The Benefits of Energy Cooperation between Industries and Utility

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Energy Co-operation between District Heating Company and Industries in the municipality of Kisa

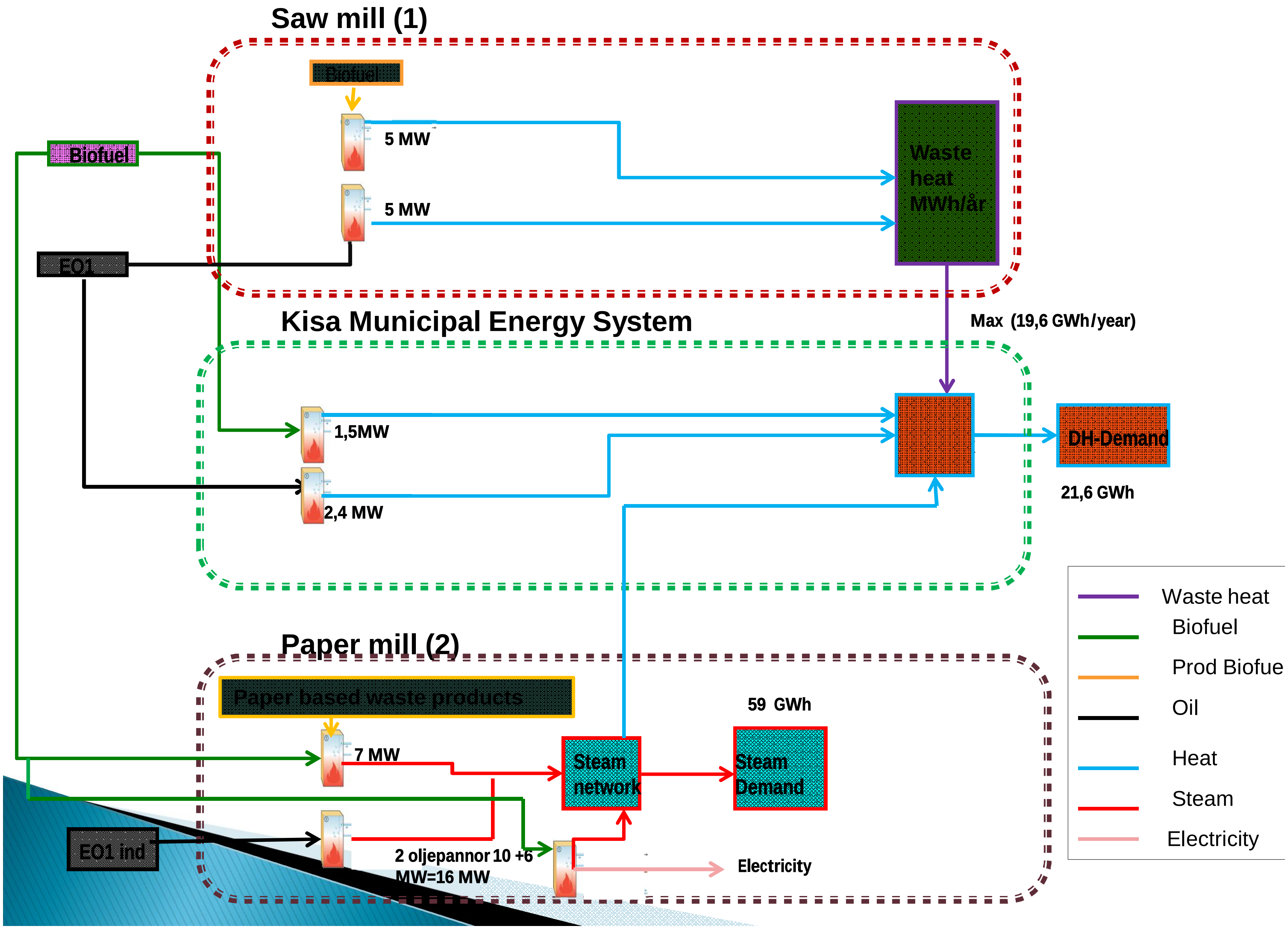
- **District heating** in the society of Kisa is locally produced from biomass. The District heating company, Tekniska Verken owns the district heating system. The oil boilers are used as a reserve and peak load boilers
- The **saw mill** is situated in the municipality of Kisa in the county of Östergötland. The saw mill unit, has been linked to the municipalities district heating network. The heat produced in the boilers at saw mill covers not only their own energy needs but also deliver waste heat (surplus energy in the form of heat spillage) to the Kisa-municipal district heating system.
- There is also a **paper mill** , located in the municipality of Kisa. The boilers owned by Tekniska Verken are used to produce steam for the paper mill. Much of the fuels are waste products from the mill (chips and bark).

Objectives

- The objectives of this study are:
  - to present a model for the integrated energy system in order to achieve a cost-efficient system, and
  - to assess the effects of the energy cooperation on Kisa municipal district heating system and the environment.
  - to analyze the conditions for connecting a combined heat and power (CHP) plant to the system.
  - to analyze the sensitivity of the system by varying important parameters (electricity and fuel prices, electricity certificate price)

Case study design

- Building the model , see slide pages 5-16
- Design of scenarios, see slide page 17
- Input data, see slide page 18
- Assumption, see slide page 19-20
- Result and conclusion, see slide page 21-29
- Sensitivity analysis, see slide page 30
- Result of sensitivity analysis, see slide page 31-34
- Conclusion, see slide page 35-37



Saw mill (1)
Biofuel
5 MW
5 MW
Waste heat MWh/år
Biofuel
EO1
Max (19,6 GWh/year)
Kisa Municipal Energy System
1,5MW
2,4 MW
DH-Demand
21,6 GWh
Paper mill (2)
Paper based waste products
59 GWh
7 MW
Steam network
Steam Demand
EO1 ind
2 oljepannor 10 +6 MW=16 MW
Electricity
Waste heat
Biofuel
Prod Biofue
Oil
Heat
Steam
Electricity

Local, Regional, National Energy System Modelling by MODEST

MODEST

Method for **O**ptimisation of **D**ynamic **E**nergy **S**ystems with **T**ime dependent components and boundary conditions.

With the MODEST model framework a representation of an energy system can be made.

MODEST

- Is an energy system optimisation model ,use linear programming (LP) for cost minimisation and has been developed in the Linköping University (IEI), Department of Management and Engineering, Division of Energy Systems (1986, Backlund L).

- Is used for operational optimisation and evaluating economic and enviromental consequences of future changes in the Energy system.

MODEST

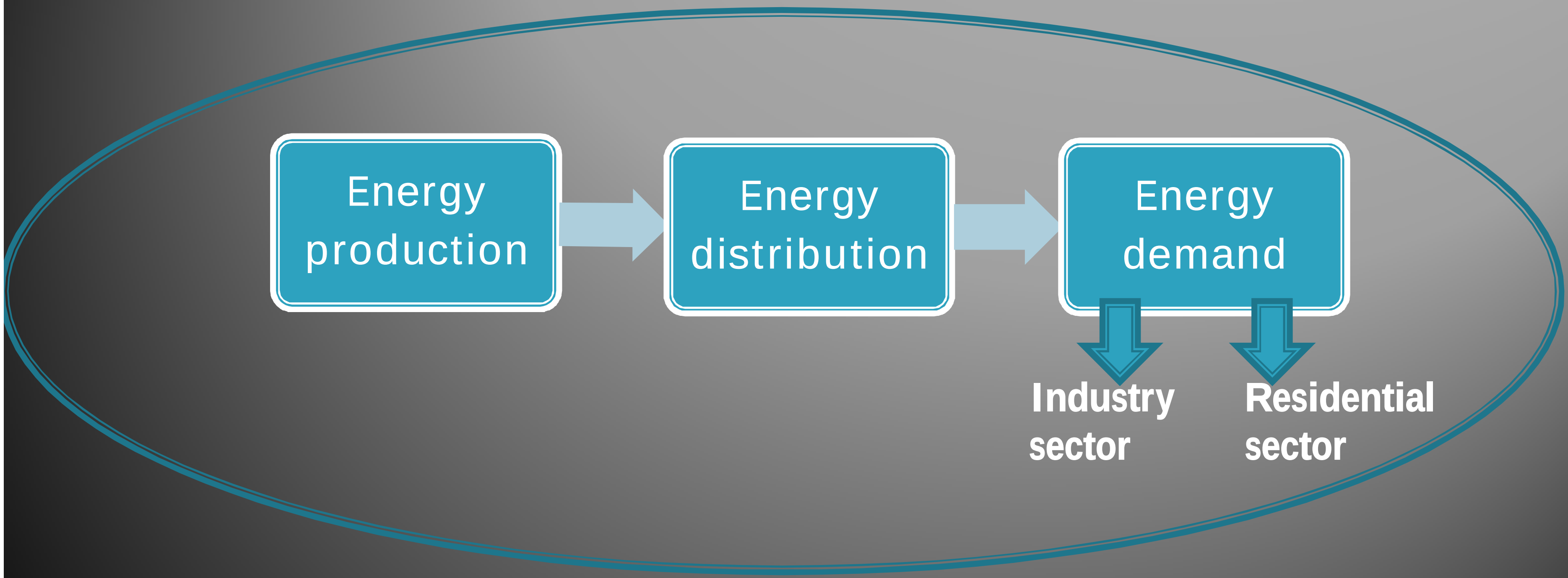
- MODEST uses the optimisation method linear programming to calculates how energy demand should be satisfied at lowest possible cost:

  The **total system cost** is minimised through the optimisation. The result includes the total cost for satisfying the DH-demand, as well as the optimal investments that should be made , plant operation, marginal cost for supplying various energy forms and **emissions the system causes**.

- Energy demand could be power ,heat, biogas-production and cooling generation in local, regional and national energy systems.

- The best system design and operation is obtained considering present and possible plants, energy costs, available resources etc.

System boundary for MODEST



MODEST
Summary

- Country, municipality
- Electricity, heat, biogasproduction and cooling generation
- Short and long-term variations
- Cost minimisation with the optimisation method linear programming.
- Investments in new plants: type, size, occasion
- Given energy service demand :

  Which combinations of energy sources, conversion plants and energy conservation measures are most beneficial?

Advantages of MODEST

- With the MODEST model framework a comprehensive representation of an energy system can be made, where the level of detail can be chosen.
- MODEST has arbitrary division possibilities concerning space (e.g. city or province), sector (e.g. heating or industrial processes), time (e.g. day, season) and quality (e.g. heat, electricity).
- MODEST has a flexible detailed time division, which can reflect demand peaks and long-term variations in energy demand and other parameters e.g electricity prices, capacity. It can be adapted to real variations.
- Flexible boundary system which does that the MODEST can be used both for analyzing municipalities district heating systems and for national energy systems.
- Short time concerning optimization.

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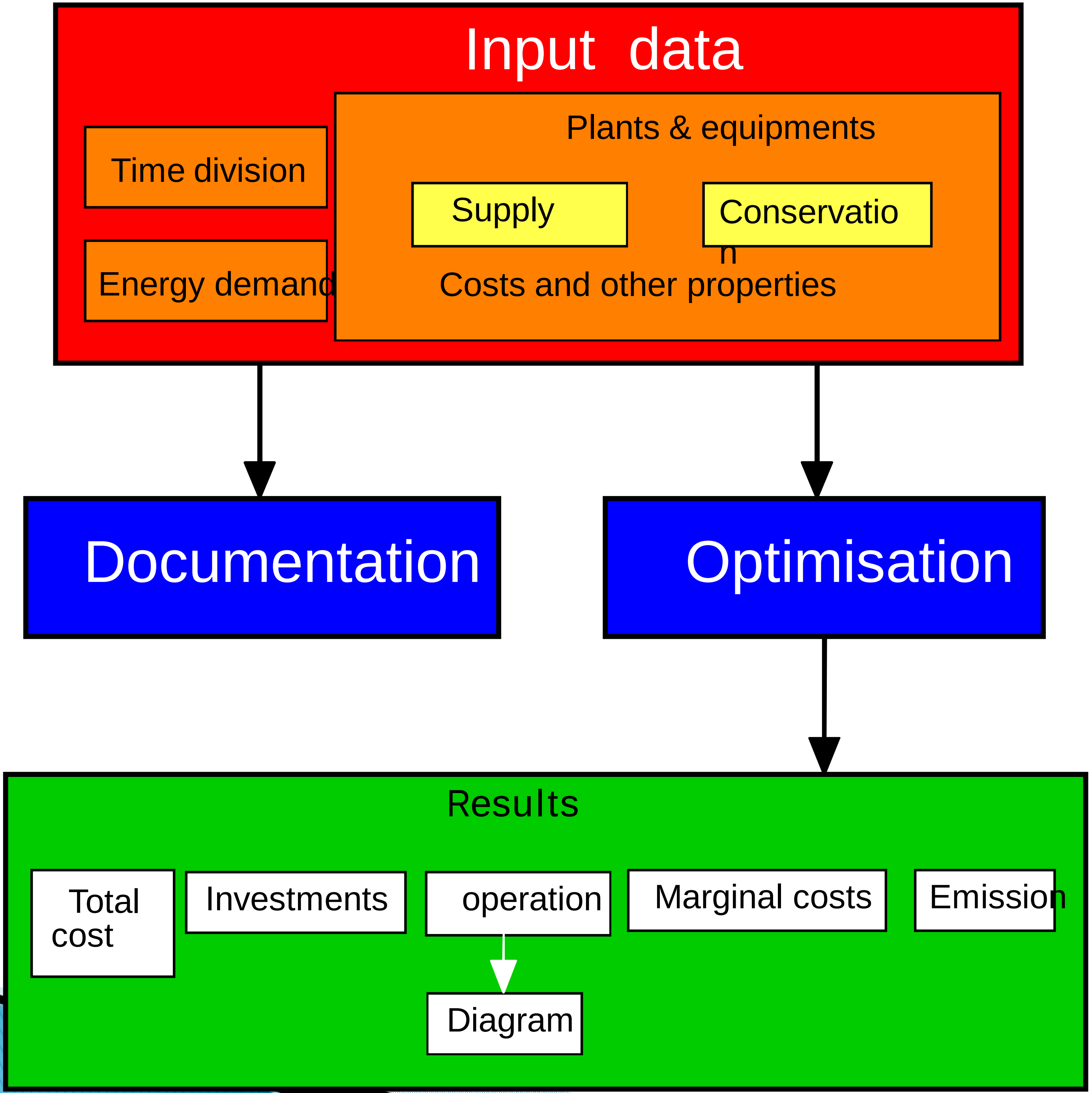
Input data
Plants & equipments
Time division
Supply
Conservatio
n
Energy demand
Costs and other properties
Documentation
Optimisation
Results
Total
cost
Investments
operation
Marginal costs
Emission
Diagram

MODEST

- MODEST has been used to analyze district-heating systems, electricity production and cooling generation in many Swedish municipalities.

MODEST
some examples

MODEST has been used to study the energy systems in about 50 Swedish municipalities:

- Connection of district heating networks.
- Connection of heat sparse areas to district heating systems
- Assessment of the natural gas potential for heat and power generation in the County of Östergötland in Sweden.
- Advantages of absorption cooling in Swedish District Heating System
- Benefits of biofuel utilisation in three Swedish provinces
- External costs of electricity and heat production in a municipal energy system.
- Heat trading between Sweden and Denmark.

Responsible institute

- **MODEST**

Institution: Linköping University / IEI / Division of Energy Systems

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Design of scenarios

- Case 1: The Kisa municipal DH- System without energy cooperation (renew biomass boiler to 10 MW)
- Case 2: The Kisa municipal DH- System with energy cooperation: Waste heat from Saw mill to Kisa DH-system. (biomass boiler 1,5 MW)
- Case 3 : Case 2+deliver steam to Paper mill
- Case 4: Case 3+CHP

Input data

- Fuel costs, Energy and CO_2-taxes are included in the model.
- The electricity prices in the model are general price profile that reflects the electricity prices of today. The prices are an average value of the actual Swedish electricity prices on the Nordpool spot market during (Nordpool, 2011). An average value electricity price is calculated for each time period in the model.
- In the model, electricity sales are considered as income, and the model chooses to produce electricity when it is profitable.

Assumptions

- See the next slide page 20

CO_2 emissions and marginal electricity production accounting modell

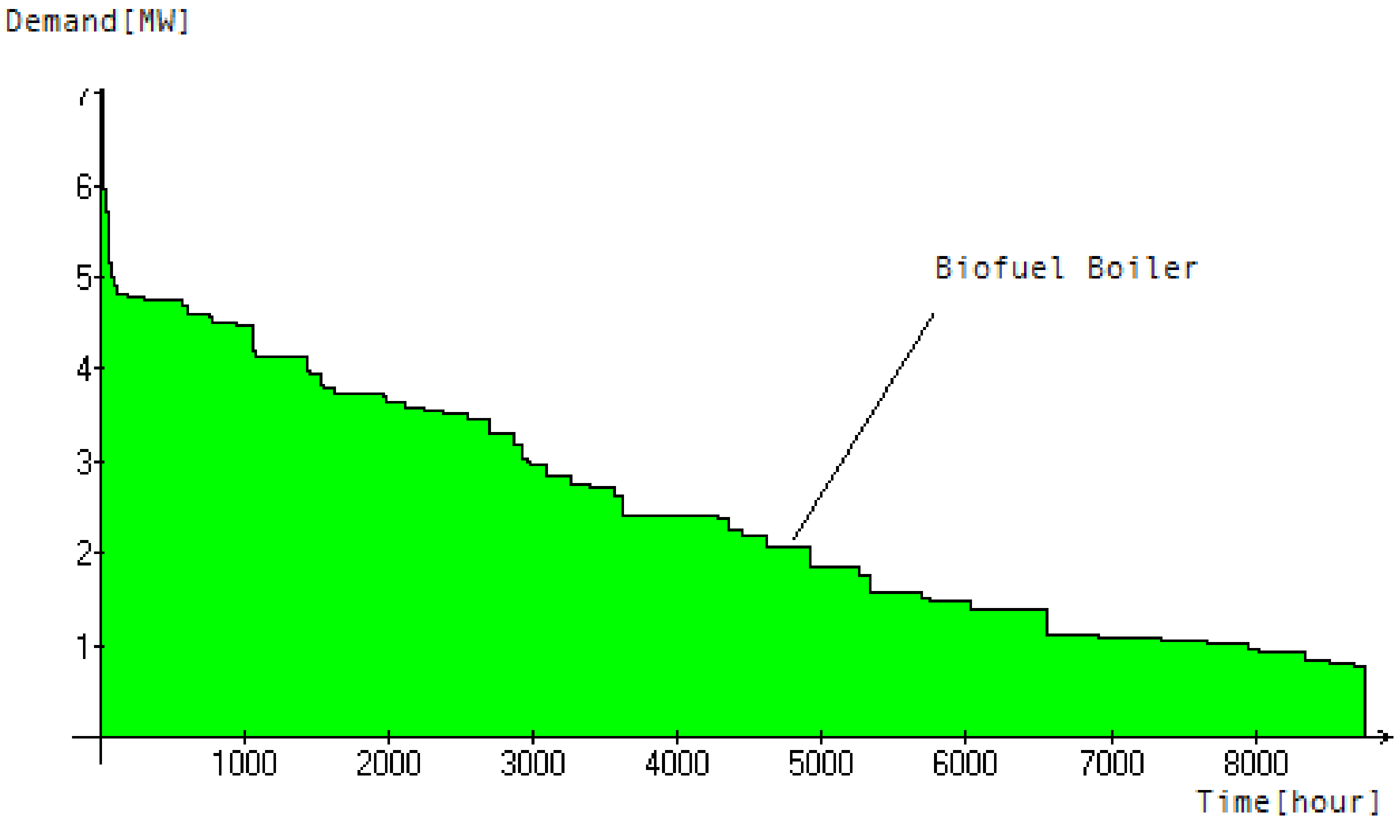
- Bio-fuel is assumed to be CO_2 neutral, according to the IPCC guidelines for national greenhouse gas accounting.
- Coal-fired condensing power (CFCP) plants have been assumed to be the short term marginal power plant in the European electricity system and the electricity market is fully deregulated.
- The local electricity production e.g. by bio-fuel CHP power plants will replace the electricity produced by coal-fired condensed power plants. This means that CO_2 emissions can be credited for the local electricity production:

  1 GWh electricity = 974 tonne CO_2

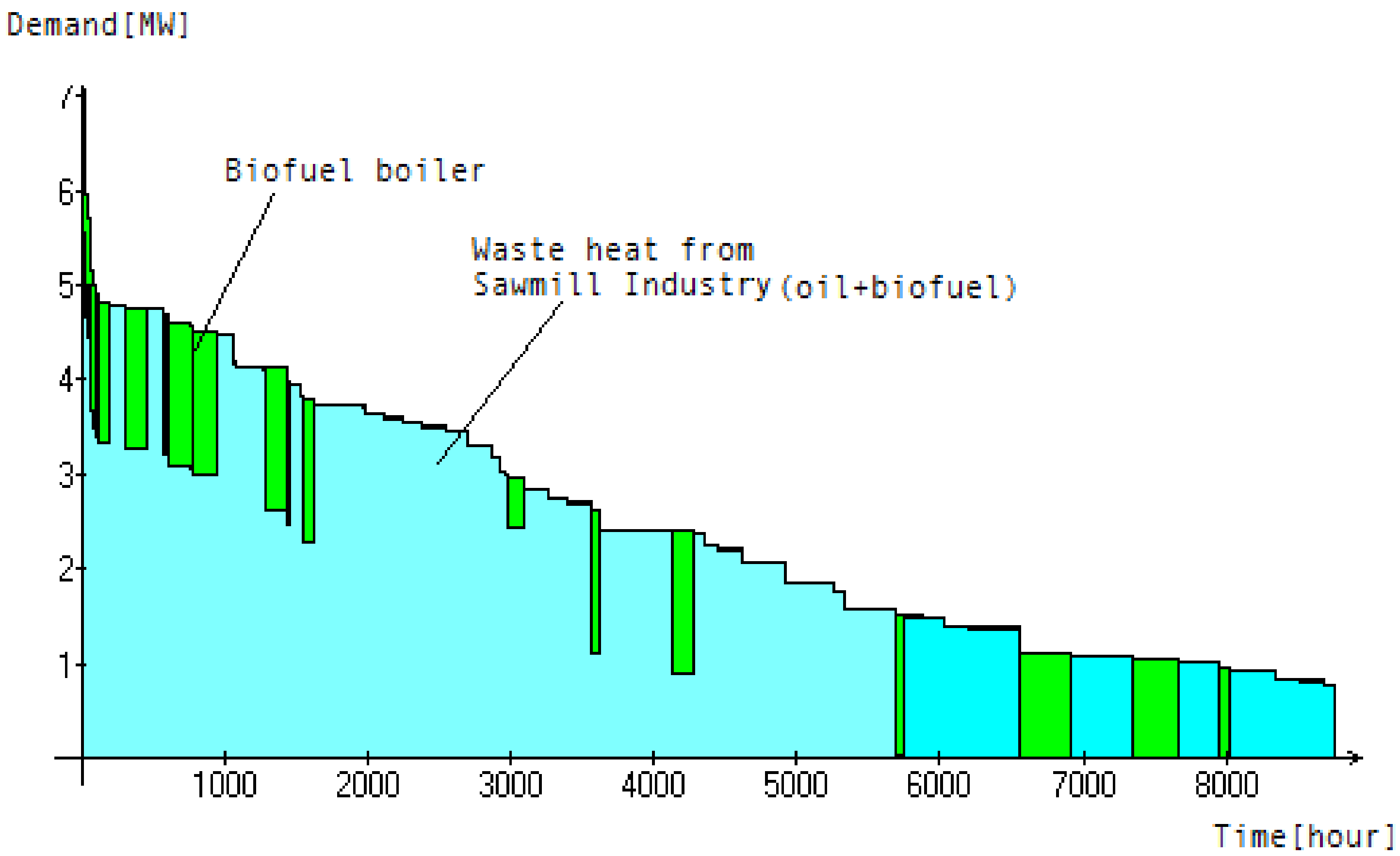
Results

- Duration diagram . See the slide pages 22-27
- Used fuels. See the slide pages 28.
- Energy production (heat, steam, electricity). See the slide page 28
- System cost and profit. See the slide page 28
- Local and global CO_2 emissions. See the slide page 28

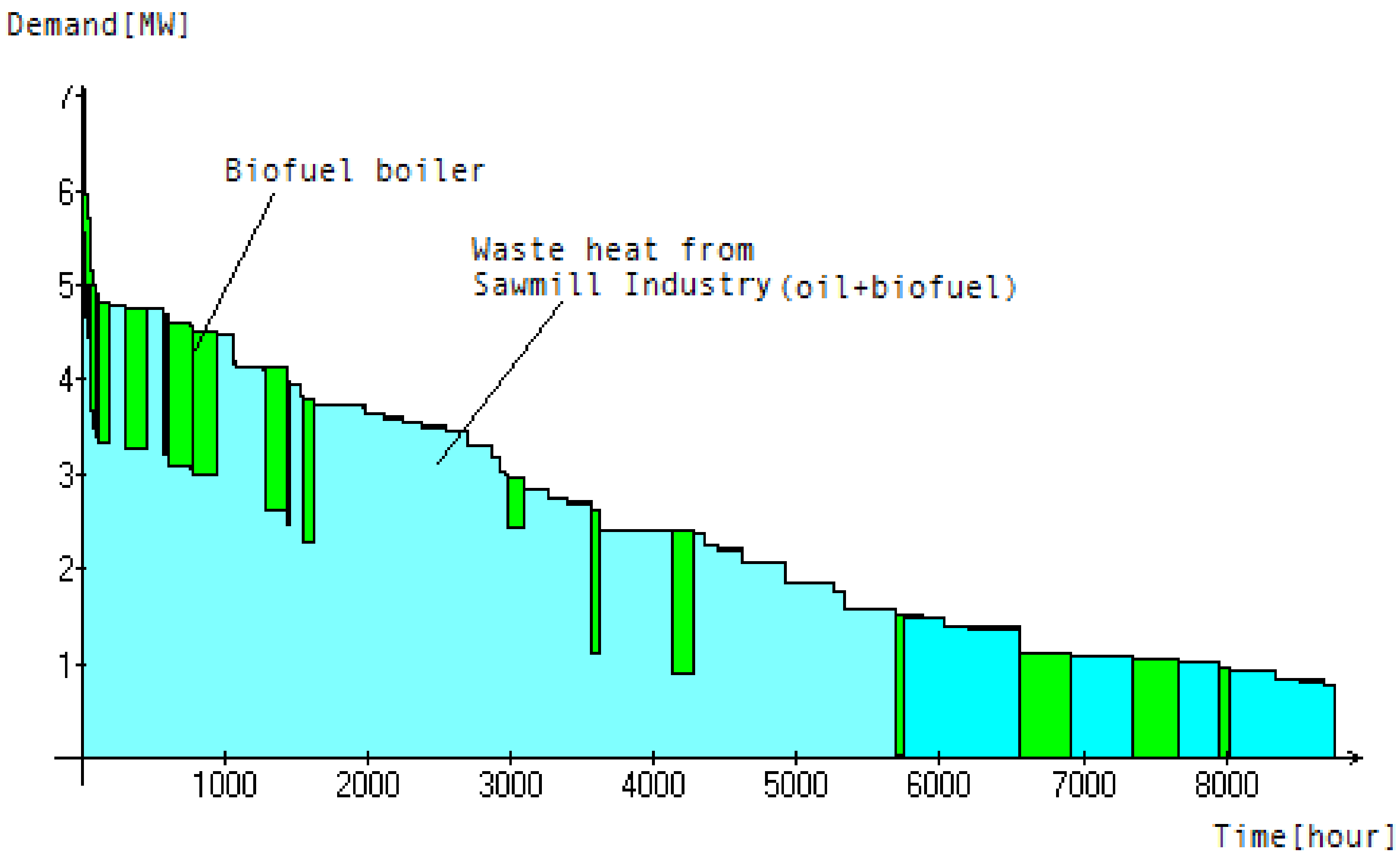
Case 1: The Kisa municipal DH- System without energy cooperation



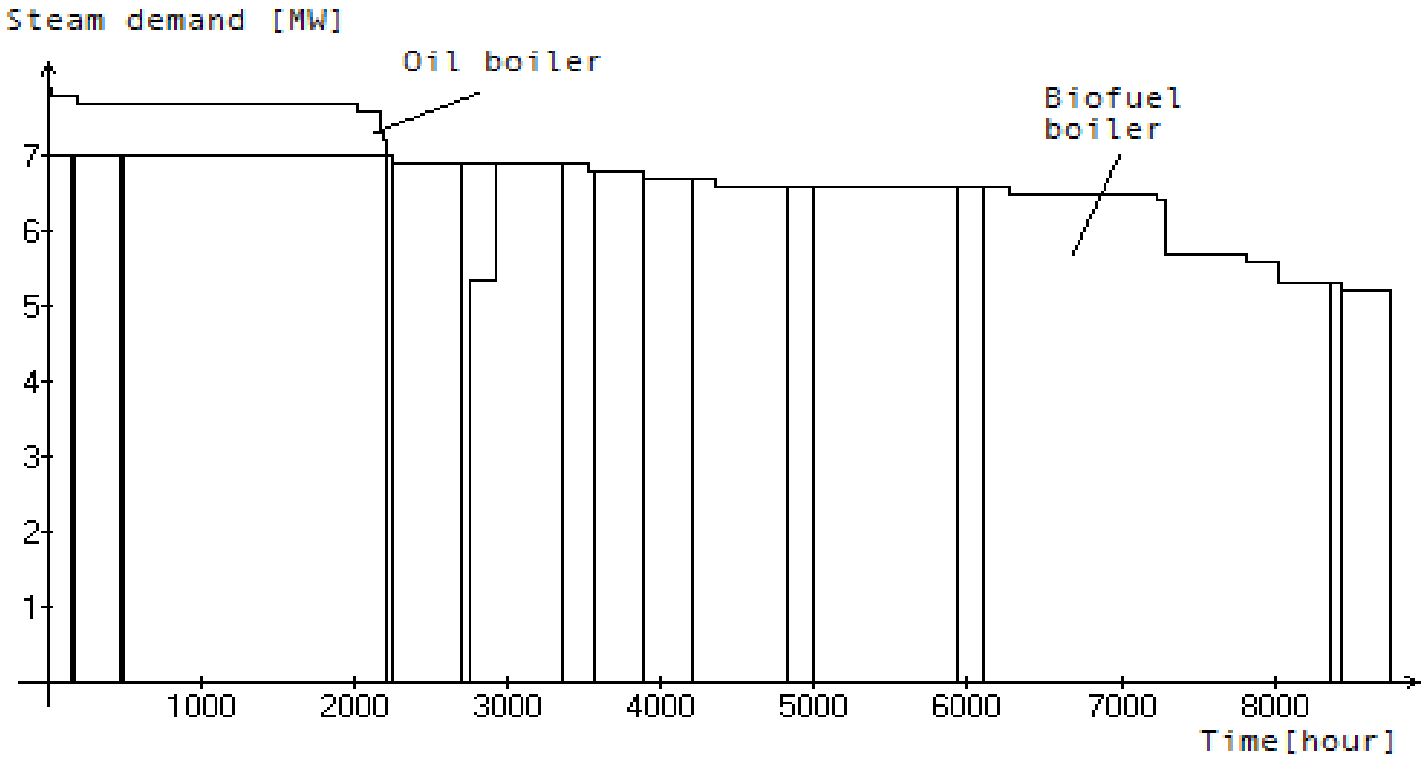
Case 2: Energy Cooperation with Saw mill



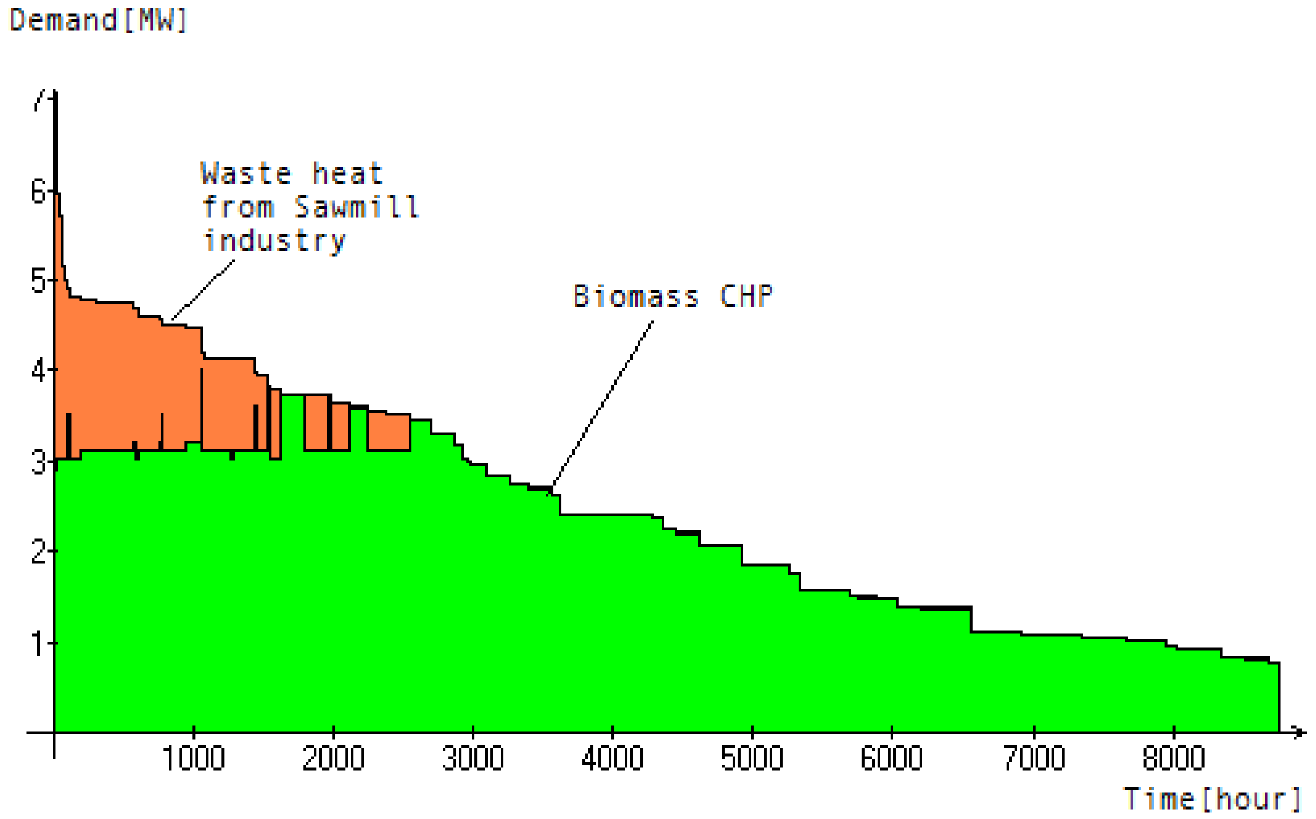
Case 3: Energy Cooperation with Saw mill and Paper mill



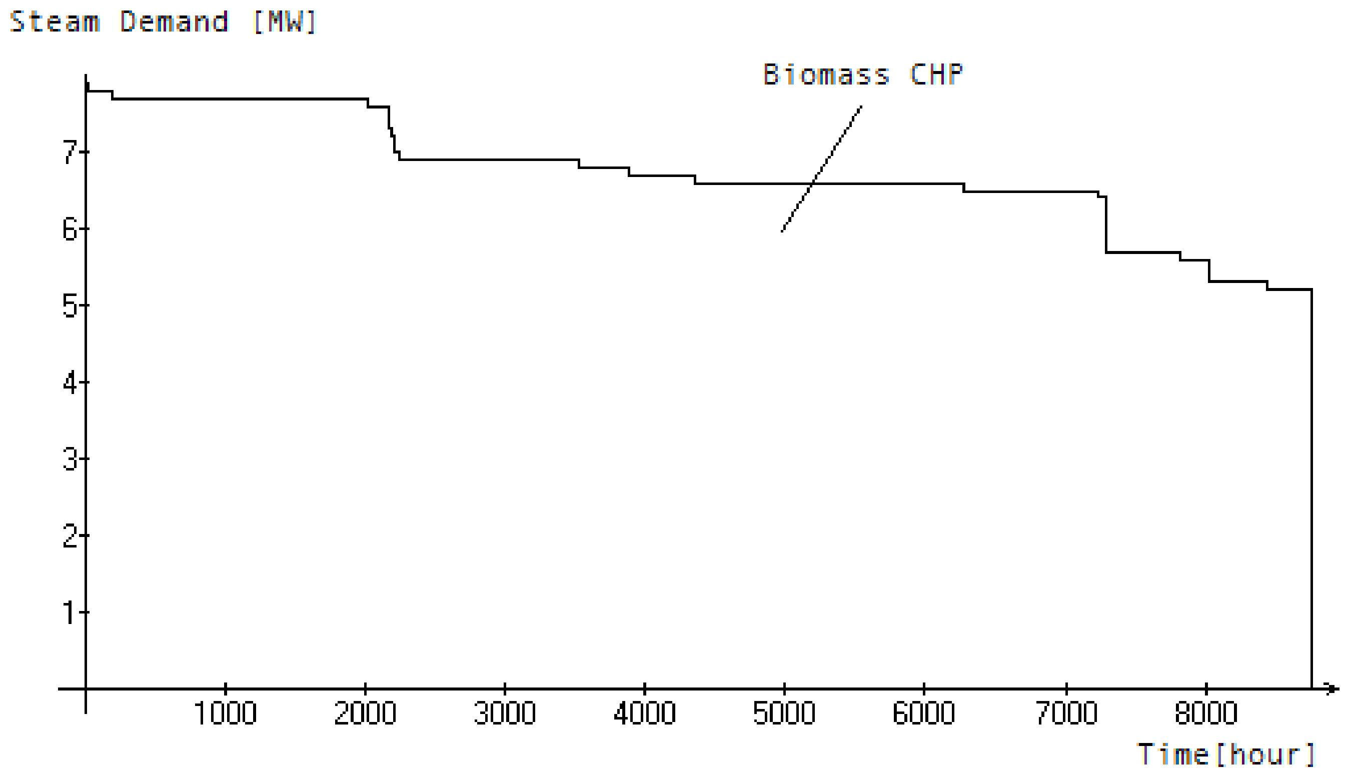
Case 3: Energy Cooperation with Saw mill and Paper mill



Case 4: Energy Cooperation with Saw mill and Paper mill+CHP



Case 4: Energy Cooperation with Saw mill and Paper mill+CHP



Results :

Energy production, Used fuels, CO_2-emission, System cost and Profit

	Case 1	Case 2	Case 3	Case 4
Heat/Steam/ Electricity production [GWh/year]	21,6/0/0	21,6/0/0	21,6/59/0	21,6/59/28,9 CHP: Electricity: 28,9 Heat: 19 Steam:59
Used Fuels [GWh/year]	Bio : 29,9 (EC)	Bio: 24 (SM+EC) Oil: 0,008 (SM)	Bio: 77,8 (SM+EC+PM) Oil: 10,6 (SM+PM)	Bio: 100 (SM+CHP)
[1]System cost [MSEK/year]	-4,51 (EC)	-8,37(EC) -3,95 (SM)	-16,82 (EC) -3,95 (SM) -1,37 (PM)	-37,1(EC) -0,53 (SM) -1,37 (PM)
Local CO_2 emissions [tonne/year]	0	2,3	2 896	0
Global CO_2 emissions [tonne/year]	0	0	0	- 28 149
[2]Profit (MSEK/year)	0	+7,81	+17,63	+34,39

NOTE! Energy sales: the flow is associated with revenue (negative cost).

[2]Profit: plus sign means net income and – minus sign means net loss

[1]The sum of all annual costs converted to its present value is called the system cost and is the total cost to meet the heating demand . District heating ,steam and electricity sales is included.

Conclusion

Energy cooperation between utility and industries provides an opportunity for municipality of Kisa to increase:

- The amount of biomass to about 78 GWh per year, an increase by 160%.
- The amount of biomass to about 100 GWh per year, an increase by 230% or by factor 3, due to the new CHP.
- Use of district heating which in turn contributes to reducing municipalities' need for fossil fuels. The amount of oil is decreasing by 11 GWh per year.
- Electricity production by about 29 GWh annually.

This study shows also how the increased biomass in municipality of Kisa helps to reduce:

- Global emissions of CO_2 by about 28,000 tonne per year in the county of Östergötland,

And how the energy cooperation gives :

- Economic benefits for both utility and industries , about 34 MSEK / year.

Sensitivity analysis cases

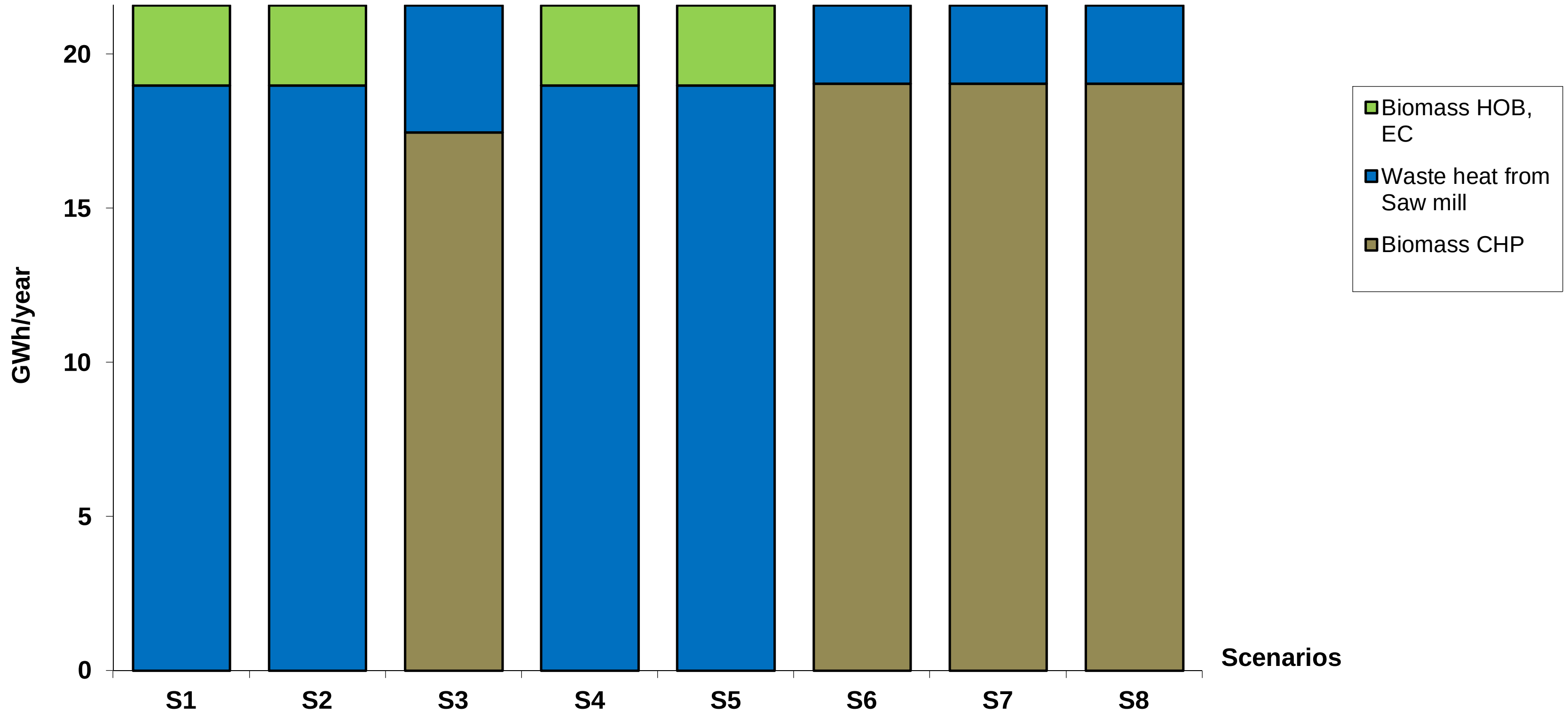
Changing of important parameters in Case 2, Case 3 and Case 4 and analysis of the system:

- Case S1 = Case 2+25% increasing biofuel price.
- Case S2 = Case 3+25% increasing biofuel price.
- Case S3 = Case 4+25% increasing biofuel price.
- Case S4 = Case 2+25% increasing waste heat price.
- Case S5 = Case 3+25% increasing waste heat price.
- Case S6 = Case 4+25% increasing waste heat price.
- Case S7 = Case 4+25% increasing electricity price.
- Case S8 = Case 4+25% increasing electricity certificate trading market price.

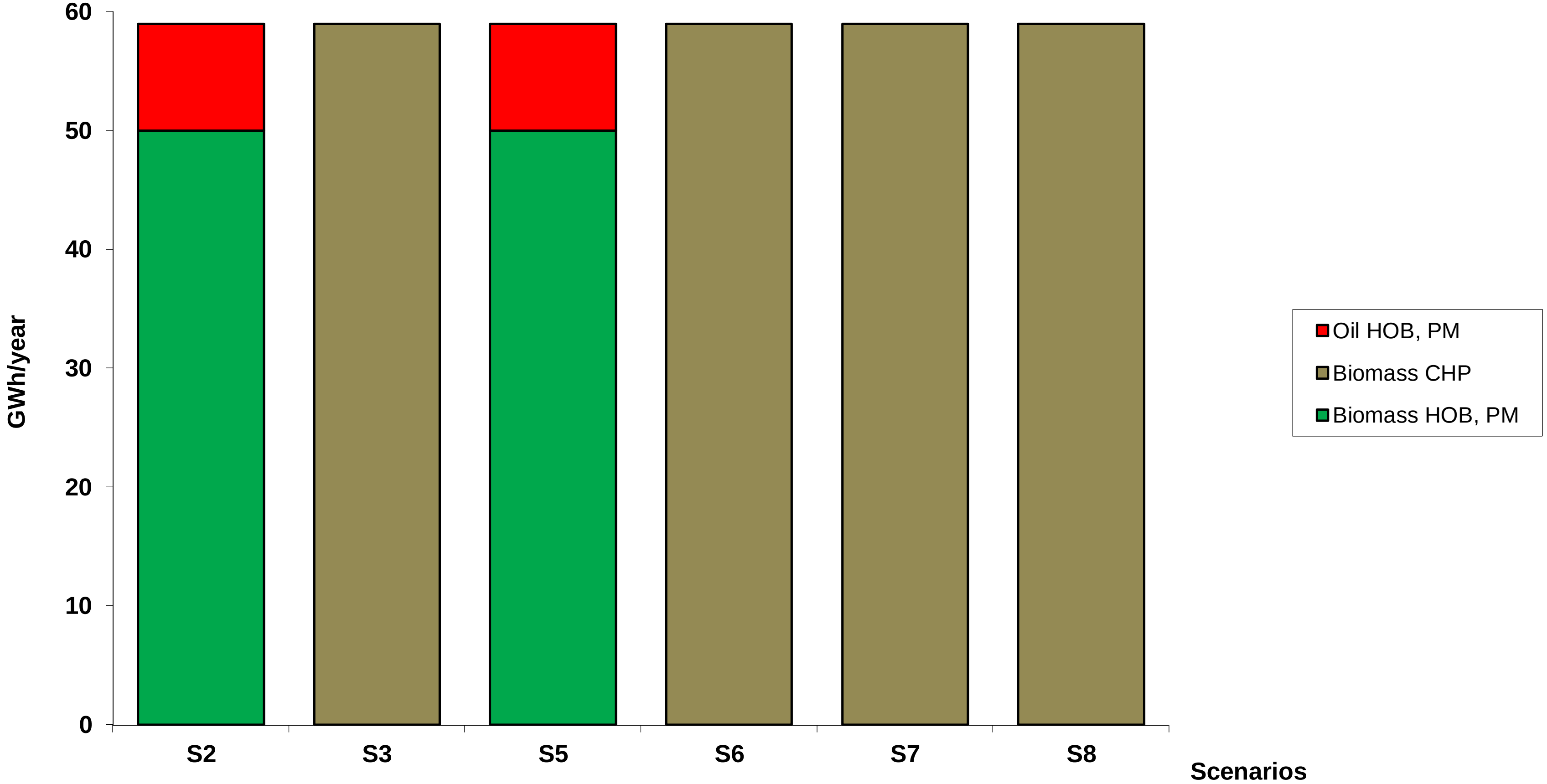
Sensitivity analysis result

- Energy production (heat , steam and electricity). See the slide pages 32-34.
- System cost and profit. See the slide page 34
- Local and global CO_2 emissions. See the slide page 34
- Conclusion. See the slide page 35

Heat production of district heating (Case S1- Case S8)



Steam production (Case S2- Case S8)



Sensitivity analysis result

Case	Bio fuel Price [SEK/ MWh]	Waste heat Price [SEK/ MWh]	El Price [SEK/ MWh]	El-Cert Price [SEK/ MWh]	System Cost [MSEK]	Local CO_2-emissions [tonne]	Global CO_2-emissions [tonne]	Profit [MSEK]	El-Prod [GWh/ year]
1	X	X	X	-	-4,51	2,3	-	-	-
S1 Case 2	+25%	-	-	-	-8,10 (EC) -3,95 (SM)	2,3	-	7,54	-
S2 Case 3	+25%	-	-	-	-13,11 (EC) -3,95 (SM) -1,70 (PM)	2 896	-	14,25	-
S3 Case 4	+25%	-	-	-	-31(EC) -0,86 (SM) -3 (PM)	0	- 27 552	34,86	28,3
S4 Case 2	-	+25%	-	-	-7,38 (EC) -4,94 (SM)	2 283	-	7,81	-
S5 Case 3	-	+25%	-	-	-15,8 (EC) -4,94 (SM) -1,37 (PM)	2 896	-	17,6	-
S6 Case 4	-	+25%	-	-	-37 (EC) -0,66 (SM) -1,37 (PM)	0	- 28 121	34,62	28,9
S7 Case 4	**-**	**-**	**+25%**	**-**	**-40,3 (EC) -0,53 (SM) -1,37 (PM)**	**0**	**- 28 121**	**37,69**	**28,9**
S8 Case 4	-	-	-	+25%	-38,8 (EC) -0,53 (SM) -1,37 (PM)	0	- 28 121	36,19	28,9

Conclusion - Sensitivity analysis

- The result of sensitivity analysis shows that larger economic gains would be achieved by an increase in the electricity and electricity certificate prices.

- By 25% higher electricity prices, the system costs reduces and the profitability increases by another 3,3 MSEK / year due to more revenue from electricity sales and electricity certificate trading.

- It also results in 28,000 tons less global CO_2 emissions per year than now.

Conclusion

Energy cooperation between utility and industries provides an opportunity for municipality of Kisa to increase:

- The amount of biomass to about 78 GWh per year. That is an increase of 160%.
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Conclusion

- The results shows that energy cooperation between utilities and industries reduce the system cost and CO_2-emissions.
- The result gives incentives for investments in new biomass CHP plant which in turn reduce local and global CO_2 emissions.
- The result shows also that the energy policy and policy measures (legislation and market based instruments: *energy taxes* and *electricity certificate*) are important for promoting energy cooperation and to provide CHP.

System Cost

- The aim of the optimisation is to find that way to satisfy the energy demand which has the lowest system cost for a certain number of years.
- The system cost is the present value of **capital costs, fixed costs**, **costs related to the output power** and **costs associated with the amount of energy used (energy costs)**. The later includes **costs of purchased fuel, electricity and heat as well as operation and maintenance costs.**
- The sum of all energy costs discounted to their present values is one part of the system cost.

System Cost

- The present cost of using the energy concerned during the year studied. The energy costs of each year are discounted to their present values and added. The sum of the discounted energy costs is:

  C.dfn

  C= Fuel flow[MW] the time period length per year Energy cost per MWh [Kr/MWh].

- dfn is discounting factor :
  $dfn=(1-(1+r)^{-P})/r$

Sweden’s Green Electricity certificate

- Sweden’s Green Electricity certificate scheme is a market-based support system to assist expansion of production of electricity in Sweden from renewable sources.The objective of the system is to increase the production of electricity from such energy sources by 25 TWh by 2020 (as compared with production in 2002). The scheme is intended to run until the end of 2035.

- Producers of renewable electricity receive one certificate unit from the state for each MWh of electricity that they produce. This provides an incentive to expand electricity production from renewable energy sources and/or using new technology. Demand for certificates is created by the fact that all electricity suppliers are required to buy certificates corresponding to a certain proportion (their quota) of their electricity sales or use.

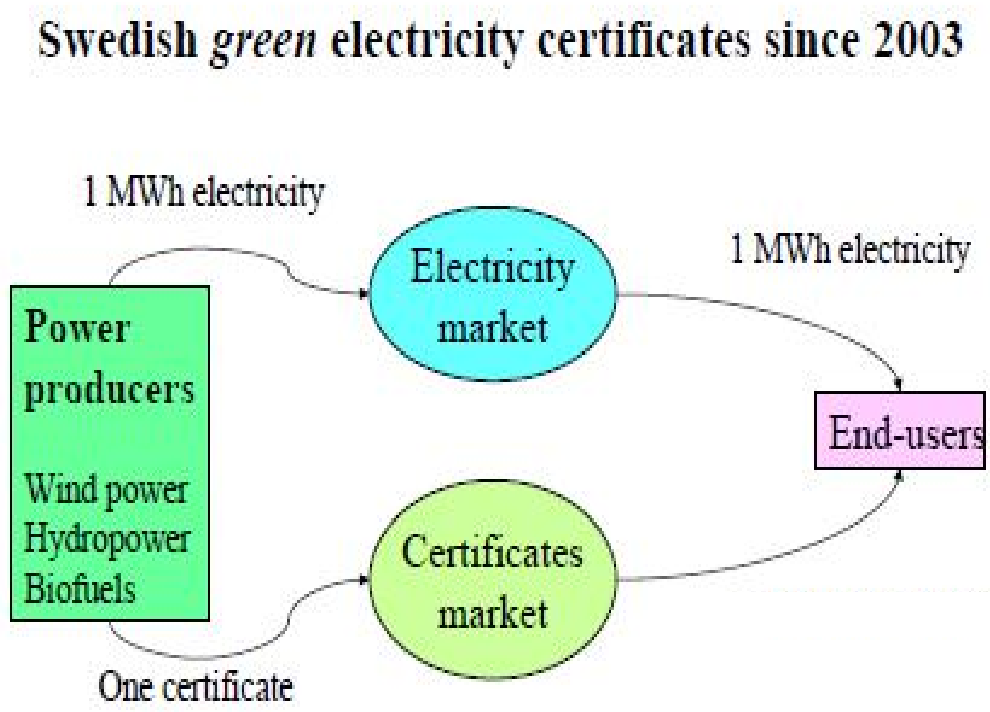
Sweden's Green Electricity certificate

- In 2009, users were required to buy certificates corresponding to 17.0 % of their electricity use.

- The price of certificates depends on the interaction of supply and demand on a c ompetitive market. Several factors affect the price levels, such as the expected demand for electricity. If the market is expecting, for example, a shortage of electricity, then the price of certificates will rise, and vice versa .

Policy instruments

Electricity certificates (250 kr/MWh renewble electricity, year 2010)



Simplified layout of the Green Electricity certificate system in Sweden.