4.2. Finland

4.2.1. Investment, Operating Costs and Profitability

The costs of producing heat in a medium sized (100 kW–5 MW) heating plant can be roughly divided into three categories; capital costs, fuels, and operation and maintenance. Typically, capital costs account for 30–45%, fuels 30–50% and maintenance etc. 10 to 30% of the prime cost of heat production at such a plant. However, these costs can vary significantly, depending on the individual case. For example in Eno, Northern Karelia, the investment costs of the Eno Energy Cooperative heating plants were as follows:

- 25–35% for equipment; boiler, plumbing, control system, conveyors, meters, etc.
- 25–40% for buildings; boiler house and wood chip store
- 30–45% for heat distribution network; pipes, plumbing and trenching

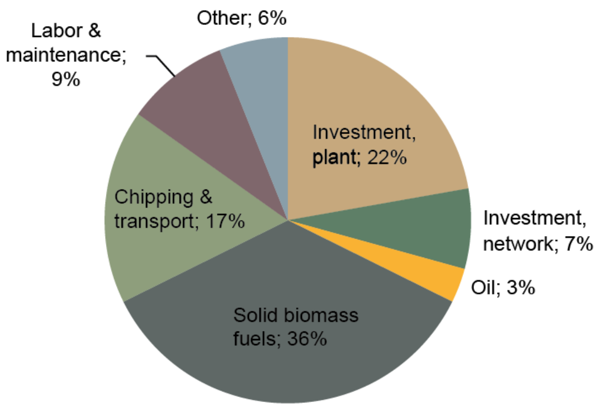

Figure 49. Average prime costs of heat production at a biomass heating plant run by a heat entrepreneur (Sauvula-Seppälä, 2010)

Investments naturally cover the whole heating system, including the boiler house and wood chip store, and often the heat distribution network, or at least a connection to it. Fuel costs include not only purchasing costs of wood fuels but also costs of other fuel used in a back-up system, which is most often heating oil for an oil fired boiler. Because of the northern climate, back-up systems are always installed, or old fossil fuel fired boilers, if they are still in a good working condition, are used to provide heat in the event of malfunction, maintenance or extremely cold weather. Maintenance and labour costs depend very much on how well a plant is designed to meet the heat demand and the quality of supplied wood fuels. Usually these kinds of plants are operated unmanned, so labour costs include only actual service and other occasions when staff are called to the plant, for example when there is a disturbance in feeding of wood chips.

In a study conducted in western Finland, about 60% of the studied heating plants (average size 800 kW) were owned by heat entrepreneurs and the rest were owned by the end user, for example municipalities. In the years 2006 and 2007 the average total income from selling heat was 56.2 €/MWh and average prime costs were 43.8 €/MWh. The total income consists of consumption - based payments and flat rates. Among the entrepreneurs, the annual average income varied between 4,300 and 28,500 €. The greatest income was in the group of the largest plants (Sauvula-Seppälä 2010).

Figure 50. Eno Energy Cooperative heating plant (Urpo Hassinen)

A heating plant is considered a long term investment and therefore pay-back time is usually at least ten years. Often real profit is made after the plant has been paid off. However, the net income from selling heat does not represent the total income from the heating business. For example heat entrepreneurs receive compensation for operating the plant, possibly selling wood to it, and for other tasks agreed on in the heat supply contract. Furthermore, cooperatives usually return possible profits as a surplus to their members. If heat customers invest in the plant but outsource its operation, they benefit from a lower heat price compared to that for fossil fuel heating.

Because heat plants are long term investments, it is important to carefully consider the best way to set a price for heat (see also Chapter 5.4). Usually the bigger the plant the greater there is a need for a steady income to meet monthly instalments. This means in practise that the flat rate (basic fee) is set higher so as to also ensure enough income when heat consumption is low, for example in summer. Naturally consumption-based payments vary throughout the year. The following principles are followed in pricing heat:

- Investments in distribution networks are usually covered by one-time customer connection fees
- Other capital costs are covered by basic fees (flat rate)–this is based on either expected consumption input, €/kW, or contracted water quantity
- Variable costs are covered by metered consumption fees (energy fee)

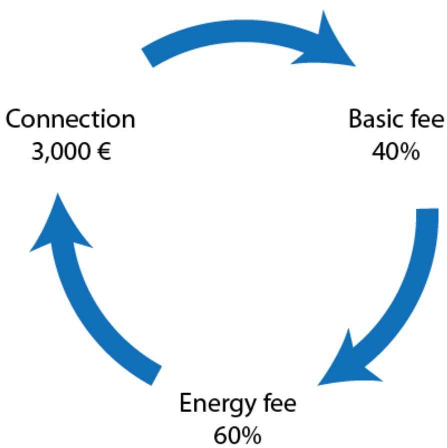

Figure 51. Example of pricing of heat

However, it is important that connection fees do not prevent customers from joining the network. So if distribution network costs are high it is better to keep connection fees moderate and cover these costs with flat rates. It is also important to clearly describe in a contract how prices are fixed, and how they can change. Typically, different fees are tied to indexes such as the consumer price index (CPI) or a 'shopping basket' of fuels, e.g. light fuel oil and wood chips. Usually prices can be adjusted at certain intervals, for example, twice a year. Price formation can have minimum and maximum levels. Adjusting the price can also involve clauses such as 'if the price changes less than XX% from the previous, the adjustment will not be made'.

4.2.2. Funding Possibilities

In principle, there are three common ways to fund heating plant investments. The main customer, such as a city council, invests in and owns the plant and heat distribution network, as was often the case when heat entrepreneurship began in Finland. Running and maintenance of the plant, as well as fuel supply, are then outsourced to an energy company, entrepreneur or cooperative.

It is also common that an entrepreneur invests in the plant, and owns and operates it as usual business while a city council takes care of the heat distribution network.

Sometimes entrepreneurs or small heating companies make all investments themselves, including in the network. Investments are funded with own capital, loans and possibly pre-paid entrance fees. In rural areas it is possible to receive investment subsidies, usually up to 20–25%, from regional development funds.

4.2.3. Sample Investment Calculation for a Realised Heating Plant

The following table gives a sample calculation of investments and prime costs of heat. This calculation was made for a 250 kW new heating plant, primarily operated on wood chips. All investments were made by the owner of a large industrial building which the plant was built to heat. In addition, the owner intended to sell heat to a nearby school. This heating plant, located in central Finland, was built in 2010.

Table 11. Calculation example of prime costs of heat (IEE Agriforenergy 2, Case Mäkinen, Finland)

INVESTMENTS			VAT 0%
Earth moving and foundation			25,000
Boiler and equipment			140,000
Oil boiler and equipment			3,000
Buildings and smoke stack			65,000
Connection to existing network			0
Heat pipes and distribution equipment	120 €/m	40 m	4,800
Planning, overseeing, permissions			5,000
TOTAL			242,800
Payback time, years			15
Interest rate,%			5
Capital recovery factor			0.0963
Investment subsidy,%			20%
Residual value		0%	0
Instalments, /year/month	18,714	€/year	1,559
Investment costs/heat price,%, €		57%	46.8
Energy sold, MWh			400
Distribution loss, MWh	30 W/m	40 m	11
Energy produced with biomass,%, MWh		98%	402
Energy produced with oil,%, MWh		2%	8
Biomass fuel price at plant, €/MWh			15.0
Oil price, €/MWh			90.0
Total price of biomass/a, €	efficiency	85%	7,099
Total price of oil/a, €	efficiency	90%	821
Service and repair, €			2,428
Electricity, €	€/MWh	2	821
Management, insurance, €			1,000
Running of plant and maintenance, €			2,000
Variable costs, €/MWh	14,169	€/year	35.4
PRIME COST OF HEAT PRODUCTION, €/MWh	32,883	€/year	82.2

This heating plant represents a typical solution for medium scale biomass heating plants (see Chapter 3.2). The boiler house includes a 130 m^3 wood chip store which holds enough wood chips for at least one week's use in winter. It should be noted, however, that the prime cost of heat was calculated based on the minimum consumption. Therefore the production costs of heat are quite high, but still lower than for heating oil. For example, if energy supply could be doubled to 800 MW per year, prime costs would only be 52 €/MWh.

It is very important to size a biomass heating plant correctly because heat costs are very sensitive to the amount of produced heat. Boilers and heating systems that are too big make investment costs too high compared to expected revenue from heat sales. Another important cost factor is the payback time. A simple cost sensitivity analysis is illustrated in the figure below. Changes were calculated by increasing and decreasing the original values by 10-50%.

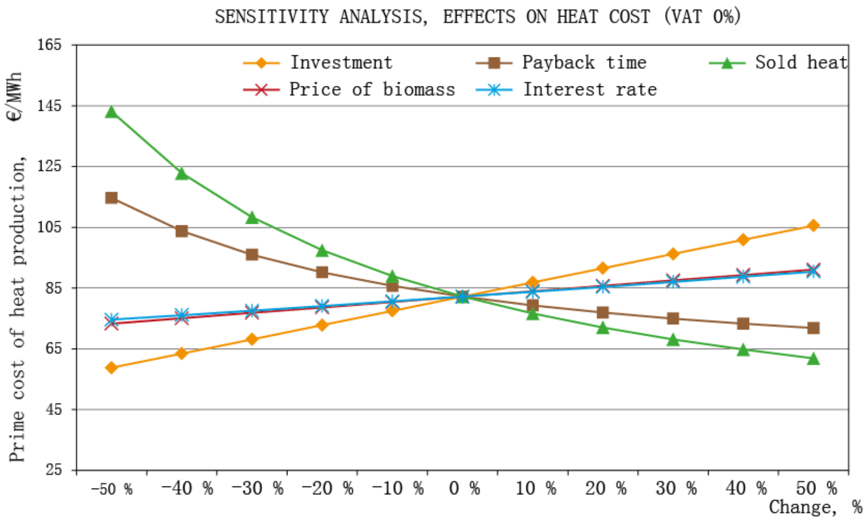

Figure 52. Illustration of sensitivity analysis of heat costs (VAT 0%) (IEE Agriforenergy 2, Case Mäkinen, Finland)