Small is beautiful

In Denmark's smaller CHP installations, all electricity produced is used in-house *Credit: Jan de Wit*

Denmark has recently seen a growing number of cogeneration units installed in care homes, sports centres, schools and other municipal buildings. These installations have shown many annual operating hours, short ROI and significant CO_2 savings. Jan de Wit looks at how they do it.

The cogeneration installation potential for supplying heat to Denmark's district heating grids is almost covered, as up to 80% of the heating in these grids can be supplied from cogeneration. Energy prices and the spark spread between electricity sales on the open market and gas price has led to a decline in new installations of this kind and in the annual operation hours for these units.

However, a rapidly increasing number of smaller cogeneration units have now been installed in Denmark. These units are installed in institutions, sports centres, retirement homes, schools and other municipal buildings. They are installed and controlled in such a way that no electricity is exported, as export is not as valuable as production for in-house use. All electricity produced is, therefore, used in-house and will reduce the bill for grid power. The spark spread between the value of electricity and gas is 2–2.5 including taxes on both electricity and natural gas for this segment of customers. Electrically driven heat pumps may also be installed to include sustainable energy in heat production and to make it possible to influence in-house electricity consumption.

By doing so, a high number of annual operating hours can be obtained for the cogeneration unit, leading to simple payback times less than five years, and sometimes down to two years.

The system layout

The system layout of the installations often consists of a number of cogen units, heat storage units and – if adaptable – an electrical heat pump, the latter most frequently of the air/water type. A boiler is used for peak heat supply (see an installation layout example in Figure 1).

The key to successful operation and many annual operating hours for the cogen units is the load management control system and a feasible hydraulic connection. These key items are shown in Figure 1.

SCANIA

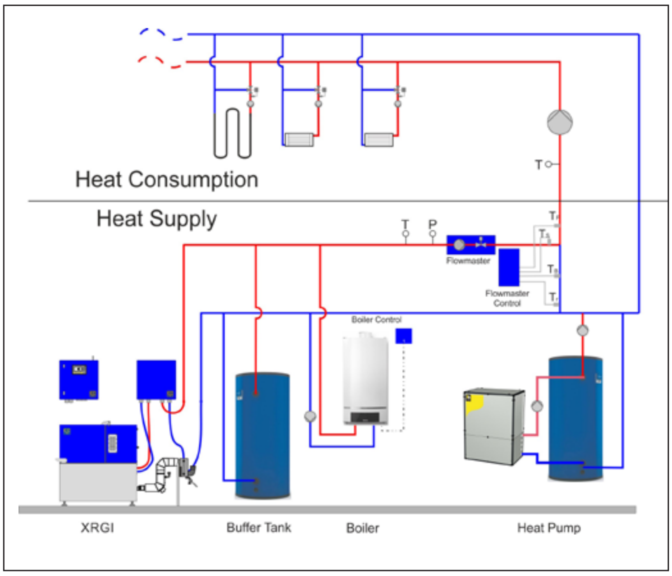

Figure 1. An example of a typical system layout, showing the cogen unit, a heat pump, heat storage units and the necessary controls for creating optimal working conditions for the installation. A peak load boiler is also seen.

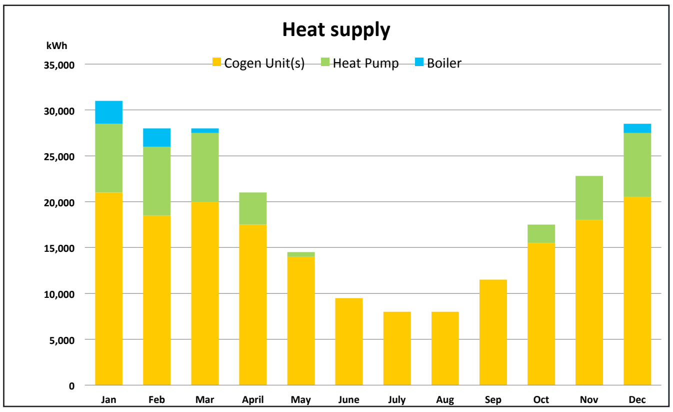

Figure 3. The heat production and the origin of the heat on a monthly basis over a year for a sports centre.

The hydraulic connection box is called Flowmaster in Figure 1.

Figure 2 shows an installation where three cogen units are installed at a sports centre. This installation also includes a heat pump, for which the heat source is outdoor pipes in the ground and humid ventilation outlet air from the indoor swimming stadium.

Planning, sizing

The better the available information regarding annual, monthly and possible daily heating and electricity needs, the better the sizing of the units, the necessary heat storage, etc. To give the shortest payback time, a high number of annual operation hours for the unit/units should generally be obtained. Most of these installations have obtained over 7000 annual operating hours for the cogen units.

The units should operate in cogeneration mode only to achieve the highest fuel efficiency, and no power-only operation mode should occur. If the electricity export is not favourable (or allowed), part-load operation might be made in periods.

If there is a power need and enough capacity in the heat storage tanks, full-load operation is preferred; surplus heat can be stored in the heat storage tanks. Typically, a heat storage capacity of 25 or 50 litres/kWe is used.

The in-house electrical power need can be influenced by installing an electrical heat pump system in connection with the CHP unit/units. By doing so, sustainable energy is included in the heating supply.

In Figure 3, the annual heat production from the various production units in such an installation is shown.

Figure 4 (see next page) shows a Sankey diagram with the energy flows during operation of both the cogen unit and the heat pump. It can be seen that, due to the inclusion of the heat pump, more energy (electricity and heat) is supplied to the building than is supplied by the gas.

Figure 2. An installation with three cogeneration units (20 kWe each). This installation also includes a heat pump (not shown in the picture) and four storage tanks with a total volume of 3500 litres.

Huge potential

There is a huge technical installation potential for such small cogeneration units. Examples of heating stations where they could be or are being used are:

- Schools;
- Sports centres;
- Museums and other institutions;
- Health care centres for the elderly;
- Office buildings;
- Hotels/conference centres;
- Hospitals;
- Municipal buildings.

The concept/units might also be used in multi-family houses or heating blocks. Often, such places have a joint in-house heating grid, but do not have a joint in-house power distribution system after the meter. If symmetrical power sale-and-buy tariffs are used and no other costly barriers exist, the electricity produced could be exported and immediately re-imported at no economic loss. This would yield the same payback time as if the electricity produced was being distributed in-house.

Business models

There are multiple business models for 'upgrading' a heating-only station to include mini-cogen units and possibly also heat pumps:

PRIVATE OWNERSHIP

The owners themselves invest, operate and request (or contract) the service and repairs needed. The risk connected with possible repairs is on the shoulders of the owner. However, service

ZEECO

The cogen unit (20 kWe)		
Electrical output	kWe	20
Heat output *	kW	40/43

The heat pump unit (63 kW), example		
Heat output	kW	63
Electrical power input	kW	18
COP, annual average	(-)	3,5
Investment cost[1])	Euro/kWth	525[1])

*Including installation costs

Installation type	Number of CHP units (-)	Including heat pump?	CO_2 saving (tonnes/ year)
Retirement home	2	No	31 – 80
Primary school	2	Yes	57 – 83
Sports centre	1	Yes	29 – 45
Folk high school	1	No	17 – 39

Figure 5. CO_2 savings from four different Danish installations. The calculation is made with a reference to natural gas-fired boiler heating. If oil had been used as reference, the savings would have been higher. The span given for the CO_2 saving is due to whether the average number for CO_2 emission or a number representing marginal fossil based power-only plants is used for the electricity production substitute.

contracts are offered by the unit suppliers, including also unforeseen events.

EQUIPMENT LEASE

This kind of lease lowers initial investment costs, but makes little difference compared to the private ownership described above. Seen over a lifetime, equipment investments will be higher, as revenue to the leasing company must be included in the monthly leasing payments.

ESCO MODEL, ETC

Third-party ownership (energy distributors, suppliers, ESCOs etc) and operation in designated areas will give the building owner less investment and economic risk for the installation. Third-party professional ownership means a potential for lower service and repair costs, as logistics can be negotiated and optimised as a kind of fleet management. For the building owner this means low investment.

Key performance and financial figures for the cogen unit and a typical heat pump as shown in previous illustrations can be found in the fact boxes above.

CO_2 savings

CHP as a production principle generally leads to reduced primary energy and, therefore, CO_2 savings compared to separate production of power and heat.

The CO_2 savings obtained related to the in-house produced electricity (= the reduced purchase from the grid) can be calculated based on the average national CO_2 emission figures per kWh. For Denmark, this average CO_2 emission figure is approximately 450 g/kWh. This figure includes non-polluting electricity production from wind turbines, solar panels and so on. which will hardly be substituted by the power production from the CHP units. It is much more likely that production from less efficient, larger traditional power-only production units will be substituted first. This marginal figure could be as high as 750 g/kWh for power supply in Denmark.

The CHP units have an additional natural gas consumption compared to a heat-only production. The CO_2 emission from this should, of course, be taken into account, leading to reduced savings.

Examples of calculated CO_2 savings based on actual production numbers at a number of Danish installations are shown in Figure 5.

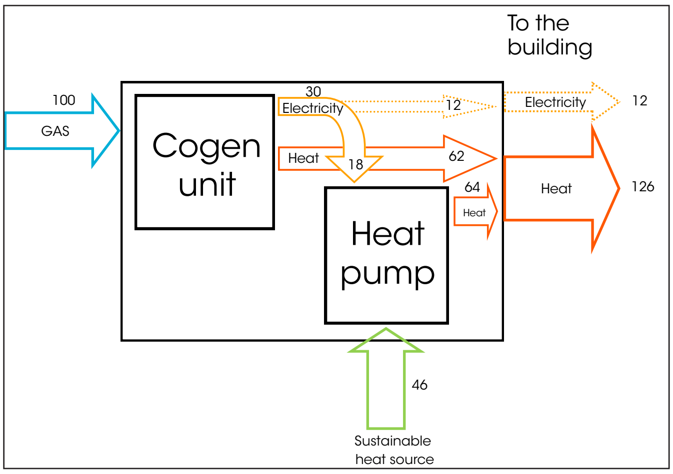

Figure 4. Sankey diagram of the energy flows during operation of both the cogen unit and the heat pump.

Significant development

Analyses and the plants erected have shown that a short return of investment (ROI) can be achieved by installing mini-cogen units in countries and installation segments with relatively high energy prices and a favourable spark spread between electricity and gas. The installations erected in Denmark have shown many annual operation hours, short ROI and significant CO_2 savings, as shown in the article.

Many of the plants installed include heat pumps, which also paves the way for a successful integration of gas and renewables. And as gas gets greener (biogas injection, syn-gas, etc) this will make the complete project even greener.

Financing of the projects can be done by ESCO partners. By doing so, the customer has no need for entry costs. If the supplier offers various service contracts, the operational and related economic risk for the customer can also be minimised, if desired.

A key to successful installation, operation and achieved ROI is well-adapted equipment, well-proven planning tools, remote monitoring/surveillance and a short response time for service and maintenance.

The vital key to optimal planning and sizing is customer knowledge of heat and electricity needs over the year, as well as typical patterns of daily electricity need. Modern digital meters can be of great help here.

Significant development of all these issues along with product improvements and lowering costs has been seen over the last five to 10 years, leading to a rapid increase in the actual number of installations.

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