'ENERGICENTRALEN'

A new combined plant serving Bjerringbro in Denmark with district heating and Grundfos with cooling for their machinery used in production of intelligent pumps

The plant seen from a public road in Bjerringbro.

The project is presented in May 2013 to

The Global District Energy Climate Awards

under category c) modernization of existing district energy scheme, including system parts

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Energicentralen

- a jointly owned district energy plant to the benefit of citizens and industry

Summary

Improvements of the local environment and a positive effect on the climate due to reduced CO_2 emissions are two important results of this project created by an equal partnership between *Grundfos* and *Bjerringbro Varmeværk* (DH Company). A third result is a reduction of the annual fuel costs.

Energicentralen is the jointly owned energy station hosting five compressors to co-generate heating and cooling. It is linked to a nearby Aquifer Thermal Energy Storage (ATES) used as a seasonal storage. *Energicentralen* is also connected to *Grundfos*' machinery via a new cooling network and to the CHP-plant and the DH-station via an existing heat transmission line.

The two partners have shared - one to one - the total investment of 4.48 mill. €. Also the savings achieved are equally shared so that each partner will save 200,000 € annually. The pay back period will be less than 15 years and the annual reduction of CO_2 emission will be about 3,700 tons.

The plant performs as follows:

- 3,500 MWh of cooling based on 9° C groundwater will during four months in the summer be supplied by from the ATES and will cover the full demand in the machinery connected.
- 10,500 MWh of cooling will during 8 months be supplied by the cooling machinery in Energicentralen, which will cover the full cooling demand and the re-cooling of the groundwater.
- 13,400 MWh of district heating will be produced yearly by heat from the cooling machines.

Bjerringbro Varmeværk was founded in 1959 and today has 2,100 consumers (buildings) with an annual production of 90,000 MWh. The new plant will cover some 15% of the annual demand. The original boiler station from 1959 was designed for operation on oil but has later on been converted to operate on natural gas. In 1994 a CHP-plant based on natural gas engines was added, and in order to achieve flexibility between power and heat generation, a heat storage tank was installed. In recent years, heat pumps were installed to cool and condense the water in the flue gases in order to increase the heat production.

The project demonstrates that the innovative solution was created by virtue of the open and equal cooperation between the two partners. It turned out quite early in the planning process that each of them alone was not able to realise savings to the same extent as achieved jointly.

See video: https://www.youtube.com/watch?v=P6E_D3hBnj0&feature=youtu.be

1. Introduction

Improvements of the local environment in Bjerringbro (in Viborg Municipality) and a positive effect on the climate due to reduced CO_2 emission are two important results of this project created by an equal partnership between *Grundfos* and *Bjerringbro Varmeværk* (The local DH Company).

A third result is a reduction of the annual fuel costs. As the DH-company is operating on a non-profit basis, the consumers get a lower heating bill. A further consequence of the project is that Grundfos has outsourced the operation and maintenance of the cooling machinery to the DH-company.

2. Energicentralen

The link between the two partners is the new and jointly owned *Energicentralen.* This energy station consists of five compressors to co-generate heating and cooling, and it is designed to use the nearby Aquifer Thermal Energy Storage (ATES) as a seasonal storage via a new pipe connection. *Energicentralen* is also connected to *Grundfos*' workshops via a new cooling network, to the CHP-plant and the DH-station via the existing heat transmission line.

The two partners have shared the investment 1:1 so that each of them have invested 16.8 mill DKK (2.24 mill €). The two partners have also shared the savings equally, so that each of them will save 1.5 mill DKK annually (200,000 €) on energy spent.

The pay back period of the total investment of 34 mill. DKK will be less than 15 years.

Fig. 2.1 is a schematic illustration of the overall system. As it can be seen, cold water for cooling is supplied at 6° C and 12° C. District heating is supplied at app. 70° C with the return temperature around 40° C. The use of these relatively low temperatures contributes to the fairly high COP-values for heating (COP 4.6) and for cooling (COP 3.6) and in combined operation COP 8.2.

2.1 The Aquifer Thermal Energy Storage

The ATES consist of five wells through which 1,500,000 m^3 of ground water is circulated per year or 160 m^3 per hour. The temperature in the storage is 9° C, and the cooling capacity is 1.5 MW.

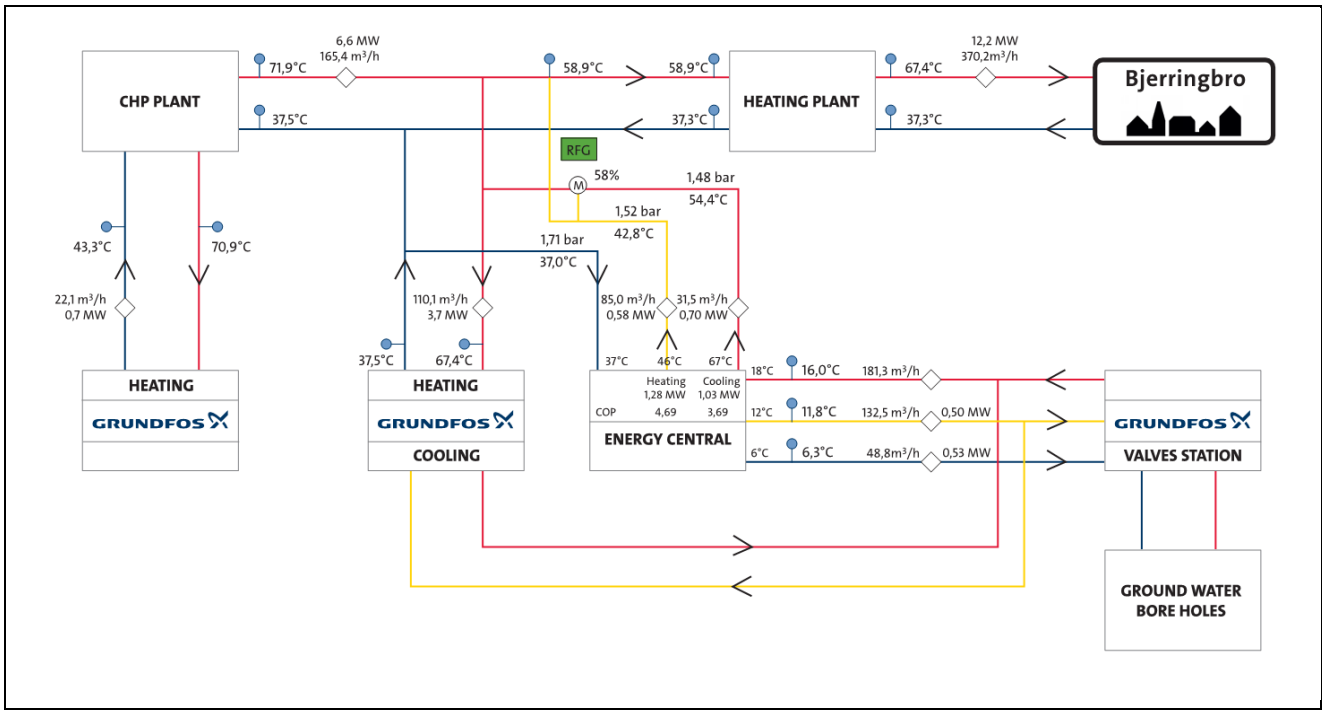

Fig. 2.1 Presentation of the total plant including production and storage facilities and consumers of heating and cooling.

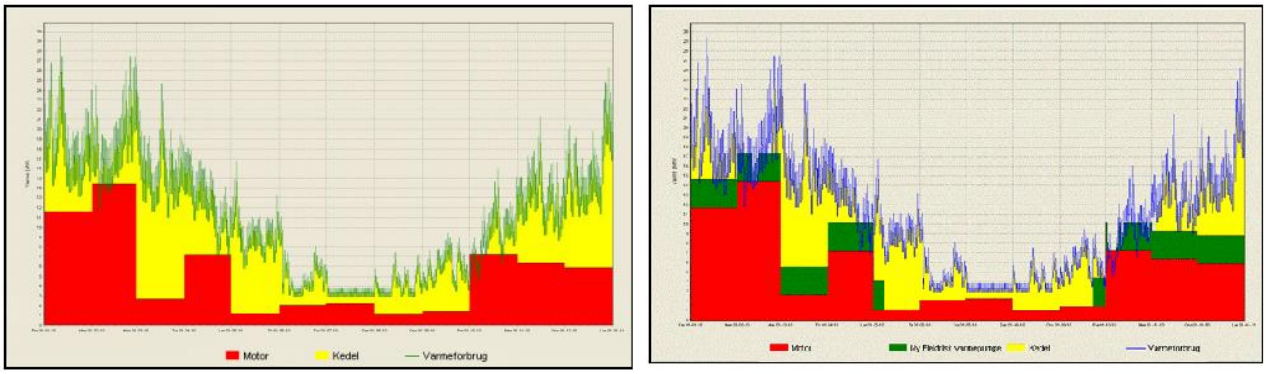

Fig. 2.2. The two graphs shows the composition of heat loads by separate production (left) and joint production (right). The red colour indicates the operation of the CHP-plant, the yellow colour is operation of the N-gas boilers. On the graph to the right, the heat contribution from compressors and heat pumps (green) can be seen replacing part of the boiler operation.

Bjerringbro Varmeværk is responsible for the operation of the plant and the networks and delivers cold water for the cooling needs to the factory from *Energicentralen,* while heat from compressors and heat pumps is used for generation of district heating.

During four summer months, the cooling needs are covered by the 9° C water from the ATES. For the operation in the remaining eight months, cooling is provided by cooling compressors and heat pumps, while the surplus heat from their condensers is used for district heating.

During the first four months of operation in 2013, the data shown below have been documented.

2013	Generated heat MWh	Generated cooling MWh	COP heating	COP cooling	Consumed electricity MWh
January	643,0	488,3	4,43	3,37	145,0
February	692,0	547,2	4,96	3,92	139,6
March	606,0	467,5	4,81	3,71	125,9
April	881,6	678,0	4,50	3,46	196,1
Period	2822,6	2181,0	4,65	3,60	606,6

Fig. 2.3 Performance of Energicentralen through January-April 2013

For the future, the plant will perform as follows:

- Cooling based on groundwater will during four months in the summer deliver 3,500 MWh. This amount will cover the full demand in the machinery connected to the system
- Cooling based on compressors will during eight months deliver 10,500 MWh, which will cover the full cooling demand in this period and the re-cooling of the groundwater.
- Heat generation based on cooling machines is 13,400 MWh, which will cover the heat demand in 750 homes or some 15% of the total heat generation at Bjerringbro Varmeværk
- The annual reduction of CO_2 emission will be 3,700 tons.

It should also be mentioned that Energicentralen is frequency controlled and designed for completely open valves. Accordingly, all thermal adjustments are carried out, by speed controlled pumps. As a result, pressure drop across the valves have been completely eliminated and replaced by energy savings.

3. District Heating in Bjerringbro

3.1 History and plant configuration

Bjerringbro Varmeværk was founded in 1959 and today has 2,100 consumers (buildings) with an annual production of 90,000 MWh. A large part of the town benefits from cheap environmental friendly district heating, which is also delivered to the offices and workshops of Grundfos. Also most public buildings are supplied.

The original boiler station from 1959 was designed for operation on oil but has later on been converted to operate on natural gas. In 1994 a combined heat and power plant based on natural gas engines was added, and in order to achieve flexibility between power and heat generation, a heat storage tank was installed. In 2009 an additional storage tank was installed.

In 2007 a heat operated absorption heat pump was installed at one unit in the CHP-plant. The purpose of this addition was to cool and condense the water in the flue gas of the machine in

order to raise the total output. In 2010, for the same reason, an electrically driven heat pump was installed in the boiler station and in 2011 another electrically driven heat pump was installed in a second unit of the CHP-plant.

Now that Energicentralen has been taken into operation, the break down of the heat generation counting 90,000 MWh pr. year is as follows:

- 15 % will be covered by heat pumps and cooling machines in Energicentralen
- 10 % will be covered by the heat pumps in the CHP-plant and the boiler station
- 45 % will be covered by the CHP-plant based on Natural gas
- 30 % will be covered by natural gas operated boilers.

3.2 Distribution network

The DH distribution network was expanded and gradually maintained and renovated since the beginning in 1959, and today covers most of the town area. The system has from the start been a traditional Danish type with flow temperatures around 80° C and return temperatures around 40° C. Over the years, the flow temperature has been lowered. It is now controlled by an online system according to actual demand and weather prognoses, and therefore the flow temperature fluctuates around 67.5° C. The return temperature is depending on the house internal installations and also varies according to consumption.

The total DH network can be seen on fig. 3.1. The total length of the system is 68 km.

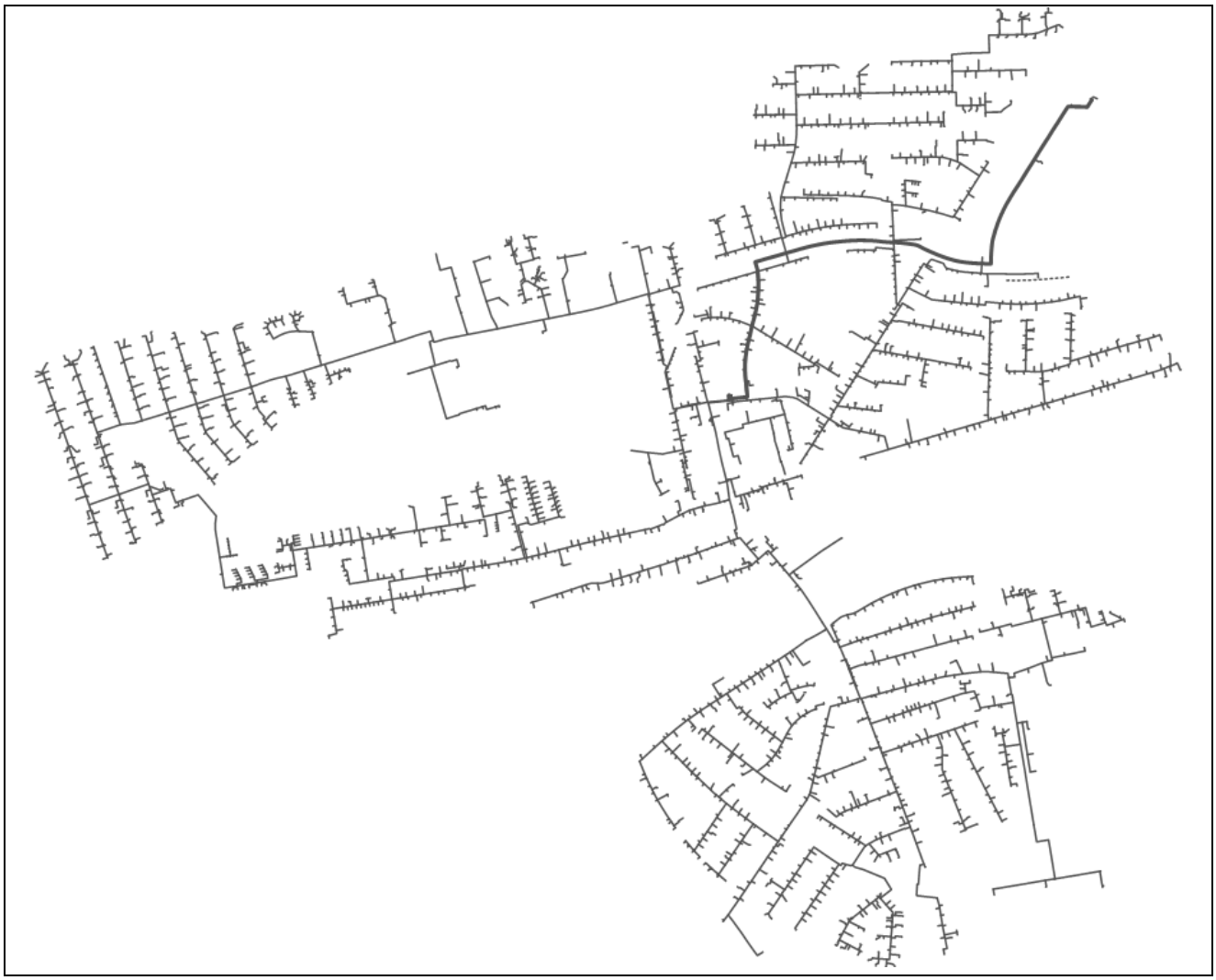

Fig. 3.1 The configuration of the DH network in Bjerringbro. The thin lines show the distribution network, which is directly connected to the consumers. The thick lines show the transmission line connecting the CHP-plant, Energicentralen and the boiler station.

It is not obligatory for the house owners to connect to the system, and for that reason not every house is connected. However, the great majority (70 %) do take district heating, and for that reason the network covers most of the town area. Totally 630,736 m^2 of floorage is connected.

4. System energy efficiency

Improved efficiency in respect of both energy consumption and emissions to the environment has very high priority at Bjerringbro Varmeværk and Grundfos.

As a public regulated energy supply company, Bjerringbro Varmeværk has to meet demands set up by the energy authorities. When new initiatives are taken focus is on use of energy, emissions to the environment and the economy in respect of society, business and customers. In addition, annual targets for lowering energy consumption have to be met.

Therefore, in 2011 calculations of energy efficiency, greenhouse gas emission reductions and other environmental benefits were calculated according to Danish legislation and was approved by the municipal authorities in Viborg Municipality. Please find the outputs of these calculations in below.

It should be mentioned at this place that the actual results achieved have proven to be better than data calculated at the early planning stage. Therefore some of the figures mentioned above do not comply exactly with below figures.

4.1 Energy and environment

The change of fuel consumption during the future 20 year project period (defined acc. to Danish rules) can be seen below.

Concept	Past: Separate generation	Future: Joint generation in Energicentralen
Type of energy used	Natural gas MWh	Electricity MWh
Generation in boilers Power consumption heat pumps Saved power in Grundfos' cooling towers	280,193 0	0 80,000 - 110,526
Total fuel consumption	280,193	- 30,526

Fig. 4.1. Energy consumption calculated during the 20 years project period.

It can be seen that the change from individual operation of production plants for district heating at Bjerringbro Varmeværk and cooling at Grundfos to joint generation of heating and cooling in Energicentralen result in direct reductions of the energy consumption. The reason for this is that the exploitation of surplus heat for DH-production replaces production at the gas fired boilers and the power consumption to run the former dry coolers of the compressors at Grundfos.

The numbers in fig. 4.1 indicates the amount of natural gas and electric power used in the two cases. In this figur the actual fuel spend to provide electric power is not specified. In fig. 4.2, the fuel consumption involved has been taken into account, and the emissions have been calculated accordingly.

Emissions	Natural gas tons	Power consumption tons	Difference tons
CO_2 and CO_2 equivalents	- 57,226	- 9,430	- 66,657
SO_2	- 0	- 6	- 6
NO_X	-42	-15	- 57
$PM_{2,5}$	- 0	0	0

Table 4.2. Change of emission during 20 years.

It is to be seen that the new plant entails reductions of CO_2, SO_2 and NO_x.

4.2 Economic effects

It is part of Danish energy legislation that a project must present savings of the cost to the society in order to be approved. The calculations have been done according to the conditions given in the rules of April 2011. In these rules also the methodology and the values to be used are specified.

Society economy calculated as net present value during the 20 year project period	
- Continuation of former separate generation - Joint generation in Energicentralen	- 71.2 mio. DKK - 6.2 mio. DKK
Difference	65.0 mio. DKK (approx. 10 mio. €)

Fig. 4.3. Achieved savings in costs to the society

As can be seen, there is a clear saving to be achieved during the project period.

Also the economics of the supply company involved must be calculated. In this case a graph showing the costs pr. produced MWh during the 20 year period is shown.

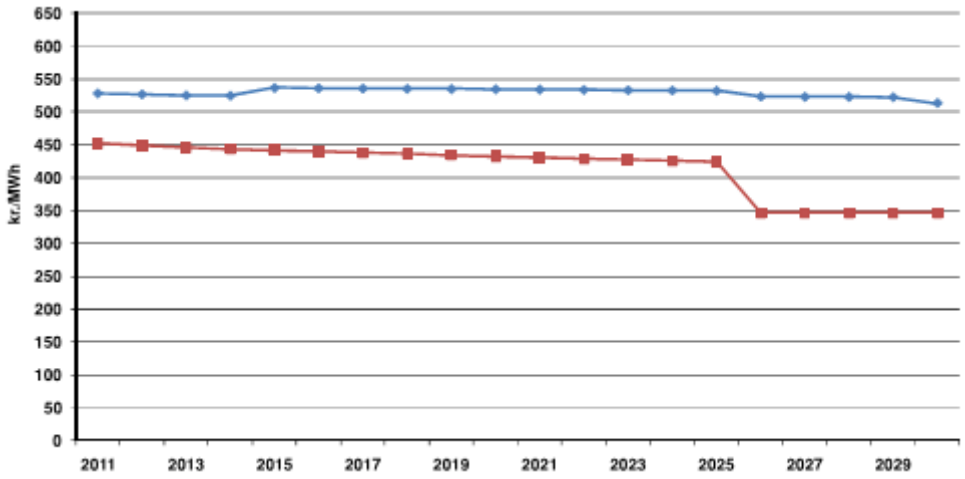

Fig. 4.4 Costs pr. produced MWh.
The blue line indicates the costs/MWh produced in separate plants
The red line indicates the reduced cost by joint generation.

It is seen that the curve for joint generation steps down after 15 years of operation. This is the point, when the investments have been paid back completely.

The economic consequence to the customers of district heating is also a point of interest. In this connection, there are clear savings in the annual costs, and as the economy towards the customers is governed by the principle of non-profit operation, any saving in the operation costs,

must be given back to the consumers in the shape of a lower price for heat. The amount of energy saved corresponds to app. 15 % of the previously used energy, and therefore the consumer prices will be deducted with this share.

In addition to above described calculations and results, it is part of the legislation that also a number of sensitivity analyses must be carried out. The results of these analyses are not mentioned in this paper.

4.3 Grundfos

Grundfos has formulated the following commitments in a Climate White Paper:

1. We will take our own medicine and never emit more CO_2 than we did in 2008
2. We will invest in innovating new sustainable products and solutions
3. We will continue to develop an organisation with a culture of sustainability
4. We will influence the global climate agenda and position Grundfos as a true global player
5. We will communicate our progress and provide full transparency

Since 2008, the CO_2 emission decreased by 6 percent and the energy consumption decreased by percent. During the same period, Grundfos' sales increased by 10 percent.

Energicentralen started to contribute to these goals by the beginning of December 2012.

5. Innovation and replicability

First of all this project demonstrates that the innovative solution was created by virtue of the open and equal cooperation between the two partners. It turned out quite early in the planning process that each of them alone was not able to realise the same fine results as established jointly.

Seasonal storing of thermal energy is an important issue in the district energy industry these years. This project is therefore a remarkable show case of how it is possible to exploit considerable amounts of surplus heat stored during summer and cooling energy stored during winter. In this way the partnership has provided a fine balance in need for district heating and industrial cooling.

According to the best knowledge of *Bjerringbro Varmeværk* and *Grundfos,* there are no other similar plants combining and balancing an industrial need for cooling of machinery with district heating by means of heat pumps and compressors and use of seasonal storage.

Bjerringbro Varmeværk and *Grundfos* are convinced that local partnerships will be able to create similar combinations of district heating plants and industry in many other cities that needs heating and cooling. The possibilities to make use of ATES or other ways to store hot or cold water in the ground or on the surface are possible many places.

Important is the will to cooperate!