ST-4 Polygeneration plant

Parc de l’Alba
Cerdanyola del Vallès
POLYCITY project

Energy supply in Parc de l’Alba

District Heating and Cooling network

ST-4 Polygeneration plant
Production of electricity and heating
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POLYCITY project

The objective of the POLYCITY project, financed by the European Commission’s initiative CONCERTO (VI Framework Programme), is to reduce the consumption of fossil and non-renewable fuels by means of:

- Measures to reduce the energy demand of buildings.
- Improvement in the energy efficiency of energy production and supply systems (polygeneration).
- Increase in the use of renewable energy systems.

The research undertaken in the framework of the project focuses on using technological innovation to save energy. In this regard, simulation processes are used to optimise energy production and to improve the design of buildings. POLYCITY supports various aspects of the urban development of three European cities: new buildings and the polygeneration system in the Directional Centre of Cerdanyola del Vallès (Barcelona), the rehabilitation of the Arquata district of Turin, and new buildings and the improvement of supply in Scharnhauser Park, a former military zone near Stuttgart.

POLYCITY’s innovation in these three urban areas is managed by the various regional partners who ensure that the results are effectively exploited and disseminated. The purpose of this leaflet is to present the first polygeneration plant installed in the Directional Centre of Cerdanyola del Vallès. For further information, please contact the Directional Centre Urban Development Consortium.

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Energy supply in Parc de l’Alba

The Polycity project is taking place in a 340-hectare site in Cerdanyola del Vallès. It will finally have a roof area of 1,890,000 m², a residential area for 15,000 inhabitants and an activity area that will create 40,000 jobs. A high efficiency energy system is to be implemented in the new urban development called Parc de l’Alba (formerly known as the Directional Centre), in order to produce electricity, heating and cooling. This polygeneration system will comprise high efficiency natural gas cogeneration plants with thermal cooling facilities and a district heating and cooling network to connect the plant with the Science and Technology Park, the core of Parc de l’Alba.

Parc de l’Alba will include a Science and Technology Park with the Synchrotron Light Facility (ALBA) as well as residential buildings. The polygeneration plant ST-4 will provide electricity, hot and chilled water for the Synchrotron and the technological park buildings through a four-pipe district heating and cooling network. The development is managed by the “Consorci del Centre Direccional”, consisting of the city council of Cerdanyola del Vallès and the “Institut Català del Sòl”. The foreseen DHC network and the polygeneration plants the following distribution:
The Parc de l’Alba in Cerdanyola del Vallès will be developed in several stages in line with the pace of the urban development:

**Phase I:** construction of an energy production plant ST-4 in the technological park, to supply energy to the Synchrotron Laboratory (ALBA) and other users of the park (442,700 m² office space and 62,000 m² facilities). This stage was completed in July 2010. The ST-4 will use a district heating and cooling network to provide hot and chilled water simultaneously.

**Next phases:** enlargement of the ST-4 plant and construction of three new energy supply plants (ST-2, ST-3 and ST-5).
District Heating and Cooling network

District heating and cooling (DHC) is an integrative technology that can significantly reduce emissions of carbon dioxide and air pollution and increase energy security. The fundamental idea of DHC is to connect multiple thermal energy users through a piping network to environmentally optimum energy sources. The ability to assemble and connect thermal loads enables these sources to be used in a cost-effective way. DHC is important for implementing cogeneration because it extends the pool of potential users of recovered thermal energy beyond the industrial sector to include commercial, institutional and multi-unit residential buildings. In Cerdanyola’s Parc de l’Alba new urban development, a District Heating and Cooling network will be implemented within the Science and Technology Park, which represents the core of Parc de l’Alba, as well as the commercial area and some of the public and private equipment buildings.
The residential area has not been included in the DHC network, since its demand profile does not justify the additional investment required. As a result, the DHC network will cover heating and cooling demands of a total floor area of above 1.63 million m². This network, as a part of the Cerdanyola polygeneration system, has been designed according to criteria of maximum availability and modularity, and it will be connected to 4 cogeneration plants that will supply both hot and chilled water. The total length of the network will be 32.6 km.

The implementation of the first stage of the district heating and cooling network has already been finished. It is a 4-tube network with diameters ranging from DN150 to DN800. It interconnects two cogeneration plants with all the land plots of this stage of urban development (around 600,000 m² of built surface) and has a total length of 15.3 km.

The design temperatures are as follows:

Chilled water: supply 6 ºC, return 13 ºC

Hot water: supply 90 ºC, return 75 ºC

Regardless of the district network, specific interconnecting pipelines have been designed to meet the requirements of the Synchrotron Light Laboratory. The Synchrotron building has been connected directly to ST-4 polygeneration plant, with the following pipelines:

Chilled water: DN500 (508/630 mm) pre-insulated pipe, with diffusion barrier and built-in surveillance system. Total length: 770 m

Hot water: DN150 (168/250 mm) pre-insulated pipe, with diffusion barrier and built-in surveillance system. Total length: 770 m
ST-4 Polygeneration plant

This facility, which simultaneously produces electricity, hot and chilled water (known as a polygeneration power plant), provides service of exceptional quality and reliability and is therefore the main supplier of power to the Alba synchrotron. Generating power near the supply point avoids the significant energy loss of traditional systems during transport from large power plants to the many points of use. Additionally, the facility can supply a significant part of the demand for hot and chiller water by using residual energy, the heat given off during the production of electricity.

Local generation and distribution of energy allows for much higher levels of energy efficiency, close to 86%, which is well above the levels achieved using traditional systems. This system reduces the use of primary energy sources and CO₂ emissions by up to 27%.

The main installations in the plant are:
- 3 cogeneration engines, of 3.35 MW each.
- 2 absorption chillers.
- 1 natural gas boiler.
- 1 electrical compression chiller.
- 1 chilled water storage tank that enables the plant to shift demand peak loads.
- A cooling tower

ST-4 energy services

- Natural gas
- ST-4 Polygeneration plant
- Electricity
- Hot Water up to 95 °C
- Chilled Water 6 °C
- District Heating and Cooling
- Cooling 37-30 °C
- Cooling tower
Production of electricity and heating

Cogeneration engines

The cogeneration engines are the main units of the ST-4 plant. The engines driven with natural gas produce electricity and heat (in the form of hot water and exhaust gases) that can be used to supply the heating demand and/or to produce cooling by means of absorption chillers. The high efficiency of these engines ensures the maximum energy efficiency of the input fuel.

Currently the ST-4 polygeneration plant has three Jenbacher JMS 620 cogeneration engines. The nominal electrical capacity of each engine is 3,354 kW with a recoverable thermal energy of 3,102 kW (approximately). The electrical efficiency is 45% and the total efficiency is 86.5%. The number of engines installed can be increased from three to five as the amount of surface area increases, so the electrical output of the ST-4 (10 MW) can be increased to 16 MW.

<table>
<thead>
<tr>
<th>Energy performance for each engine (rated)</th>
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<tbody>
<tr>
<td><strong>Natural Gas</strong> 7553 kW</td>
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<tr>
<td><strong>JMS 620 Engine</strong></td>
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<tr>
<td>1350 kW exhausts gases</td>
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<tr>
<td><strong>170 kW</strong></td>
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Natural gas boiler

A natural gas boiler producing hot water up to 95 ºC has been installed as a backup, for peak demand periods or for periods of low energy demand. The hot water produced is injected directly into the district heating network. The gas burner capacity of the boiler is 5MW with a 90% efficiency.
Production of chilled water

The heat produced by the cogeneration engines can be used to supply the heating demand or to produce cooling by means of absorption chillers. At present the ST-4 plant has installed two absorption chillers: a double effect absorption chiller driven directly by exhaust gases, and a simple effect absorption chiller driven by the hot water produced in the cogeneration engines.

Double effect absorption chiller

The Thermax ED 80C CX absorption chiller has a capacity of 5 MW and it is fired directly with the exhaust gases of the cogeneration engines. It has a high efficiency (COP = 1.3) and ensures good energy recovery from the exhaust gases. A second double effect absorption chiller also driven with exhaust gases and with a cooling capacity of 3 MW is foreseen as the demand grows.

Exhausts gases from the engines

DE Absorption Chiller

COP = 1.3

5028 kW
13-6.5 °C
661 m³/h

8898 kW
30-37 °C
1075 m³/h

Chilled water

Cooling tower

Energy performance for DE Absorption chiller (rated)

Thermax ED 80C CX double effect absorption chiller
Simple effect absorption chiller

The simple effect absorption chiller produces chilled water using the hot water obtained from the cogeneration engines. This absorption chiller has an efficiency of COP = 0.75. A second simple effect absorption chiller with a nominal cooling capacity of 2 MW is foreseen as the cooling demand grows.
Compression chiller

The purpose of the compression chiller is to produce cooling in peak demand periods when the capacity of the absorption chillers is not enough. A cooling capacity of 5 MW and a second compression chiller with the same characteristics is foreseen as the demand grows.

Energy performance for the compression chiller (rated)

Compression chiller
Carrier 19XR8587

Cooling storage system

An underground chilled water storage tank has been installed to enable the plant to shift demand peak loads. The tank can hold up to 4,000 m³ meaning 7 MW for 2.5 hours with a temperature difference of 6°C. A plate heat exchanger is used to charge or discharge the tank to the cooling network.

Charge-Discharge operation of the cooling storage system (bottom temperature of the tank during five days)
Cooling tower

The cooling towers dissipate the heat from a water stream at low temperature (37-30 °C). All the heat produced in the oil refrigeration circuit of the engines, the condenser/absorber of the absorption chillers and the condenser of the compression chiller is dissipated in these cooling towers.

Due to the operational characteristics of the absorption chillers, the cooling towers are indispensable if these chillers are to operate properly. The use of cooling towers to refrigerate the compression chillers means that they work at higher efficiencies than conventional applications.
A complete control system has been installed to ensure the reliability and security of the whole plant. The mass flow rate and the temperature for all the input and output streams of each unit are monitored so that the performance of each unit can be calculated individually. Several calculations are performed in order to calculate the efficiencies and the primary energy consumptions.
Monitored temperatures of the absorption chiller during five days

The control system enables the production of energy (electricity, heating and cooling) to be calculated for the whole plant and for each unit. The primary energy consumption and the overall efficiency is calculated for the whole plant, as are the efficiencies of each unit.
Energetic analysis including future extensions

An energy analysis has been carried out for all the units envisaged (including future extensions) and the energy demand expected in 2014, so that the demands of the full operation of the plant can be taken into account. The objective of this energy analysis is to assess the energy savings of the polygeneration system with respect to conventional supply systems. The main units considered are listed below:

- 5 Jenbacher JMS 620 cogeneration engines
- 2 double effect absorption chillers
- 2 simple effect absorption chillers
- 2 compression chillers

Annual energy demand:
- Electricity: 32.7 GWh
- Heating: 17.0 GWh
- Cooling: 73.6 GWh

Foreseen annual energy flow for 2014 considering the ST-4 plant
The energy analysis was carried out bearing in mind the expected operational conditions of the engines and optimizing the operation of the rest of the plant in order to maximize the economic benefits. Considering this hypothesis, half the electricity produced is exported to the grid and the rest is used to supply the electrical demand of the Synrotron Alba and other plant utilities.

Taking into account the electricity exported to the grid (43.7 GWh/year), the net primary energy consumption is 105 GWh/year.

The polygeneration system can be compared with a conventional system in order to assess the potential in energy savings. In the conventional system a highly efficient combined cycle is considered for the separate production of electricity (electrical grid) and individual boilers and compression chillers to produce heating and cooling, respectively.

In comparison to the conventional system, the polygeneration system can save up to 27% of primary energy and CO₂ emissions.

**Foreseen annual energy flow for 2014 considering the conventional system**

- **Natural Gas**
  - 19.0 GWh
  - For heating demand 17.1 GWh

- **Combined Cycle**
  - Electricity 26.7 GWh
  - Compression Chillers
  - Cooling demand 77.4 GWh

- **Natural Gas**
  - 119 GWh
  - Combined Cycle
  - Electrical demand 32.7 GWh
ST-2 Renewable plant

Besides the ST-4 polygeneration plant, more energy plants are planned as the energy demand grows. One of these, the ST-2 plant, uses renewable sources to produce electricity and chilled water.

The ST-2 plant is currently at the engineering stage and consists of a solar cooling plant and a biomass gasification plant.

Biomass gasification plant

In the biomass gasification process, the biomass is converted into a gaseous fuel, the major components of which are carbon monoxide and hydrogen. The gas produced is used as a fuel for a cogeneration engine and is usually contaminated with tar and dust that should be removed first. The electricity produced can be sold to the grid and the heating (hot water and exhaust gases) is used to drive an absorption chiller to produce cooling. The gasification plant is planned to have a capacity of 1,000 kg/h of biomass, which will provide an electrical output of 1 MW.
Solar cooling plant

The ST-2 plant has been planned to include a solar cooling plant. Combining thermal solar energy with thermal cooling equipment produces solar air-conditioning systems. These systems have the great virtue of satisfying the maximum cooling demand when most solar energy is available: i.e. in summer. They are used as a source of renewable energy that reduces the use of fossil fuels and consequently CO₂ emissions.

In Parc de l’Alba a solar thermal plant with a surface area of 1600 m² is to be constructed with flat plate solar collectors. These collectors will be connected to adsorption chillers that have a thermal output of 600 kW and which will provide 700 MWh of cold water at 7 °C to be distributed by the district heating and cooling network.
2nd European Conference on Polygeneration
Technologies and perspectives

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www.polygeneration.net