PITAGORAS

Sustainable urban planning with innovative and low energy thermal and power generation from residual and renewable sources

D5.6: Financial models that best suit for the developed system demonstrated in Brescia pilot plant

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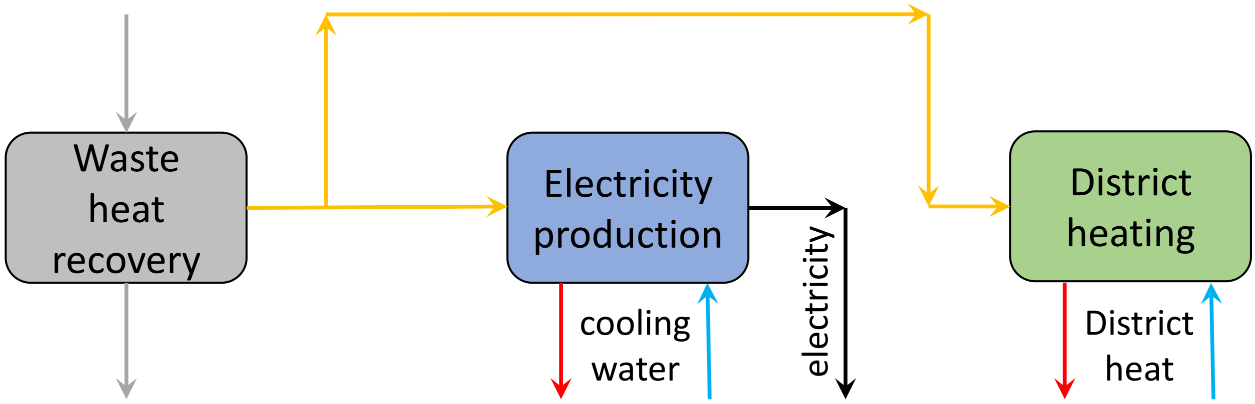

Figure 1: Block diagram of a waste heat recovery plant like the Brescia pilot plant

Figure 1 shows a simplified block diagram of the Brescia pilot plant and its three main functional blocks: the waste heat recovery from the flue gases of the electric arc furnace (EAF), the electricity production by means of a water cooled ORC-module which is only in operation during the summer period (mid-April – mid-October) and the district heating supply for the city of Brescia which is in operation only during the winter period (mid-October – mid-April). This constellation allows the production of district heat in winter, when it is needed and allows for a higher electric efficiency of the ORC-module in summer due to its water cooling on a lower temperature level compared to a CHP-unit where the waste heat of the condenser is fed to the district heating network on a higher temperature level.

Table 1 shows a summary of the cost and revenue structures of the three main functional blocks described above.

Table 1: Cost and revenue structures of the main units of the waste heat recovery system

Waste heat recovery	Electricity production	District heating
Cost structure		

• investment costs
• maintenance costs
• personnel costs
• operation costs
  ○ el. own consumption
• capital costs
	• investment costs
	• maintenance costs
	• personnel costs
	• operation costs
	  ○ el. own consumption
	• capital costs
		• investment costs
		• maintenance costs
		• personnel costs
		• operation costs
		  ○ el. own consumption
		• capital costs

Revenue structure		
• incentives for waste heat utilisation based on the EU-directive for energy efficiency (2012/27/EU)	• electricity sellings / savings (if used for own consumption)	• heat sellings

4. FINANCIAL MODELS

For the heat recovery system described in the section above, depending on the boundary conditions, many different financial models are applicable. The main difference between these models is the “cost-interface” i.e. who pays for different things e.g. investment, plant operation and who earns money in which way e.g. waste heat selling, selling of electricity and district heat etc. In the following paragraphs some of the possible combinations shall be summarized briefly.

In the following paragraphs the term industry describes the industry company with the waste heat available while 3rd party describes another company e.g. an energy service company (ESCo) which is independent from the industry partner.

Scenario 1: industry does it all

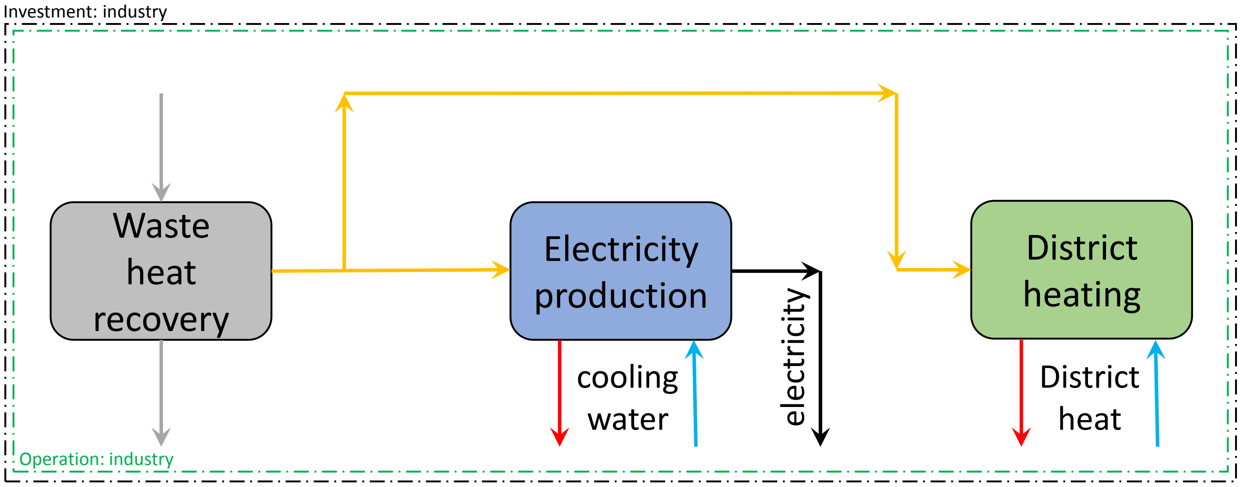

Figure 2: Investment and operation interfaces - scenario 1

In this scenario the industry with the available waste heat assumes the necessary investment for the whole waste heat recovery plant including the electricity and district heating production facilities. Further the staff as well as all other consumables necessary for running the plant are paid and taken care for by the industry. Also the sales of the produced electricity and heat to various utilities are handled by the industry and they get the respective revenues. The described interfaces are illustrated in Figure 2.

Scenario 1 represents the situation for the Brescia pilot plant. The waste heat recovery unit, the ORC-module for electricity production as well as district heating heat exchanger were invested (including funding by the PITAGORAS project) and are operated by ORI-MARTIN. The heat is then sold to the company A2A, who operates the district heating network of Brescia, in order to be distributed to the end consumer.

Scenario 2: 3rd party does it all

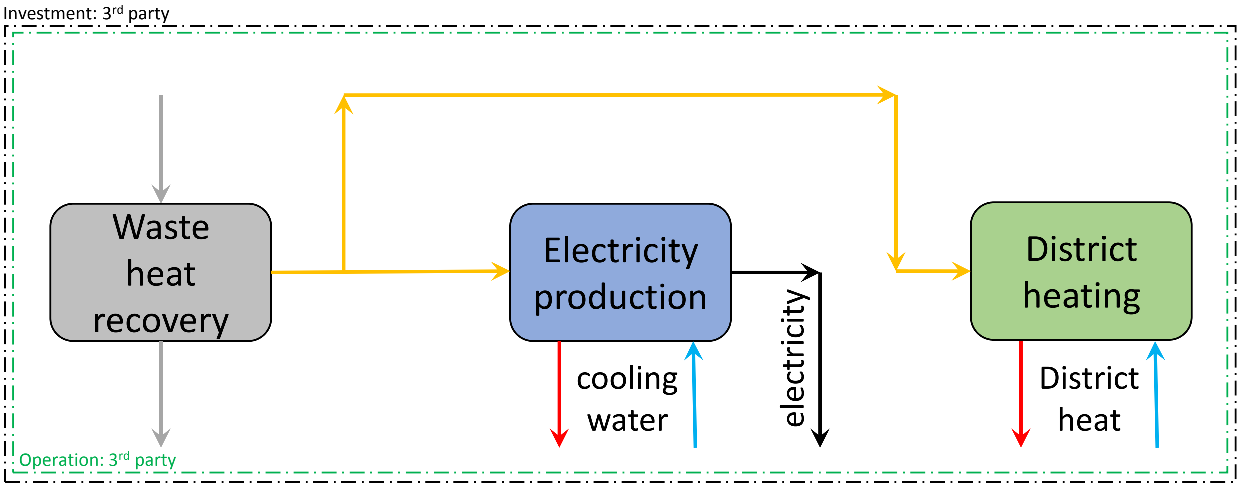

Figure 3: Investment and operation interfaces - scenario 2

Contrary to scenario 1 here all the investment as well as the operation of the plant are carried by a 3rd party (e.g. an ESCo - energy service company), see Figure 3 for the investment and operation interfaces. The industry only offers the waste heat as well as the real estate to build the plant into the existing process. The 3rd party then sells the produced electricity and heat. The industry gets a provision by the 3rd party for supplying the waste heat and the real estate. This provision may be based on the amount of waste heat used by the waste heat recovery (€/MWh waste heat) or some other model.

Scenario 3: Investment by industry but operation by 3rd party

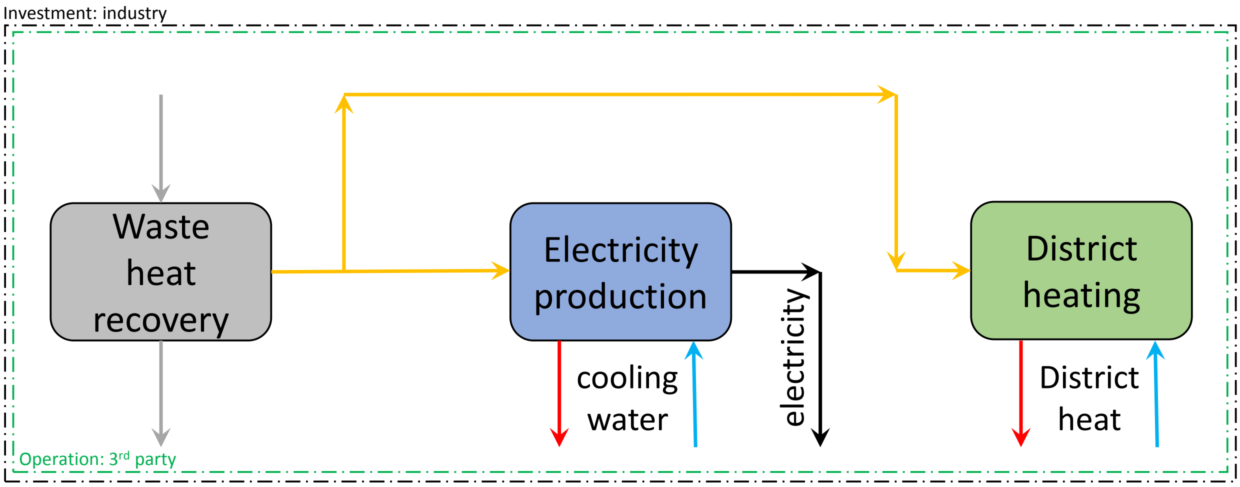

Figure 4: Investment and operation interfaces - scenario 3

This scenario is a mixture of scenarios 1 and 2. Here the investment for the whole plant is carried by the industry but the whole operation of the plant is done by a 3rd party (also 3rd party staff), see Figure 4 for a graphic representation. The 3rd party is responsible for the selling of the produced electricity and heat and pays the industry a provision for providing the waste heat as well as the plant infrastructure. Since the whole investment risk bears on the industry the provision in this scenario will be higher than in scenario 2 where all the risk is taken by the 3rd party.

Scenario 4: Investment and operation of the plant shared between industry and 3rd party

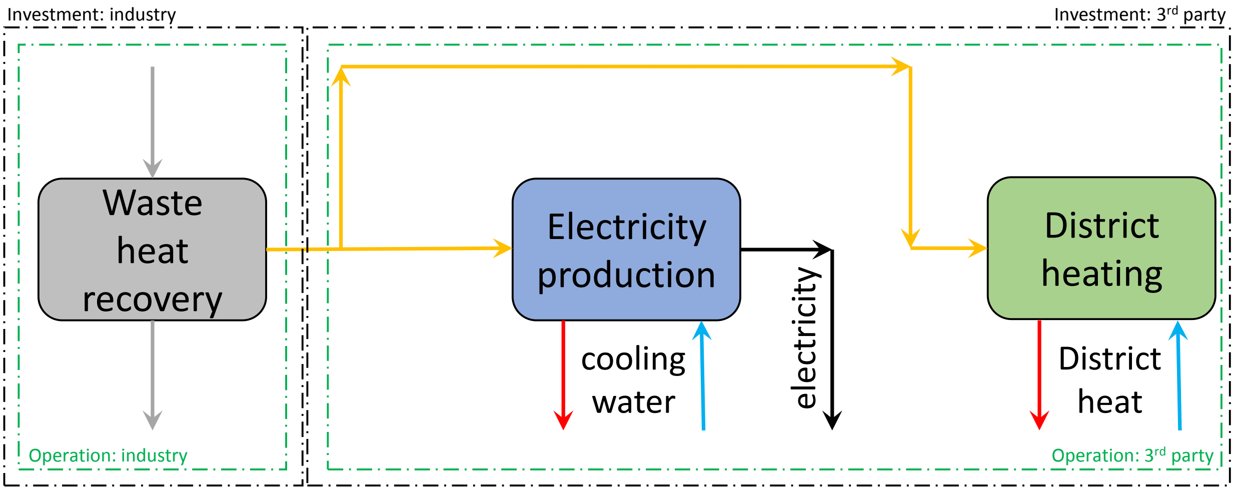

Figure 5: Investment and operation interfaces - scenario 4.1

In this scenario investment and operation of the waste heat recovery plant are split between industry and 3rd party. There are different possibilities for this interface, one is shown in Figure 5. In this example (scenario 4.1) the waste heat recovery system (heat exchanger / boiler and surrounding systems) is invested and operated by the industry while the systems needed for the usage of the recovered waste heat, i.e. the electricity and district heat production facilities as well as the selling of the produced energy are covered by a 3rd party. The real estate for the waste heat usage facilities may be provided by the industry or the 3rd part, depending on the circumstances (these would be defined in a contract). Similarly to scenarios 2 and 3 the industry receives a provision from the 3rd party for providing the waste heat and possibly the real estate.

For this scenario also other positions for the interface industry/3rd party are possible. For example the electricity production could be included in the industry side if the produced electricity shall be used within the plant and not sold to the utility as shown in Figure 6 (scenario 4.2).

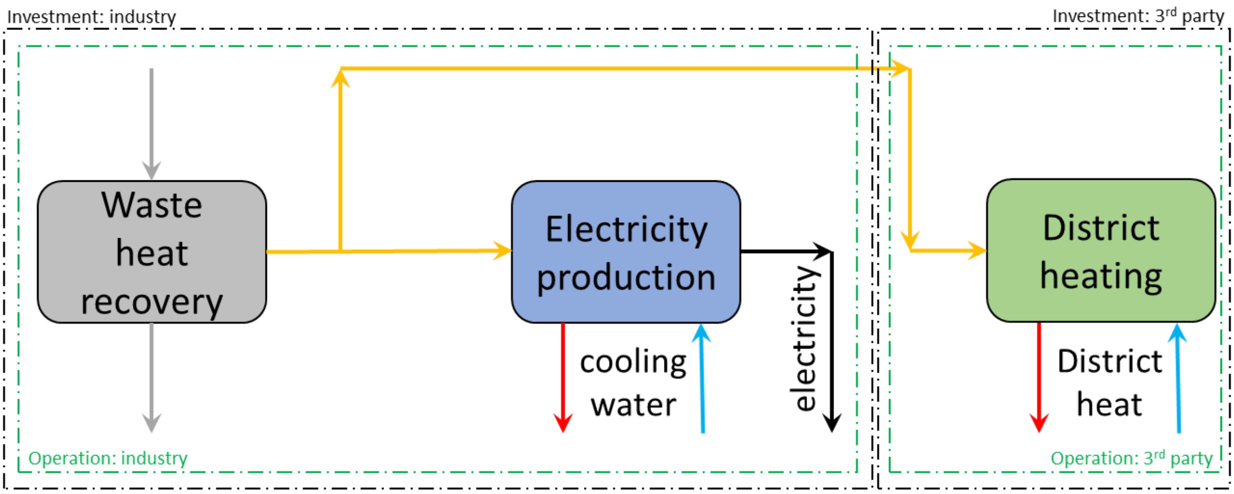

Figure 6: Investment and operation interfaces - scenario 4.2

Energy billing schemes:

In order to sell the electricity and heat produced from the industrial waste heat different billing schemes can be applied:

The electricity can either be used within the plant or sold to the utility. Here the price is dominated by the market or, if the local legislation supports it, a promoted feed-in tariff is available.

For selling the heat to the end-customer (like an ESCo would do it) the situation is different. Here a number of different billing schemes are available and are briefly described below.

Energy price only: the costumer pays a certain energy price per kWh of consumed energy. The energy is usually billed once every month or once every two month. This means that the payback for the ESCo works only by means of the energy sold. This scheme is generally favourable for the customer.

Energy price and basic price: Additionally to the cost per kWh, the customer is also charged a basic monthly price regardless of the energy delivered. In return, the energy price for the kWh of delivered energy is lower. This model provides some more security for the ESCo as it gets the monthly payments in any case.

Energy price and connection fee: Similar to the installation fees where a customer is charged for being connected to a district heating network, in this scheme the customer pays (some share of 100%) the installation cost of the system. This amount of money is often denominated a connection fee and may be calculated based on the kWh delivered per year. In return, the energy price for the costumer is reduced, so the ESCo needs to perform a very thorough economic feasibility calculation. Connection fee has to be paid once at the delivery of the plant.

Independently from the model chosen, a certain amount of money (penalty fee) should be agreed upon in the case the costumer wants to exit the energy supply contract before the agreed validity period of the contract.

5. EXEMPLARY ECONOMIC CALCULATIONS

In this section exemplary economic calculations for the scenarios described above are summarized.

The scenarios shall be viewed from the perspective of the industry and the 3rd party and shall give an overview how the different scenarios change the economic feasibility of the project.

The data in Table 2 is the calculation base for all scenarios and both perspectives shown below.

Table 2: Base data for economic calculations

Parameter	**Value**	**Unit**
waste heat input power	5	MW_{th}
electric output power of the plant	1	MW_{el}
thermal output power of the plant	5	MW_{th}
full load operating hours heat mode	3.500	h/a
full load operating hours electricity mode	3.500	h/a
share of engineering costs	15	% of total investment cost
share of maintenance costs	2	% of total investment cost
Specific investment costs waste heat recovery	800	€/kW_{th}
Specific investment costs ORC-module	1.000	€/kW_{el}
Specific investment costs heat production	150	€/kW_{th}
price for heat selling to district heating	25	€/MWh
price for electricity buying	90	€/MWh
price for electricity sales	35	€/MWh
labour costs	80	€/h

The absolute numbers and also the ranking of the scenarios presented below are highly dependent upon the applied parameters in parameters for the calculations.

5.1. INDUSTRY PERSPECTIVE

Table 3 shows parameters which were changed for the various scenarios. The differences in waste heat price are related to the effort for the industry in the relative scenario, e.g. the price for scenario 3 is highest because the whole investment risk is taken by the industry and the waste heat sellings are the only revenue stream. The electric self-consumption and person working hours vary throughout the scenarios since for the different scenarios different parts of the plant have to be operated by the industry.

Table 3: data for economic calculations changed for various scenarios

Parameter	Value for scenario					Unit
	1	2	3	4.1	4.2	
price for waste heat selling	-	2,5	9,0	8,0	8,0	€/MWh
el. own consumption	100	-	-	40	70	kW
person working hours	1.000	-	-	500	700	h/a

Table 4 shows a summary of the exemplary calculations for all five scenarios from the perspective of the industry. The table is divided into four sections: the investment costs, the costs caused by the plant (operation and maintenance), the revenues generated by the plant (selling of heat or electricity) as well as the economic result and resulting payback period.

According to the definition of the various scenarios the total investment varies between 0 € for scenario 2 to 6,6 Mio.€ for scenarios 1 and 3. The other scenarios are in between these values.

The plant operation costs are represented by costs for electricity own demand, for personnel and maintenance. They vary according to the separation between industry and 3rd party. In the scenarios 1 and 4.2, where the electricity production is operated by the industry, it was assumed that the electric own demand will be covered from the electricity production. Therefor the costs for electricity own consumption were set to 0 €/a and the electricity available for sale was reduced accordingly.

The revenues of the plant for each scenario are calculated according to the applicable revenue streams (selling of electricity, heat or waste heat). These parameters lead to the presented economic result and payback period, where a shorter payback period presents an economically more interesting project.

With the parameter set chosen for this exemplary calculations Scenario 1 leads to an acceptable payback period of about 14 years and an annual difference between revenues and costs of about 480.000 €/a. This scenario also benefits from the fact, that no further contracts with 3rd parties are necessary, which simplifies the project development. Scenario 2 only leads to a small revenue but does not require any effort at all. Scenario 3, where the whole financial risk of the investment is carried by the industry leads to a quite long payback period which does not make it very attractive. Scenarios 4.x, with the financial risk somewhere between scenario 2 and scenario 3 lead to even longer payback periods.

Table 4: exemplary economic calculations for the different scenarios – industry perspective

		Scenario 1	Scenario 2	Scenario 3	Scenario 4.1	Scenario 4.2
Investment						
Waste heat recovery	€	4.000.000	-	4.000.000	4.000.000	4.000.000
Electricity production	€	1.000.000	-	1.000.000	-	1.000.000
Heat production	€	750.000	-	750.000	-	-
Engineering	€	862.500	-	862.500	600.000	750.000
Total investment	**€**	**6.612.500**	**-**	**6.612.500**	**4.600.000**	**5.750.000**
Costs						
El. Own consumption	€/a	-	-	-	25.200	-
Personnel	€/a	80.000	-	-	40.000	56.000
Maintenance	€/a	132.250	-	-	92.000	115.000
Total cost		**212.250**	**-**	**-**	**157.200**	**171.000**
Revenues						
electricity sellings/savings	€/a	252.000	-	-	-	270.900
heat sellings to DH	€/a	437.500	-	-	-	-
incentives	€/a	-	-	-	-	-
waste heat selling	€/a	-	87.500	315.000	280.000	140.000
Total revenues	**€/a**	**689.500**	**87.500**	**315.000**	**280.000**	**410.900**
Revenues - Costs	**€/a**	**477.250**	**87.500**	**315.000**	**122.800**	**239.900**
Payback period	**a**	**13,9**	**-**	**21,0**	**37,5**	**24,0**

5.2. 3RD PARTY PERSPECTIVE

Table 5 shows the parameters varied for the various scenarios adapted for the 3rd party perspective of the calculation. The figures for the electric own consumption and the person working hours have been adapted according to which part of the plant are operated by the 3rd party in the different scenarios. Scenario 1 is not relevant for the 3rd party because there only the industry is involved

Table 5: data for economic calculations changed for various scenarios

Parameter	Value for scenario					Unit
	1	2	3	4.1	4.2	
price for waste heat selling	-	2,5	9,0	8,0	8,0	€/MWh
el. own consumption	-	100	-	60	30	kW
person working hours	-	1000	-	500	300	h/a

The total investment for the different scenarios varies between 0 € for scenario 3 to 6,6 Mio.€ for scenario 2. The other scenarios are in between these values.

The plant operation costs here are represented by costs for electricity own demand, for personnel, maintenance and the waste heat purchased from the industry. They vary according to the separation between industry and 3rd party. In the scenarios 2, 3 and 4.1, where the electricity production is operated by the 3rd party, it was again assumed that the electric own demand will be covered from the electricity production. Therefor the costs for electricity own consumption were set to 0 €/a and the electricity available for sale was reduced accordingly.

The revenues of the plant for each scenario are calculated according to the applicable revenue streams (selling of electricity or heat). These parameters lead to the presented economic result and payback period, where a shorter payback period presents an economically more interesting project.

With the parameter set chosen for this exemplary calculations Scenario 4.2 leads to a short payback period of about 4 years and an annual difference between revenues and costs of about 340.000 €/a. This scenario also only bears a minimal financial investment risk for the 3rd party since most of the plant is invested and operated by the industry. Scenario 4.1 shows a significantly longer payback period of around 11 years the financial risk is also higher since the electricity production is included. The scenario with the highest investment, scenario 2, also shows the longest payback period (28 years) and is therefore not economically attractive. Scenario 3, which has involves no investment by the 3rd party only yields about 8.000 €/a and is thus also not economically attractive.

Table 6: exemplary economic calculations for the different scenarios – 3rd-party perspective

		Scenario 1	Scenario 2	Scenario 3	Scenario 4.1	Scenario 4.2
Investment						
Waste heat recovery	€	-	4.000.000	-	-	-
Electricity production	€	-	1.000.000	-	1.000.000	-
Heat production	€		750.000	-	750.000	750.000
Engineering	€	-	862.500	-	262.500	112.500
Total investment	**€**	**-**	**6.612.500**	**-**	**2.012.500**	**862.500**
Costs						
El. Own consumption	€/a	-	-	-	-	18.900
Personnel	€/a	-	80.000	80.000	40.000	24.000
Maintenance	€/a	-	132.250	132.250	40.250	17.250
Waste heat	€/a	-	87.500	315.000	280.000	140.000
Total cost		**-**	**299.750**	**527.250**	**360.250**	**200.150**
Revenues						
electricity sellings/savings	€/a	-	98.000	98.000	107.800	-
heat sellings to DH	€/a	-	437.500	437.500	437.500	437.500
incentives	€/a	-	-	-	-	-
Total revenues	**€/a**	**-**	**535.500**	**535.500**	**545.300**	**437.500**
Revenues - Costs	**€/a**	**-**	**235.750**	**8.250**	**185.050**	**237.350**
Payback period	**a**	**-**	**28,0**	**-**	**10,9**	**3,6**

6. CONCLUSIONS

As described above different financial models can be applied when implementing a waste heat recovery plant for generation of electricity and district heat into an industry process. The scenarios differ from each other in the way how and by whom the investment and the operation of the waste heat recovery plant is accomplished.

One extreme is a scenario where everything (invest and operation of the whole plant) is done by the industry itself, the other extreme is a 3rd party doing everything. For the other scenarios investment and operation of the plant are somehow split between the industry and the 3rd party.

Which of the different scenarios is economically attractive is highly dependent on various boundary conditions which are different from project to project. For one set of boundary conditions the economic calculation results, both from the perspective of the industry and the 3rd party, were summarized above.

When evaluating the economic attractiveness of the various financial models the resulting payback period is one, but not the only indicator to be taken into account. Other important parameters are the annual profit (difference between cost and revenue) as well as the general risk of the investment. The annual profit is an indicator on how much money you will earn from the plant once you have reached the break-even-point for the investment.

If for example the scenario with the shortest payback time also presents the highest profit per year, this scenario is clearly the best choice. If on the other hand, a scenario which does not have the shortest payback period, has a considerably higher annual profit this scenario might be the better choice if the financial risk of the longer payback period is bearable.