LOW-ENTHALPY POWER GENERATION WITH ORC-TURBOGENERATOR THE ALTHEIM PROJECT, UPPER AUSTRIA

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INTRODUCTION

Altheim is a municipality in the Upper Austrian "Inn-region" with 5000 inhabitants and encloses an area of about 22 km^2. The budget on a yearly base is about 6,300,000 Euro (5,670,000 US$). The decision to construct a geothermal heat supply, for environmental reasons, was made by the municipal council in January 1989.

The district heating system is fed by 106ºC geothermal fluid flowing from an aquifer about 2300 m deep. Since 1989, efforts were undertaken by the municipality to supply 10 MWe of thermal heat to a district heating network. In order to keep the water balance in the Malm aquifer, a injection drill hole was required. The new idea was to use the income from power production to finance the injection drill hole. A binary cycle or Organic Rankine Cycle (ORC) turbo-generator was proposed.

The main contractor and operator for the installation is the Marktgemeinde of Altheim. The Altheim project is challenging from the ORC point of view, both because of the low temperature of the heat source and the fact that the well head and the turbogenerator are placed within the town, near the town hall. Hence, very efficient silencing is required and the use of a flammable working fluid was excluded for safety reasons. As a working fluid, a harmless fluorocarbon was selected instead. A total power of 1000 kWe was generated during the test run, and it is presently operating at about 500 kWe.

The ORC is cooled by the water from a nearby canal. After use, the geothermal water is pumped back at a temperature of 70ºC to the deep geothermal Malm-aquifer, allowing a sustained exploitation of the system. As a result, the balance of the water in the Malm reservoir is maintained.

HEAT SUPPLY/PRODUCTION DRILL HOLE/SUPPLY NETWORK

The production borehole was drilled in 1989. After two months, the water bearing Malm was encountered at 2300 m depth. The artesian flow rate was finally 46 L/s, at a temperature of 104ºC. Thus, the desired heat distribution of 2500 kWe was possible. The expenses for the first drill hole amounted to 1,450,00 Euro (1,305,000 US$).

Presently, about 650 consumers are connected to the heat supply, with a thermal power load of 10,000 kWt. About 40 % of the inhabitants of Altheim live in buildings that are connected to the heat supply. The supply network has a length of about 14.5 km. The biggest single consumer are municipal facilities with about 1000 kWt thermal power (school, gymnasium). The majority of the supplied buildings are one- and two-family houses.

The fee for the heat supply is 39.39 Euro (35.45 US$) per MWh. To create a demand for the consumer to be connected to the heat supply, the contract conditions in 1989 were made consumer friendly; since, almost exclusively a fix temperature difference of 30ºC was charged. The real temperature difference is greater, thus the consumers pay less per MWh. Meanwhile the community is in a better position, as the increasing demand made it possible to create more favorable conditions for them (the new consumers are charged for the actual supplied energy). The calculated 1500 operating hours per year in 1989 could not be obtained, as the actual number is about 1200.

The use of geothermal energy for heat supply led to a significant reduction of air pollution and greenhouse gas in the community area as well as an immense saving of fossil fuels, as shown below.

Comparison of 1989 and Present State

	1989	Present State	Reduction
CO_2	11,150,000 kg	3,094,000 kg	72%
NO_2	8,000 kg	2,600 kg	67%
SO_2	32,200 kg	11,200 kg	65%
CO	411,000 kg	173,000 kg	58%
Fossil Fuel Savings: 2,500 t/year			

REINJECTION DRILL HOLE/CONSTRUCTION OF THE POWER PLANT

In order to keep the water balance in the water bearing limestone of the Malm, authorities were ordered to inject the geothermal water. The question was how to finance this second drill hole. Since incomes for the district heating were not sufficient, new possibilities had to be found.

Then in 1994, a project of geothermal power generation was developed. The power output from the very first design was calculated at 240 kWe–not enough to finance a drill hole; thus, a new concept had to be developed.

A minimum production rate of 100 L/s had to be achieved to produce electrical power of 1 MWe.

As the costs per MWh without fundings were calculated to 140 Euro (126 US$), a proposal for additional financial support by the Commission of the European Communities was combined with three other project partners.

A funding level of 35% was granted by the Commission. With additional funds from the local government of Upper Austria and the federal government of Austria, the project was completely financed. Negotiations with the local energy supplier "Energie AG - Oberösterreich" followed. Liberalization of the energy market leads to a decreasing reimbursement of the generating costs--but nevertheless an appropriate financial contribution of the energy utility also helped in this case. With that, an economic operation of the power plant by the municipality was then ensured. In 1998, the drill bit went downward once more--40 m away from the first drill hole.

In order to reach the geothermal water bearing layer at a horizontal distance of 1700 m, the drill hole had to be deviated from the vertical. This technically ticklish operation started at a depth of 460 m. The drill bit had to be guided several times into the right direction. The deviation operation was performed by Becfield Drilling Services.

After eight months of drilling, the final depth was reached. With a total length of almost 3100 m, the drill hole reached the target at 2200 m depth--the white treasure in the Malm karst of the Molasse Basin. The horizontal distance between starting and ending point of the drill hole is 1700 m.

Hydraulic tests showed that hot water with 100 L/s at a temperature of 93ºC could be produced. The same rate can also be injected.

According to the planning, the first well was used for production and the second drill hole as the injection well. The geothermal water is produced by a high temperature downhole pump which is installed at a depth of 290 m.

A Rankine turbogenerator was constructed by Turboden in Brescia, Italy. To obtain a high efficiency of the binary cycle, the working parameter of the turbogenerator had to be well adapted to the flow rate and temperature of the produced water. The working fluid had to be non toxic, as there must be no danger of explosion and it should also not affect the ozone layer in any way. A suitable fluid was found by Turboden, a harmless “Fluorocarbon.” The thermal water heats up the working fluid in a heat exchanger. The fluid evaporates at relatively low temperatures of 28-30ºC. As steam, it drives the turbine. The vaporized medium is cooled down, condensed and then once again, continues its way through the closed turbine cycle.

After using the heat of the geothermal water, it is injected into the underground at a temperature of 70ºC. By this measures, the balance of water in the Malm reservoir is maintained.

The ORC plant was installed in spring/summer 2000, and first tests started in September 2000. Due to insufficient purification of the cooling water (taken out of a creek), the

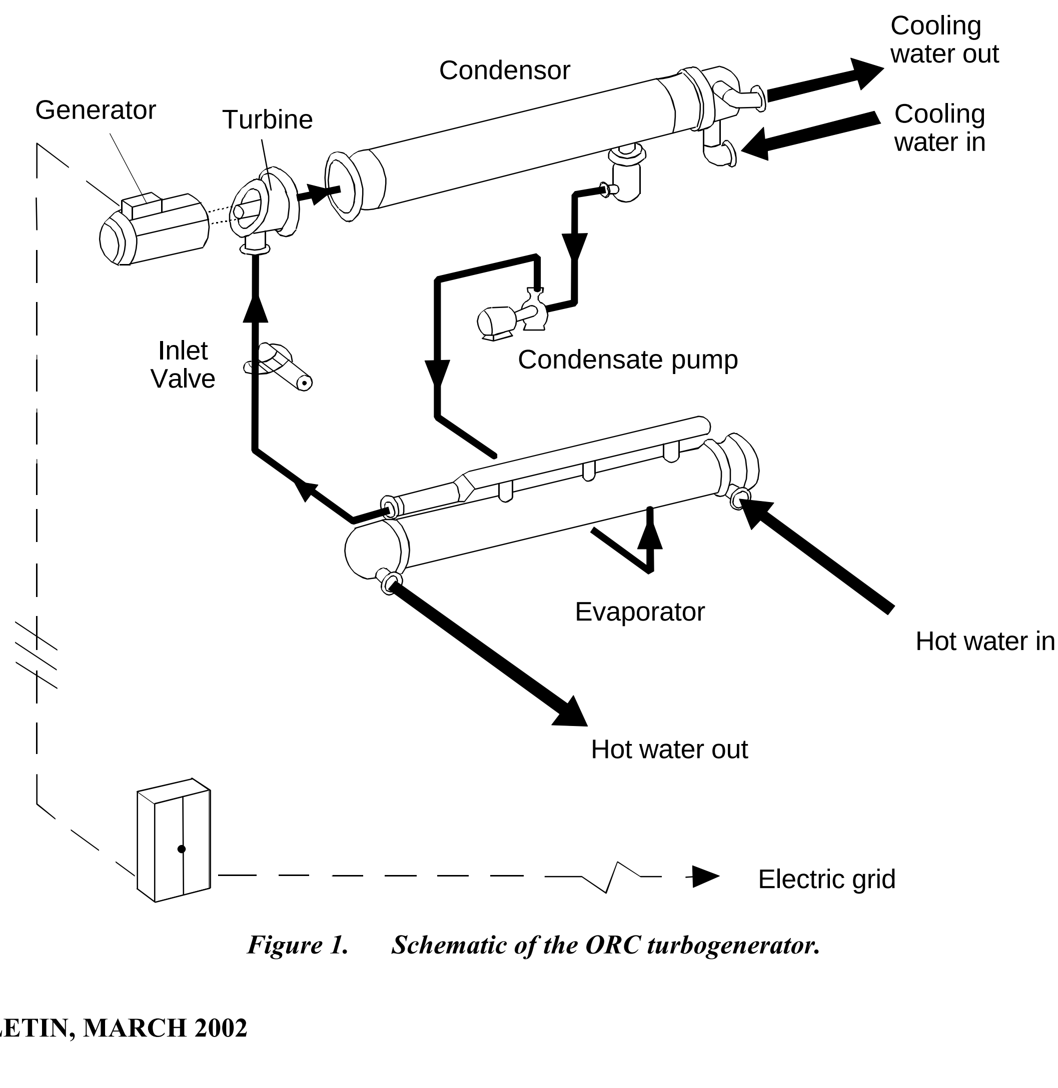

Figure 1. Schematic of the ORC turbogenerator.

Table 1. Altheim ORC Turbogenerator Performance Data Sheet

Geothermal water inlet temperature:	106 ºC (223 ºF)
Geothermal water outlet temperature	70 ºC (158ºF)
Geothermal water flow rate:	81.7 kg/s (1,295 gpm)
Cooling water flow rate (about):	340 kg/s (5,389 gpm)
Cooling water inlet temperature:	10 ºC (50ºF)
Cooling water outlet temperature:	18 ºC (64ºF)
Electric generator:	synchronous,.low voltage
Net electric power output:	1,000 kW

Table 2. Expenses for the Project

Electricity power plant	1,580,000 EURO (1,422,00 US$)
Reinject. drillh. / Completion prod. drillh.	2,117,000 EURO (1,905,000 US$)
Underwater product.- / Inject.- installation	378,000 EURO (340,000 US$)
Further expenses	436,000 EURO (392,000 US$)
Total expenses	4,511,000 EURO (4,060,000 US$)

Table 3. Yearly/Production Costs (Due to the funding of the European Commission, the continuous expenses could be reduced to the following numbers)

Yearly costs	349,861 EURO (315,000 US$)
Production costs per MWh	91.47 EURO (82.32 US$)

Table 4. Input Tariff per kWh (fixed price guaranteed for 15 years)

		ATS*	EURO**	US$
Winter -	High rate	0.72	0.0523	0.0445
Winter -	Low rate	0.607	0.0441	0.0397
Summer -	High rate	0.473	0.0344	0.0310
Summer-	Low rate	0.421	0.0306	0.0275

* ATS = Austrian Schilling (1US$ = 15.4 ATS)

** 1 EURO = 0.90 US$

plant was shut down after a short time. After installation of additional filters in the cooling water system, the plant started operation again in January 2001. At this time, the highest capacity of the plant was 1027 kWe.

Unfortunately, after a few days the plant had to be shut down again. The reason was damage to some of the turbine blades. After changing of all turbine blades, the plant was restarted at the beginning of March 2001.

During the following period, the plant had good performance–the capacity to the public grid was more than 500 kWe (peak 564 kWe).

In April and May, problems emerged again–both in the condenser and the turbine. The aproximately 5,000 copper pipes in the condenser were changed and the turbine was fitted with new blades (a reduced number with a modified shape).

Since December 2001, the plant has been in operation again. The highest capacity to the grid was 414 kWe. The current thermal water flow rate is about 85 L/s–up to half of it goes to the district heating. After winter when the demand of the district heating systems is decreased, the capacity to the grid can be increased up to 500 kWe.

To improve the clarification of the cooling water, an automatic flushing filter system will be installed in the next months.

Since January 2001, the following quantities of power have been supplied to the grid.

Period	kWh_e	Max. Capacity in kWe
January 2001	40,907	545
March 2001	132,694	545
April 2001	115,103	564
May 2001	99,67	530
December 2001	64,818	360
January 2002	171	414

About 63% of the gross power production of the plant is supplied to the grid of the electricity company Energie AG Oberösterreich. The remaining power is used for the submersible pump, the pump to increase the pressure in the injection borehole, the cooling water pumps and other auxiliaries. The submersible pump is also necessary to maintain a stable operation of the district heating; otherwise, other pumps in the central station have to be used.

The floor space requirement is very low. The heating plant with a thermal capacity of 10 MWe needs only 70 m^3. Both well heads of the two drill holes require 50 m² each, and the power house requires some 230 m^3.

The general planning of the integration of the turbogenerator system into the district heating grid was carried out by Geotec Consult from Markt Schwaben in Bavaria. The staff of Geotec Consult was also responsible for the design and supervision of the drill hole.

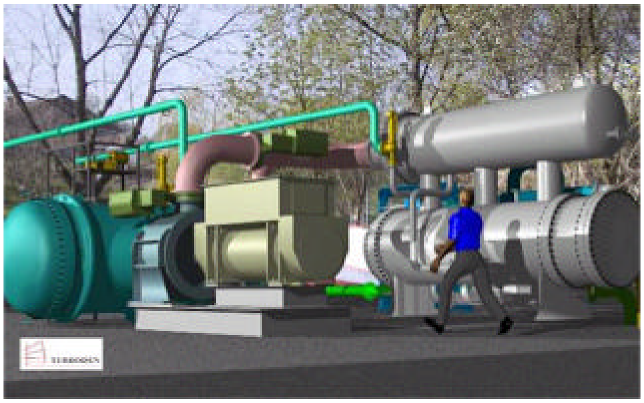

Figure 2. ***ORC Turbo Generator Without Housing Nearby the Townhall of Altheim****.*

The first geothermal power generation from low enthalpy resources in Middle Europe is complete. Only geothermal energy is the one which is independent from climate and can be used all year and is capable of supplying base load energy.

With this contract and tariff concept it will be possible to run the geothermal station for heat and power in the municipality of Altheim economically.

ACKNOWLEDGMENTS

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Figure 4. ***Well 1A with pump house.***

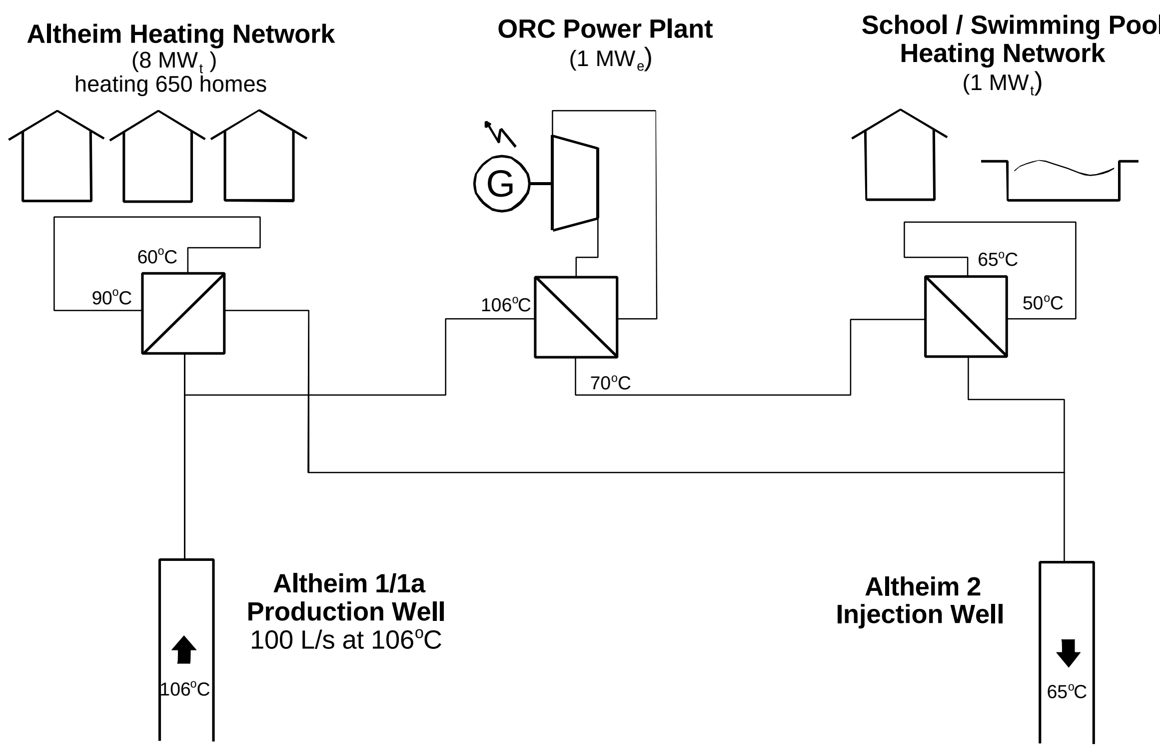

Figure 3. ***Schematic of the power plant and district heating system.***

Figure 5.		*ORC turbine.*

Figure 6.		*ORC generator.*

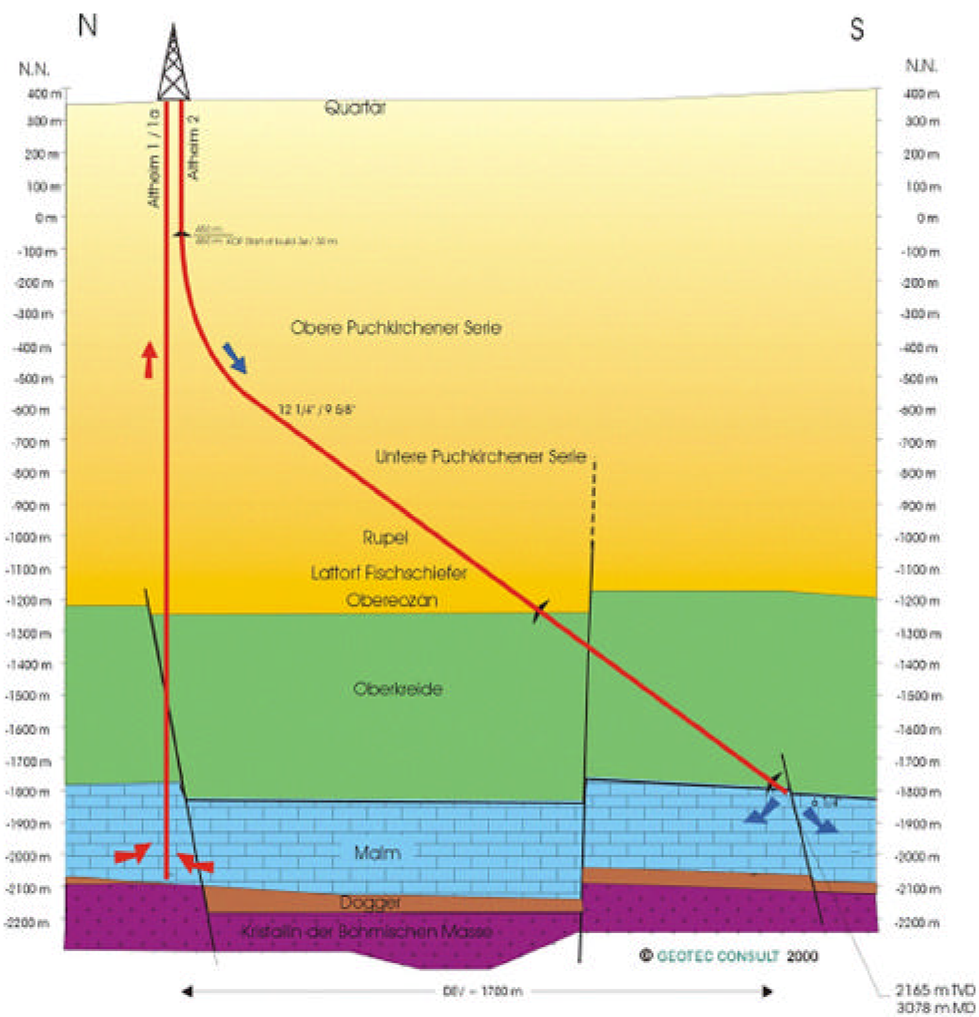

*Figure 7.	Geological Cross Section with Production and Injection Well.*